Market Efficiency and Limits to Arbitrage: Evidence from the Volkswagen Short Squeeze*

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September 19, 2020

Abstract

On October 26, 2008, Porsche announced a largely unexpected domination plan for Volkswagen. The resulting short squeeze in Volkswagen's stock briefly made it the most valuable listed company in the world. We argue that this was a manipulation designed to save Porsche from insolvency and the German laws against this kind of abuse were not effectively enforced. Using hand-collected data we provide the first rigorous academic study of the Porsche-VW squeeze and show that it significantly impeded market efficiency. Preventing manipulation is important because without efficient securities markets, the EU's major project of the Capital Markets Union cannot be successful.

JEL classifications: G10; G12; G13; G14; G18.
Keywords: Limits to arbitrage; short selling; stock cornering; disclosure and securities regulation.

*We are grateful for the valuable research assistance of Matteo Pirovano and Luca Sportelli. The paper greatly benefited from discussions with Carlo Altavilla, Nikolay Dinev, Douglas Foster, Co-Pierre Georg, Christina Queisser, Bob Whaley, as well as seminar participants at the Universitá della Svizzera italiana, the International School of Management (ISM) Munich, the University of Luxembourg, Vanderbilt University, and the National University of Singapore, where Eric Nowak was a visiting professor on a scientific exchange supported by Swiss National Science Foundation Grant No. IZSEZ0_177044 while part of this research was conducted. We have also greatly benefited from the valuable suggestions of an anonymous referee and Bill Schwert (the editor). The views expressed in this article are solely those of the authors, who are responsible for the content, and do not represent the views of our employers. Angel Tengulov and Marlene Haas acknowledge the support of the Institute of Finance of the Universitá della Svizzera italiana. Any remaining errors are our own.

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1. Introduction

At the height of the financial crisis on Monday, October 27, 2008, Volkswagen's (VW) stock price rose dramatically and surged past EUR 1,005 per share on Tuesday, October 28, 2008, from a close the previous Friday of EUR 211 per share. As a result, VW briefly became the most valuable listed company in the world in terms of market capitalization. We argue that this price increase was the result of a largely unexpected press release that Porsche Automobil Holding SE (Porsche SE or Porsche) made on Sunday, October 26, 2008 (the press release or the October 26 press release), when the company announced its domination plan for VW.

The press release proved especially problematic for investors who were short in VW's stock.[1;[1]] Porsche had entered into option contracts with Maple Bank, the German subsidiary of the Canadian firm Maple Financial Group Inc., to lock in an acquisition price for VW's shares. Maple Bank in turn hedged its position by purchasing derivative contracts on VW shares through other banks. These other banks held VW's shares as a hedge. They all kept their holdings under the 5% threshold that required public disclosure so these holdings were not publicly known. This implied that the free-float of VW's shares was decreased significantly. Therefore, it became increasingly difficult for short sellers to acquire VW shares to cover their short positions when the share price started rising after Porsche's press release. This in turn exerted increasing price pressure on VW's stock and resulted in more than EUR 20 billion losses for investors that had entered into these short-sell trades.[2] The rise in VW's price, that the short squeeze caused, was extremely advantageous to Porsche. We argue that it resulted in a profit of at least EUR 6 billion and allowed them to avoid bankruptcy.

Understanding what happened prior to and during this sequence of events is important for at least three reasons. First, while short squeezes did occur with some frequency historically, extreme examples such as this one are almost unknown in recent times. The reason is that behavior precipitating short squeezes is illegal in most countries, which in turn helps to ensure

[1] We are using a variety of legal sources for much of our data. We have referred to these with the notation [1], [2], etc., and included a list of legal and other source notes at the end of the Internet Appendix (see A.11 Legal and Other Source Notes for Paper and Internet Appendix). We refer to the standard explanatory footnotes in the usual way.

capital market efficiency. The latter 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 arbitrage 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 floating supply and the price rises as a result. A corner is an extreme form of short squeeze, when the buy side has almost complete control of all floating shares. The VW squeeze has been damaging to market efficiency in Germany because it has demonstrated to those thinking of shorting a security that they bear the risk of being caught in a short squeeze.

Second, the data available in modern markets means that the precise way in which this kind of manipulation affects the operation of the market can be studied in a detailed way that historical manipulations cannot. This paper considers how the short squeeze impacted market quality and intraday trading activity in a stock market in which information is in many circumstances incorporated quickly but in others, such as when there is asymmetric information, can take some time. We provide evidence that in the case of a significantly disruptive event in a market that is poorly regulated or in which enforcement of regulations is an issue, there is reduced market quality and impeded price discovery despite fast-paced trading technology, continuous news streams, and continuous information processing.

Third, understanding how such an event could occur in one of the most advanced countries in the world, namely Germany, is important for policy reasons. We argue below that in contrast to the United States (U.S.), the effective enforcement of regulation that is necessary for efficient capital markets does not occur in Germany and much of Europe. One of the most important policy projects in the European Union (EU) currently is the Capital Markets Union (e.g., Allen and Pastor, 2019). It is designed to be a complement to the Banking Union. The EU's Market Abuse Regulation (MAR) and the Directive 2014/57/EU of the European Parliament and of the Council of 16 April 2014 on criminal sanctions for market abuse (market abuse directive or CS MAD) were implemented in 2014 and came into effect in 2016. Bhattacharya and Daouk (2002, 2009) show that it is the enforcement, not the existence of market abuse

regulation, that matters. While market abuse can be sanctioned by administrative fines or criminal penalties, administrative fines are not imposed directly by the European Securities and Markets Authority (ESMA) but by the National Competent Authorities (NCAs) like the German "Bundesanstalt für Finanzdienstleistungsaufsicht" (the BaFin). CS MAD requires market abuse to be sanctioned as a criminal offense. However, this puts the responsibility on the public prosecutors and courts where there is large EU-wide heterogeneity (e.g., Perrone, 2020). The example of Germany, and the Porsche-Volkswagen case, in particular, illustrates that the system of national enforcement of criminal penalties does not work properly.

A more effective way to proceed would be for ESMA to be fully directly responsible for the enforcement of capital markets regulation such as the prevention of short squeezes and for national authorities not to play a role and/or to harmonize and supervise more strictly the enforcement actions of the NCAs. At present, ESMA only has a facilitating role to coordinate the NCAs by conducting an annual review on market abuse regulation and publishing a comparative report on administrative and criminal sanctions and other administrative measures under MAR.[3]

We start with a comparison of regulation in the U.S. and Europe. While stock price manipulations such as squeezes and corners have been outlawed in the U.S. since the Securities and Exchange Act of 1934 (the SEC Act), legal limitations have only been introduced in many European countries in recent years. There is an issue about the extent these laws are enforced in Europe. We argue that there was a short squeeze in VW's stock resulting from the actions of Porsche. There were no convictions and - so far - no settlements as a result of the short squeeze illustrating the lack of effective enforcement of market conduct rules in Germany.

Allen, Litov, and Mei (2006) show that in the nineteenth and early twentieth century squeezes and corners did occur with some regularity in the U.S. stock markets. The SEC Act was effective in outlawing two important categories of security market manipulation. The first is action-based manipulation, which is based on actions that change the actual or perceived value of the assets.[2] The second category of trading misconduct the Act was effective

[2]An example is provided by the managers of the American Steel and Wire Company (the forerunner of U.S. Steel). See Wycoff (1968) (pp. 72-78) for an account of this episode.

in outlawing can be described as information-based manipulation. This involves providing false information or spreading false rumors to profit from subsequent market reaction.[3]

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

A recent prominent example of the enforcement of the SEC Act are the events related to Tesla, Inc. On August 7, 2018, during regular trading hours, Elon Musk, Chief Executive Officer (CEO) and Chairman of the company, surprised investors when he tweeted to his more than 22 million Twitter followers that he was considering taking Tesla private at USD 420 per share, which was about a 20% premium over the stock's trading price earlier that day.[4];[5] On the same day, the stock price closed at a premium of 11% relative to the previous day's close.[5] According to the public press, this increase in Tesla's stock price led to a loss of about USD 1.3 billion for short sellers,[6] and in response short sellers reduced their positions after Mr. Musk's tweets.[4]

Regulators reacted immediately. Only a week after the tweet was published, on August 14, 2018, the SEC started an official investigation into the matter by sending a subpoena to Tesla seeking information from each of Tesla's directors.[4] The U.S. Department of Justice (DOJ) followed with a criminal investigation.[7] A settlement proposal was reached between the SEC and Tesla less than two months after the initial tweets on August 7. Both Tesla and its CEO, Mr. Musk, had to pay penalties. Mr. Musk had to step down as the chairman of Tesla's board and was replaced by an independent chairman.[8] These timely regulatory actions quickly restored

[3]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. See Sobel (1965) (pp. 248-249).

[4]In Section A.1 of the Internet Appendix we include a detailed description of these events. The description includes a figure that shows the evolution of Tesla's share price and short interest for the period of July 1, 2018 through October 1, 2018.

market confidence, and were followed by increased activity of short sellers, who increased their short positions in Tesla's stock.

In Europe, on the other hand, securities regulation and in particular the regulations against manipulation of stock prices came much later than in the U.S. In Germany, U.S.-style securities law, as described above, did not exist until the mid-1990s. Today, regulation concerning market manipulation conduct is part of the EU's MAR and the CS MAD, as well as the German Securities Trading Law (WpHG or WertpapierHandelsGesetz) and the Market Manipulation Definition Regulation (MakonV or Verordnung zur Konkretisierung des Verbotes der Marktmanipulation). Already at the time of Porsche's press release, an intentionally false statement about a fact significant to the valuation of a security, as well as any other deliberately deceptive measure aimed at influencing the valuation of a security, was punishable as a criminal act according to Section 20a of German securities law (WpHG).

Enforcement of securities laws in Germany is carried out by the 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 is cited by Nowak (2004) as the reason why there have been so few insider trading prosecutions.[5] However, as the data show, this lack of enforcement has not been changed by the implementation of MAR and CS MAD. For market manipulation cases, from 2016 to 2018, the BaFin (Annual Report 2018) started 647 investigations, and passed on 304 cases to public prosecutors. Of those, 21 final judgements were made with a conviction following a full public trial. The prosecutors turned all other cases down or settled them with down payments or administrative fines. So the risk of being

[5]Other studies have come to similar results when studying the German regulatory environment. The Doing Business 2019 report of the World Bank's International Finance Corporation ranks Germany as 72nd of 190 countries for Minority Investor Protection lagging behind Morocco and Uzbekistan but just on par with the Ukraine and Nepal. See also, "Doing Business 2019, Training for Reform," Doing Business Report 2019, available at (Link).

convicted of market manipulation in Germany - conditional on having been investigated by the BaFin - is 3%.[6] In its annual reports BaFin does not mention any incidents of short squeezes or corners as special cases of market abuse and does not seem to recognize them as an impediment to market efficiency.[7] On the contrary, a selected priority area of BaFin's annual report 2018 (p. 135) is devoted to the "phenomenon [of] short attacks," which according to BaFin are characterized by "... individual investors benefit[ing] from falling share prices [...] triggered by negative comments about the issuer." BaFin supports the narrative of criminal short sellers attacking innocent firms in the same annual report by portraying the recently bankrupt firm Wirecard AG as a victim of short attacks. The collapse of Wirecard AG, which as of the time of its default was part of the German stock index DAX-30, has the potential to turn out to be Germany's biggest corporate governance and accounting fraud scandal. Short sellers started to short Wirecard AG's stock many years ago when allegations of accounting fraud appeared for the first time - and despite the fact that "US hedge funds warned [...] that they would never again bet against German stocks after a market squeeze was allowed to develop that temporarily made carmaker Volkswagen the most valuable company in the world in 2008."[9] Instead of investigating the allegations of accounting fraud, BaFin criminalized short sellers and opened an investigation against a journalist from the Financial Times after a series of critical articles on Wirecard AG.[10]

In the case of Porsche's press release, BaFin 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. The authorities there prosecuted two of the company executives (CEO Wendelin Wiedeking and Chief Financial Officer (CFO) Holger Härter) for market abuse. However, prosecutors were unable to obtain a conviction for market abuse and convicted the two Porsche executives for credit fraud, with which they are much more familiar given the banking-based German economy.

[6] For more information regarding the BaFin's market manipulation investigations during the period 2006 through 2018, see Table A1 in Section A.2 of the Internet Appendix.

[7] Another recent example that features use of derivatives to gain ownership in another company is the Continental/Schaeffler case. In particular, in 2008, the Schaeffler Group announced that it had built up a stake of almost 36% of Continental's share capital mainly through cash-settled derivatives (28%), without any regulatory disclosure. The BaFin investigated if the Schaeffler Group should have disclosed their cash-settled derivative holdings, but came to the conclusion that this was not required under German law.

Our paper is the first detailed study of the Porsche-VW short squeeze to analyze (i) Porsche's incentives to create the short squeeze, (ii) the extent to which market participants anticipated the short squeeze, and (iii) the microstructure effects of this event on market quality and price discovery, and as a result on market efficiency. We argue that there is significant evidence that Porsche created a short squeeze in VW's stock to avoid a likely insolvency. The analysis is based on data from the public criminal case held at the regional Criminal Court in Stuttgart (LG Stuttgart) that has not been used before. This evidence enables us to reconstruct Porsche's accumulation of a significant ownership stake in VW through complex derivatives strategies and the resulting risks associated with these strategies. We assess if market participants were aware of these actions given the relative opaqueness of the German financial market system and the presumed lack of disclosure requirements for substantial cash-settled derivatives positions at the time. We show an abnormally high dispersion in analysts' price target opinions, following Porsche's takeover announcement, indicating that besides the increased risk aversion among all traders, even professional analysts covering the automotive industry were uncertain and confused about how to properly value VW's shares during the short squeeze. Finally, we analyze if the short squeeze following Porsche's takeover announcement adversely impacted market quality and impeded price discovery. We find that the short squeeze worsened market quality for both VW and VW's competitors. For example, we find that during the squeeze period relative bid-ask spreads and volatility for VW (VW's competitors) increased by 61% (10%) and 193% (41%), respectively. We also find that the short squeeze altered price discovery in VW's stock. Whereas price discovery tended to be concentrated in the first half-hour of a trading day before the squeeze, this pattern shifted towards the end of the trading day during the short squeeze. This evidence indicates that it took market participants longer than usual to filter through the newly obtained information.

Our findings contribute to the literature on stock market manipulation. Cherian and Jarrow (1995) survey the early theoretical literature and Spatt (2014) provides a recent review of the literature on stock manipulation. Hart (1977), Kyle (1984), Hart and Kreps (1986), Vila (1989), Allen and Gale (1992), Allen and Gorton (1992), Benabou and Laroque (1992), and Jarrow (1992, 1994) were among the first to study market manipulation. Later, Bagnoli and Lipman

(1996), Chakraborty and Yılmaz (2004), Merrick Jr, Naik, and Yadav (2005), and Goldstein and Guembel (2008) contributed influential papers to the manipulation literature. More closely related to our contribution are Kyle (1984) and Pirrong (1993). They develop theories of squeezes in commodity futures markets, but many of their insights are also applicable to stock market squeezes. Kyle's theory shows how short squeezes can arise even though all traders are fully rational. Pirrong shows how squeezes influence informational risk and market quality as they hinder price discovery.

Aggarwal and Wu (2006) present a theoretical model and empirical evidence on stock price manipulation in the U.S. By extending the framework of Allen and Gale (1992), 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 data set from SEC enforcement actions in cases of stock manipulation, they find that more illiquid stocks are more likely to be manipulated and manipulation increases stock volatility. Merrick Jr, Naik, and Yadav (2005) investigate the trading behavior of market participants during an attempted delivery squeeze in the March 1998 long-term United Kingdom (U.K.) government bond futures contract traded on the London International Financial Futures and Options Exchange (LIFFE). Their results show that the differences in the penalties for settlement failures in cash and futures markets create conditions that favor squeezes. Three recent papers empirically examine short selling in relation to particular manipulative or abusive trading strategies. Shkilko, Van Ness, and Van Ness (2012) study episodes of significant intraday downward price pressures in individual stocks and find that price declines during such episodes are driven mainly by liquidity demanding non-short trading volume. The authors conclude that the influence of short sellers on prices is secondary to that of non-short sellers. Fotak, Raman, and Yadav (2014) investigate the effects of naked short selling on markets using the level of failures to deliver during settlement. They show that (naked) short sellers have positive effects on market quality and market efficiency, such as reducing volatility. How failed attempts to manipulate stocks can cause a surge in informational risk and a deterioration of market quality is shown in Gehrig, Fohlin, and Haas (2015). They provide evidence of how the failure of a short squeeze in the opaque trading environment of U.S. stock markets in 1907 led to a decline

of funding and market liquidity.

Leuz and Wysocki (2016) discuss the challenges underlying empirical analyses on the economic consequences of disclosure and financial reporting regulation. Using U.S. and international evidence, the authors find that market-wide effects and externalities from regulation are not well documented and lack empirical evidence. Yet, according to the authors, such evidence is important to the economic justification of changes in regulation or the existence of regulatory frameworks. Christensen, Hail, and Leuz (2016) study the effects of the introduction of market abuse regimes and transparency regulation in EU member countries. The authors find that market liquidity significantly increases when these regulatory changes - which represent a reduction in market abuse and an increase in transparency - take effect. The authors exploit the fact that some EU countries have large unregulated markets and are mostly unaffected by new market abuse and transparency directives relative to other EU countries with stricter regulatory environments.[8]

Our paper contributes to and extends these existing studies in two ways. First, we show how a disruptive and mostly unanticipated material announcement in a *modern* market environment, which lacks strict disclosure regulation and enforcement of securities laws, can bring about a short squeeze. Second, we highlight the important role that interactions between different asset markets (in this case the markets for options and the underlying stock) play for market efficiency. This study shows that limits to arbitrage in one asset market (i.e., equities) can be exploited through trading in another asset market (i.e., equity derivatives) if disclosure regulation and enforcement of securities laws are weak. Third, our paper also adds to the literature on disclosure and financial reporting regulation by providing another example that a largely unregulated market faces deteriorating market quality and market efficiency when faced

[8]Our findings are also related to Nagel (2015), Stowell and McLarty (2009), and Godfrey (2016), each of whom analyze a different aspect of Porsche's takeover attempt of VW. Nagel (2015) summarizes the hedging strategies that Porsche had in place until the end of 2007 and points out how profitable these were. However, the case was written before the information used in our study was available and provides an incomplete picture. It is not surprising that Porsche's options strategy was so profitable given its secret agreements with Maple Bank and their agreements with various investment banks. Stowell and McLarty (2009) highlight the increasing importance of equity derivatives in takeover attempts and give the Porsche-VW case as an example. Finally, Godfrey (2016) examines VW's regional stock price variation on eight German exchanges around the short squeeze triggered by Porsche's voluntary press release arguing that an increase in the regional price variation could potentially be seen as a leading indicator of the short squeeze. These results are complementary to ours.

with a disruptive event.

The remainder of this paper is organized as follows. Section 2 of the paper reviews the events before and after the short squeeze of VW. Section 3 describes the underlying data. An analysis of Porsche's option holdings and probability of default is presented in Section 4. Sections 5 and 6 analyze the extent to which market participants anticipated Porsche's press release and whether the press release led to a short squeeze. Section 7 shows the effects of the short squeeze on market quality and price discovery. Section 8 concludes. A case study related to Tesla, additional information regarding the BaFin's market manipulation investigations, the takeover rules at the time of the squeeze, as well as robustness analyses related to Porsche's projected margin calls and liquidity, simulated probability of default, analyst coverage, market quality and price discovery are included in the Internet Appendix.

2. Porsche's plan to take over Volkswagen

2.1. The takeover strategy

For the period of interest, Porsche SE was a car manufacturer headquartered in Stuttgart, Germany. Its product line predominantly consisted of high performance sports cars. In 2005, the company's sales came mainly from the U.S. and German markets, with both markets combined accounting for about two thirds of total sales. Volkswagen Group was and is one of the largest car manufacturers worldwide and is headquartered in Wolfsburg, Germany. As of 2005, VW's automotive unit combined the brands of Audi, Bentley, Bugatti, Lamborghini, SEAT, Skoda, and VW.

In the years leading up to Porsche SE's takeover attempt of VW, Porsche SE's shareholder structure remained constant with total book value of equity of EUR 45.5 million divided equally into 8.75 million common-stock shares and 8.75 million listed preference-stock shares.[9] The common stock was held by members of the Porsche and Piëch families. More than half of the preferred stock was held by institutional investors such as "investor funds, banks and insurance

[9]This shareholder structure was unchanged over the fiscal years 2003/2004, 2004/2005, 2005/2006, 2006/2007, (see, for example, p. 39 of the 2006/2007 Porsche Annual Report).

companies," and "slightly less than half of the Porsche preference stock was widely distributed among private investors, primarily in Germany."[11] Holders of Porsche SE's common stock also held preference stock. Only holders of Porsche's common stock had voting rights.

In July 2005, the group of main decision makers in the shareholding families, which we shall refer to as the Shareholders' Committee (Gesellschafterausschuss), met in secret and passed a resolution authorizing the acquisition of 80% of VW's common stock.[12] The remaining approximately 20% were held by the state of Lower Saxony.[10] The plan included buying shares directly while also building up derivative positions consisting of a synthetic combination of cash-settled call and put options.[1]

Although the shareholders' committee had agreed to increase the stake in VW to at least 80%, partially through a derivative strategy, Porsche did not disclose this information to the public.[1] Instead, Porsche alternated between denying concrete takeover plans and increasing its stake in VW, which would trigger mandatory disclosure requirements for exceeding certain thresholds in voting rights.[11] For example, on September 25, 2005 Porsche issued a public announcement that it sought to acquire a stake of approximately 20% in the voting stock capital of VW. Furthermore, the announcement stated that the acquisition of the stake would not reach the threshold at which Porsche would be required to submit a public takeover bid for VW.[13] Yet, on March 24, 2007, Porsche publicly announced that it was planning to increase the stake held in VW to up to 31% of the ordinary shares and thus to make a mandatory offer to

[10]The stake of the state of Lower Saxony is governed by the Volkswagen Law (in German "Gesetz über die Überführung der Anteilsrechte an der Volkswagenwerk Gesellschaft mit beschränkter Haftung in private Hand" (Link)). It was enacted in 1960, when VW was privatized. The state of Lower Saxony held a voting share of 20% and had the ability to prevent takeovers by other shareholders, irrespective of the share ownership of the investor, and also to appoint two members to VW's board. In October 2007, the European Court of Justice ruled that the VW Law was illegal in the EU and also prevented the government appointing VW board members (see, "'Volkswagen law' is ruled illegal," BBC, October 23, 2007 (Link)). In 2008, the German government changed the VW Law in an attempt to sidestep the European Court of Justice ruling so that Lower Saxony would still be able to block major business decisions and takeovers (see, "EU To Sue Germany Again Over 'Volkswagen Law'," Wall Street Journal, November 24, 2011 (Link)). European regulators took the German government to court again and in 2012 the German government insisted that it would defend the VW Law. In 2013, the EU Court of Justice in Luxembourg ruled that the modifications of the VW Law meant it"complied in full" with EU rules, bringing the case to a close (see, "Germany Wins EU Court Battle Over VW Law, Escapes Fine," Bloomberg, October 22, 2013 (Link)).

[11]The German Securities Trading Act (WpHG) requires disclosure of shareholdings upon exceeding (or falling below) the following thresholds of holdings in voting rights in the target company: 3%, 5%, 10%, 15%, 20%, 25%, 30%, 50%, and 75%. The threshold and timing for providing these disclosures does not depend on the stated purpose of the holding. See, Section 33 of the German Securities Trading Act (Link). For additional details on German takeover regulations, see Section A.3 of the Internet Appendix.

VW.[12] On March 26, 2007, Porsche announced the implementation of this decision.[14] Porsche made the lowest offer allowed and the bid failed.[13] At the same time Porsche denied its interest in a takeover of VW.[15] Fig. 1 provides a summary of these events.

[Insert Figure 1 here.]

Porsche changed this direction less than a year later when on March 3, 2008 Porsche's board announced its support of the CEO's goal to increase the net position in VW to 50%. Yet, at the same time Porsche stated that it was not planning to merge the two companies.[16] Moreover, during the period between March and October, 2008, Porsche's officials refuted rumors that Porsche would increase its position further.[15] For example, on March 10, 2008, Porsche SE denied "reports in the media which claim that the enterprise intends to increase its stake in VW to 75%."[17] However, on March 4, 2008, Porsche had already acquired a combined physical and synthetic position in VW exceeding 61%, and by July 27, 2008, the combined position exceeded 72%. Over 30% of VW's ordinary shares were held through cash-settled options.[1] The financing of this position was ensured by a syndicated loan facility and selling additional put options.

[12] The link to the English version of the announcement on March 24, 2007 can be found here (Link). According to the Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz - WpÜG), a mandatory offer has to be made upon exceeding the shareholding threshold of 30%. The Securities Acquisition and Takeover Act "distinguishes between three different types of offer, namely takeover offers, mandatory offers and simple purchase offers. Takeover offers are voluntary and aim at the initial acquisition of control, being defined as the ownership of 30% or more of the voting rights in the target. A mandatory offer must be made if the 30%-threshold is reached or exceeded by other means than a public offer or in connection with a public offer [...]. [...] Voluntary takeover offers and mandatory offers both have to be made for all the target shares not already held by the bidder (and the persons acting in concert with it). Whereas in the case of a simple purchase offer (or partial offer) the bidder only seeks to acquire less than 30% of the voting rights or reinforce a controlling (30% or more) interest it already holds, e.g. following a previous takeover offer." See, "Public Takeovers in Germany," Cameron McKenna (Link).

[13] According to the Securities Acquisition and Takeover Act, the "offeror must offer the shareholders of the target company adequate consideration." See, Section 31 of the German Securities Acquisition and Takeover Act (Link). The "consideration must be equal to the higher of the volume-weighted average stock exchange price of the target shares, calculated for the three months prior to the publication of the offer announcement, and the highest price paid or agreed by the bidder during the six months prior to the publication of the offer document." See, "Public Takeovers in Germany," Cameron McKenna (Link). If the offer fails, the offeror is prohibited from submitting a new offer for the period of one year. See, Section 26 of the German Securities Acquisition and Takeover Act (Link). Upon written application, the Supervisory Authority may exempt the offeror from the prohibition if the target company consents to such an exemption.

2.2. Porsche's options strategy and public disclosures

Porsche began acquiring cash-settled call options and writing cash-settled put options[14] linked to VW's stock in 2005, when the share price was below EUR 100 (see Fig. 1).[1] The purchase of the call options gave Porsche the right to receive a future cash payment (the amount by which VW's share price exceeded the strike price of the options). The idea behind Porsche's derivatives strategy was that they wanted to effectively lock-in a predetermined price for VW's shares, i.e., Porsche could exercise the options if VW's price increased and receive the difference between the higher market price and the strike price. The resulting cash would then be used in the acquisition of VW's shares. The regulations were unclear but many believed that investors did not need to disclose de-facto ownership through holdings of cash-settled options in Germany.[15] This, in turn, allowed Porsche to build a large stake in VW while keeping the rest of the market uninformed.

Porsche's counterparty to the derivatives strategies was Maple Bank GmbH (Maple Bank).[1] Maple Bank was the German unit of the Maple Financial Group Inc., which is based in Toronto, Canada. Maple Bank constructed a range of option strategies for Porsche and took the opposite side as a counterparty.[1] Maple Bank hedged itself by buying the corresponding number of underlying VW shares, i.e., Maple Bank sold call options to Porsche and bought the corresponding number of VW shares on the market.[1] In order not to exceed the threshold requirement to make an ownership disclosure of VW shares, Maple Bank exchanged the VW shares for options and futures contracts with other banks.[1] In that way Maple Bank was always hedged and no disclosure was required. It is our understanding that since no disclosures were made, none of the other banks exceeded the disclosure threshold ownership in VW shares.[15] Therefore, the other banks were also not required to make a disclosure. The majority of Porsche's strategies involved buying cash-settled call and selling put options, effectively constructing a long synthetic position in VW's shares.[1] To finance the synthetic position in VW's shares and generate

[14] Cash-settled options are option contracts in which settlement is completed by paying cash equal to the difference between the market value and the contractual value of the underlying security at the time of exercise or expiration.

[15] For the relevant time period, no financial institution disclosed through Bafin that they had increased their holdings in VW above 4.9%. See, Bafin's database on "Major holdings of voting rights pursuant to Section 33, Section 38 and Section 39 of the German Securities Trading Act," (Link).

liquidity Porsche sold additional put options that were not tied to a synthetic position through matching call options.[1] In late 2007 the amount of the additional put options Porsche had sold, unrelated to a synthetic position, accounted for more than 20% of VW's ordinary shares.[1] Table 1 provides an overview of the option positions, written on VW's stock, that Porsche held over the years of 2005 through 2009.

[Insert Table 1 here.]

In total, Porsche owned eight different options strategies over this time period. All options were written on VW's stock. All but two strategies (strategies 5 and 8) were written on VW's ordinary shares. Strategies 5 and 8 were written on VW's preferred shares. All, except for one strategy (strategy 4), were cash settled. Except for two options portfolios (strategies 3.2 and 6), all of Porsche's options strategies included long call options and short put options.[16] Each strategy was structured such that put options and call options had identical quantities, strike prices, and rollover dates. Strategies 3.2 and 6 included only short put options. As of October 24, 2008, all, but two option strategies were active. The inactive option strategies were (i) strategy 3.2, which was merged into strategy 6 on July 27, 2007, and (ii) strategy 4, which was fully exercised on March 26, 2007. Fig. 1 includes an overview of the lifetime of each of the option strategies.

When the financial crisis hit markets around the globe in September 2008 and following the collapse of Lehman Brothers, the margin requirements on its derivative positions started to threaten Porsche's existence.[1] The derivative position Porsche had built up 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. As discussed above, on top of the more than 30% put options that were combined with cash-settled call options at identical strike prices, Porsche had sold additional put options for another 20% of VW ordinary shares.[1] The small car manufacturer Porsche had effectively issued insurance policies to market participants of more than 50% of DAX heavyweight VW against falling

[16] Strategy 3 was separated into two positions: strategy 3.1, which contained a combination of long calls and short puts, and strategy 3.2, which contained only short puts. See Table 1 for more information.

stock prices under its agreements with the conduit investment bank Maple Bank.[1] Porsche was subject to margin calls almost on a daily basis.[1] VW's share price decreased rapidly during the period October 15, 2008 through October 24, 2008. Due to its small size and the nature of its derivatives positions, the downdraft in VW's stock price led Porsche to have serious solvency problems.

On October 26, 2008, Porsche made a largely unexpected announcement, revealing that it had acquired 42.6% in VW stock. In the same statement, they also disclosed that they had acquired the rights, through cash-settled options, to purchase an additional 31.5% of VW stock and were targeting a domination agreement with VW.[17]

> Stuttgart, 26 October 2008. Due to the dramatic distortions on the financial markets Porsche Automobil Holding SE, Stuttgart, has decided over the weekend to disclose its holdings in shares and hedging positions related to the takeover of VW AG, Wolfsburg. At the end of last week Porsche SE held 42.6 percent of the VW ordinary shares and in addition 31.5 percent in so called cash-settled options relating to VW ordinary shares to hedge against price risks, representing a total of 74.1 percent.[...]
> Assuming the economic framework conditions are suitable, the aim is to increase to 75 percent in 2009, paving the way to a domination agreement. The intention to increase the VW stake to above 50 percent in November/December 2008 remains unchanged.
> Porsche has decided to make this announcement after it became clear that there are by far more short positions in the market than expected. The disclosure should give so called short sellers - meaning financial institutions which have betted or are still betting on a falling share price in VW - the opportunity to settle their relevant positions without rush and without facing major risks [...](see Section A.4 of the Internet Appendix for the full text).[18]

Given that Porsche's counterparties for the derivatives positions had hedged themselves with

[17] A domination agreement can be entered into for all types of stock corporations, both private and public. It is a bilateral contractual agreement between two companies with the goal of one party taking over the control of another company. The domination agreement can be entered without the controlling party having to acquire new shares in the target. All that is required is the conclusion of the legal contract. To finalize the domination agreement, a 75% majority needs to be obtained in the shareholder meeting of the controlled party. Hereby, only the votes of the shareholders present at the shareholder meeting are counted. Votes of shareholders not present at the shareholder meeting will not count. This means that domination agreements in practice can be finalized with less than a 75% majority of the existing shares. Upon finalization of the domination agreement, the two companies form a cooperation. Within this cooperation, certain rules and regulations are relaxed. Domination agreements are often entered together with profit and loss transfer agreements for tax reasons, in particular to establish a tax unity. See, German Stock Corporation Act, Sections 291 and 294; "Public Takeovers in Germany," Cameron McKenna (Link); "Public Takeovers in Germany," Freshfields Bruckhaus Deringer (Link).

the underlying stock and the state of Lower Saxony had a fixed stake of 20.3%[18] this meant that just 5.6% of VW's outstanding shares remained in free float, creating ideal conditions for a short squeeze. The 5.6% free float represents an upper bound estimate, since index funds also had holdings in VW's shares to maintain the corresponding weighting in the DAX Index. Furthermore, the short put option positions were not disclosed.

Market participants were aware that a short position of about 13% of the ordinary stock in VW had been built up.[19] Moreover, Porsche itself said that it was announcing its plans because the number of short positions in VW were considerably higher than it expected. On October 27, 2008, the price of VW ordinary shares opened at EUR 350 per share, a 66% increase over the previous Fridays' closing price of EUR 210. The shares closed at EUR 471, a 120% increase over the previous day's 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.

On October 28, the VW share price surged pass EUR 1,005, making VW the most valuable company in the world by total market capitalization. As explained above, Porsche had already entered into option contracts with Maple Bank, that had in turn hedged itself through other banks that held the shares. Therefore, the underlying VW shares were not freely available.[1] This made it difficult for short sellers to acquire VW shares and cover their short positions.

On October 29, 2008, Porsche made another press release announcing the closing of derivatives positions of up to 5% of VW voting stock, thereby releasing shares that short sellers of VW's stock could use to cover their positions (see Section A.4 of the Internet Appendix for the full text).[19]

In the process it is estimated that Porsche made at least EUR 6 billion,[20] which in turn helped Porsche to restore its liquidity and to roll over its remaining derivative positions.[1] Yet, the increase in VW's price was only temporary. Following the October 29, 2008 announcement, the price of VW continued to decrease. The closing price of VW's ordinary shares on Friday,

[18] For details, see Volkswagen Law.

[19] "Around 12.8 percent of VW's entire market capitalization was on loan as of October 25, the most recent day for which data were available, according to financial market data consultant dataexplorers.com. This compared with an average 5 percent for all DAX stocks...," "Short sellers make VW the world's priciest firm," Reuters, October 28, 2008 (Link).

October 31, 2008, the last trading day of the short squeeze week, was EUR 475.10. The price of VW's ordinary share on December 30, 2008, the last trading day of that year,[21] was EUR 250, a decrease of 47% relative to October 31, 2008. Similarly, the price of VW's preferred shares decreased over the same time period, from EUR 48.21 on October 31, 2008 to EUR 38.02 on December 30, 2008, which represents a decrease of 21%.

2.3. The resolution

Despite the decreasing VW price and the threat of increasing losses related to its short put options strategies, Porsche continued to increase its stake in VW. In particular, one and a half months after the October 29 press release, on December 19, 2008, Porsche acquired an additional 14.2 million VW common shares by exercising the corresponding amount of call options.[1] This brought Porsche's total ownership in VW's common shares to 139,696,680, or 47.37% of the voting shares.[1] Following this increase in ownership, Porsche increased its physical shareholdings in VW's common stock for the last time on January 5, 2009 by exercising the corresponding number of call options.[1] As of January 5, 2009, Porsche increased its ownership to 149,696,680, or 50.76% of the voting shares.[1] VW's ordinary share price continued to decline throughout the year of 2009 (see Fig. 1). Due to the decrease in VW's share price, Porsche experienced losses related to its option strategies. For example, on July 29, 2009 Porsche disclosed that a fall in value of the option strategies had led to a negative impact on earnings.[22] This prompted the company to search for a buyer of the options.[22]

Simultaneously with the decrease of VW's share price, Porsche's car sales decline continued.[23] As a result, Porsche struggled to generate cash flows that would cover the interest payments on its loans, which put Porsche's credit line repayment at risk.[24] In particular, Porsche's EUR 10 billion outstanding credit line was scheduled to expire with the repayment date set to March 24, 2009.[26];[20] Yet, given the reduction in luxury car sales and the failed takeover (domination) attempt, by March 18, 2009, it was unclear if Porsche would be able to repay its loan. According to court documents, Porsche faced the imminent threat of default.[26]

[20] Porsche had a EUR 10 billion outstanding credit line with a consortium of banks. Porsche had opened this line on February 20, 2008.

To avoid default, Porsche was negotiating a rollover of the EUR 10 billion credit line with its lenders. In addition, Porsche was exploring alternative financing options.[24] For example, Porsche considered (i) selling assets (e.g., subsidiaries such as Porsche Engineering, Porsche Design, or Porsche Consulting) to VW. Yet, given the tight refinancing deadline that Porsche was operating under, these sales would have taken too long and involved litigation risk. In particular, according to the press, VW's shareholders could have taken legal steps against such purchases because they could have been interpreted as financial bailout of the majority shareholder (Porsche).[24] Porsche also considered (ii) issuing a bond. Yet, according to the press, this plan was dismissed given the ongoing financial crisis.[24] Porsche still tried to obtain a credit rating.[25] Porsche further considered (iii) selling some (all) of its options on VW shares. While possible, if Porsche were to redeem a large number of options with Maple, the latter's counterparties would consequently sell VW shares, which would drive down their price. This in turn would have reduced the value of Porsche's call options and increased the value of Porsche's short put options, hence increased the value of Porsche's liabilities.[24] As a fourth possibility, Porsche considered increasing its share capital. This was a financing solution that Porsche actually pursued, as described in detail below.[21] By March 25, 2009 Porsche was able to avoid bankruptcy and finalize a refinancing of the old EUR 10 billion loan by issuing a new EUR 10 billion credit facility with a consortium of 15 banks.[26];[27]

Over the course of the summer of 2009, additional creditors joined the loan. At the end of May 2009, the Bank of Tokyo Mitsubishi provided an additional credit volume of EUR 750 million.[26] Despite managing to refinance the EUR 10 billion loan, Porsche was in need of additional liquidity in 2009. Fig. 2 shows this fact. The three panels in the figure show the evolution of three measures of Porsche's liquidity over the period of January 2005 through December 2009. The three measures of liquidity are (i) the current ratio, (ii) the quick ratio, and (iii) the cash ratio. We observe that Porsche had the highest liquidity levels in the German automotive industry in the years leading up to the short squeeze. From 2007 onwards, Porsche's

[21] In normal times, using retained earnings from profitable car sales would also have been an alternative. However, the company was facing a reduction in automobile sales due to the financial crisis. In light of the 2007/08 financial crisis and a looming recession in the U.S., Porsche's board of management foresaw a reduction in car sales and therefore a worsening of the company's financial situation. See Indictment of the public prosecutor, December 17, 2012, LG Stuttgart 159 Js 69207/09.

liquidity level - as measured by all three ratios - started to deteriorate significantly. This trend stopped after the publication of Porsche's press release, but continued in the second half of 2009. Liquidity levels of Porsche's competitors do not experience this trend.[22] Porsche's search for additional liquidity proved difficult. On June 30, 2009 Porsche was denied a EUR 1.75 billion loan from the German Kreditanstalt für Wiederaufbau (KfW). As a result, Porsche announced that it would enter into negotiations to consider alternative financing possibilities.[28] On July 23, 2009, Porsche announced that it started preparations for a EUR 5 billion capital increase.[29] On the same day, Porsche disclosed negotiations with Qatar Holdings LLC (Qatar) regarding a possible investment in Porsche.[30] These negotiations resulted in Porsche and Qatar entering into a Memorandum of Understanding, in which they agreed that Qatar would invest up to EUR 7 billion in Porsche by (i) joining an existing credit line with EUR 0.75 billion to EUR 1.5 billion, (ii) acquiring cash-settled options on VW's common and preferred shares from Porsche, and (iii) becoming a shareholder in Porsche for 9.9%-25% of Porsche's equity.[26]

[Insert Figure 2 here.]

Qatar made its investment in August 2009 and held a 10% ownership stake in Porsche SE through June 2013, when the Porsche and Piëch families bought back the stake from Qatar.[31] It is our understanding that the Porsche and Piëch families have since been the sole owners of Porsche SE's common shares.[23]

While Porsche's initial takeover attempt from 2008 was not successful, Porsche did not give up on its plan to takeover VW. In May 2009, it entered into negotiations with VW to build an "integrated auto company."[26];[32] On August 13, 2009 Porsche announced that Porsche and VW would form an integrated car group.[26];[33] On November 20, 2009, Porsche's supervisory board approved the plan.[34] On December 7, 2009, VW acquired an initial 49.9% equity interest in Dr. Ing. h.c. F. Porsche AG, the car manufacturing business of Porsche SE.[35] Subsequently,

[22] 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.

[23] 2016 Porsche Annual Report, which is the last report that provides detailed information on the shareholder composition of Porsche SE's common shares.

Porsche AG was fully consolidated into VW on August 1, 2012.[36] Since 2009, Porsche SE has increased its stake of ordinary shares in VW from 50.7% to 53.1%.[37]

3. Data

Our unique and primary data source is the evidence presented in the public criminal case held at the regional Criminal Court of Stuttgart on alleged market manipulation. We use hand-collected evidence publicly presented at court hearings and information reported in publicly available court documents of the Landesgericht Stuttgart (LG Stuttgart; regional court of Stuttgart) and the Oberlandesgericht Stuttgart (OLG Stuttgart; higher regional court of Stuttgart). We are the first to collect data from these documents and hearings for an empirical analysis in an academic study. This unique data set allowed us to reconstruct in detail the timeline and facts of relevant events at issue. For example, the documents allowed us to reconstruct Porsche's derivatives holdings and trading strategies as well as how its holdings in VW's stock changed over time. As the court documents relied upon company documents and witness testimony, the extracted data and facts enabled us to analyze the case in unmatched detail and completeness.

In particular, we obtained, translated, and analyzed the information contained in the Indictment of the public prosecutor,[1];[26] the judgment of the Stuttgart criminal court,[38] and the credit fraud judgement.[39] This information helped us to reconstruct Porsche's (i) total liquidity, (ii) liquidity blocked in margin calls, (iii) free liquidity (the difference between (i) and (ii)), and (iv) rollover losses from the derivatives holdings. These documents also provide information on the rollover frequency and on the threshold prices of the derivative positions that would have led to margin payments for Porsche during the week starting October 27, 2008. We view the data presented in these documents as highly reliable because they were obtained through a legal search warrant of Porsche's company records related to the criminal investigation by the public prosecutor in Germany.[40]

For accounting and stock price information we use Compustat Global as well as the annual reports and investor relations websites of Porsche and VW. Data on analysts' target price

forecasts and dispersion are retrieved from the I/B/E/S database. Intraday 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 are from Markit. The data sample includes VW and Porsche, as well as their main German automotive competitors Daimler and BMW for the period from 2005 to 2009.

4. Porsche's option strategies, margin requirements and probability of default

To analyze Porsche's financial situation during the short squeeze period, we perform a variety of tests for potential losses related to their option strategies and increase in default probability. Porsche's October 26 press release disclosed a total position of 74.1% of the voting stock of VW and announced a plan to acquire more than 75% of the company "paving the way for a domination agreement." The press release did not mention increasing margin calls or rollover losses Porsche had endured in the previous trading week nor the fact that a two-digit million number of put options that they had sold 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's voting shares was not mentioned, nor the risks they were facing as a result of this - and the additional cash-settled puts they had sold short.

4.1. Option mark-to-market values and margin requirements

To quantify the extent to which Porsche's options positions turned into a liability over the course of October 2008, we calculate mark-to-market values for all option strategies. Since all options were American style options, we apply the numerical valuation procedure outlined in Barone-Adesi and Whaley (1987). Under this methodology, to estimate the price of each option, the following information is required: 1) the price of the underlying instrument, 2) the strike price, 3) times to expiration, 4) volatility of the underlying, 5) the risk-free rate, and 6)

the underlying instrument's dividend yield. For 1) we make use of information from standard public sources. We obtain information for 2) and 3) from the relevant court documents. Table 1 provides information about the underlying shares (ordinary and preferred shares), strike prices for each strategy, and time to expiration (weekly and monthly rollover frequency), as well as details regarding the options strategies. To estimate volatility, we use a rolling 30-day realized standard deviation of returns of the underlying stock.[24] Since these are short-term options denominated in Euro, we apply a Euro-denominated risk-free rate derived from the Euro overnight index swap rate term structure.[25] For the period around the short squeeze we set the dividend yield to zero, since VW did not pay any dividends during that period.[26]

Table 2 summarizes the total mark-to-market value estimates as well as margin requirements of Porsche's option strategies during the period October 13, 2008, through October 31, 2008.[27] The table shows that as of October 17, the total mark-to-market value of Porsche's put options, which represented a liability to Porsche, was EUR 77 million. At the same time, the total mark-to-market value of Porsche's call options, which represented an asset for Porsche, was EUR 20.5 billion. To put this number in perspective, Porsche's book value of equity as of the last reporting date was EUR 16.85 billion.[28] This situation changed in the following week, when both VW's ordinary and preferred shares decreased substantially in value. In particular, from October 17, 2008 to October 24, 2008 the ordinary shares fell 41% while the preferred shares

[24]Rolling 30-day volatility is a widely used estimation procedure. For robustness we apply 60- and 90-day rolling volatility windows. Results are robust and yield the same economic interpretation (untabulated).

[25]The overnight index swap contract is an interest swap contract where two parties agree to exchange two cash flows: one party pays a fixed rate applied to some notional principal amount for the duration of the contract and the other party provides a floating rate payment applied to the same principal contract. A swap contract is settled in notional amounts, i.e., without involving a physical exchange of principals, and thus it is considered near-risk-free (see Rostagno et al., 2019 for more details). As a robustness, we also estimate the mark-to-market values by applying i) rates derived from the EONIA-EURIBOR term structure, ii) the yields of the 3-month and 10-year German government securities, and iii) the yield on U.S. 1-month Treasury Bills. These robustness estimations yield results that are quantitatively and qualitatively very similar (untabulated).

[26]The last dividend that VW paid during this period was in April 2008. As per VW's Annual Report 2008, the company paid EUR 1.93 per ordinary share and EUR 1.99 per preferred share.

[27]We report mark-to-market value estimates for this period due to data availability for the related margin requirements. The margin requirements figures and option parameters were obtained from the Indictment of the public prosecutor (see source [1] in the list of legal sources).

[28]Porsche's ordinary shares were held exclusively by members of the Porsche and Piëch families, and only Porsche's preference shares were traded on the market. We therefore compare the mark-to-market values of Porsche's option strategies to the last publicly available book value of equity figure (and not to the market value of equity estimated based on preference shares). As per the 2007/2008 Porsche Annual Report, p. 167, Porsche's book value of equity was EUR 16,846,000,000.

fell 42%.

[Insert Table 2 here.]

Correspondingly, the total mark-to-market value of Porsche's call and put options changed. In particular, the total mark-to-market value of Porsche's call options decreased from EUR 20.5 billion on October 17, 2008, to EUR 8.5 billion on October 24, 2008. This is a decrease of EUR 12.0 billion or 58% over the course of one week. At the same time, the total mark-to-market value of Porsche's options strategies liabilities, i.e., the short put options, increased from EUR 77 million on October 17, 2008, to EUR 3.7 billion on October 24, 2008. This is an increase of EUR 3.6 billion or 4,754% in Porsche's option related liabilities. In other words, in a single week Porsche incurred an unrealized loss of EUR 15.7 billion – EUR 12.0 billion from the decrease in their call option assets and EUR 3.7 billion from the increase in their put option liabilities. Since most of Porsche's options strategies had end-of-month rollover, the majority of these losses would have been realized only a week later, on October 31, 2008. However, since strategy 1 was rolled over weekly on Fridays, Porsche incurred EUR 2.6 billion of realized losses on Friday, October 24, 2008, to settle short put option contracts related to this strategy.[1]

Table 2 also shows that Porsche's derivative counterparty reacted to these price declines and to the corresponding changes in the mark-to-market values of Porsche's options holdings by increasing the margin requirements. In particular, on October 17, 2008, Porsche had EUR 3.2 billion, or 15.5% of their net options asset, locked into margins. On October 24, 2008 this amount had increased to EUR 4.3 billion, or 88.5% of their net options asset.[29]

4.2. Scenario analysis based on VaR prices

We proceed by discussing a scenario analysis for the likely evolution of Porsche's ordinary and preferred stock prices, if Porsche did not make the press release on October 26, 2008. We consider the outlook from the perspective of Porsche's management on October 24, 2008 given

[29] We note that there is an EUR 2 billion decrease in the liquidity locked into margins from October 23, 2008 to October 24, 2008. This is because on Friday, October 24, 2008 strategy 1 was rolled-over and the related margins were released. On the same day Porsche incurred EUR 2.6 billion realized losses related to strategy 1.

possible evolutions of the market prices of VW's ordinary and preferred shares and the potential risks resulting from Porsche's option strategies. Porsche stated in its 2008 Annual report that it applies "value-at-risk [VaR] calculation [...] to determine the potential change in market price."[41] Motivated by this disclosure, we discuss and apply a scenario analysis based on the VaR approach.

A probability VaR at a given time horizon for a given model is the loss amount such that the probability of a larger loss over the given time horizon is at most p. For example, a 1% daily VaR is the loss amount such that a larger daily loss occurs with a probability of at most 1%, assuming losses follow the distribution implied by the assumed model. The percentage selected will affect the VaR, e.g., a 1% VaR would be expected to show a greater risk than a 5% VaR. For completeness we apply both the 1% and the 5% thresholds. 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 VW, they faced significant losses when VW's stock price started to decrease. These rollover losses were faced at the maturity of each options strategy. Hence, the idea of this analysis is to determine for how long Porsche could have secured its own financial survival given the information available as of October 24, 2008.

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

$$VaR = [R_p - z\sigma]V_p \tag{1}$$

where, R_p is the expected return on a particular portfolio, V_p is the value of that portfolio, z is the z-value corresponding to the desired level of significance and σ is the standard deviation of returns. We augment the above-outlined equation to solve for the VaR-price (instead of the value of a portfolio) on a daily basis,[30] and apply the following VaR-price formula:

[30] Since we are interested in a very short period, i.e., daily VaR-price estimates, we set the daily return R_p equal to zero. For a very short period a (1-day) VaR can be approximated by ignoring the return component.

$$P_{t+n}^{VaR} = P_t + P_t z \sigma_t \sqrt{n} \tag{2}$$

where P_{t+n}^{VaR} denotes the VaR price at time $t+n$ with n=1, 2, ..., 5 days. P_t is VW's ordinary or preferred share price as of October 24, 2008. σ_t is the standard deviation of VW's daily return as of October 24, 2008 computed over the past 30 days. z is the z-value corresponding to -1.65 for the 5% VaR-price (i.e., 1.65 standard deviations below the mean), or -2.33 for the 1% VaR-price (i.e., 2.33 standard deviations below the mean).

Panel A of Table 3 presents the evolution of 5% VaR-prices for VW's ordinary and preferred shares for the week starting October 27, 2008, which is the week following the press release. It also shows Porsche's total mark-to-market values for the calls and the puts along with the corresponding net mark-to-market value, which is calculated as the call option assets minus the put option liabilities. Based on the 5% VaR-price scenario the total mark-to-market value of Porsche's call options is projected to further decrease to EUR 3.1 billion. In other words, under this scenario Porsche's call options would have decreased in value from EUR 20.5 billion on October 17, 2008, to EUR 3.1 billion on October 31, 2008. This is a decrease of EUR 17.4 billion, or 85%, over the course of two weeks. At the same time, the total mark-to-market value of Porsche's put option strategies liabilities would have been EUR 2.8 billion on October 31, 2008. Furthermore, Porsche already incurred EUR 2.6 billion of realized losses on Friday, October 24, 2008, to rollover options of strategy 1. In other words, in a two-week period Porsche would have incurred a loss of EUR 22.8 billion – EUR 17.4 billion from the decrease in their call option assets, EUR 2.8 billion from the increase in their put option liabilities, and EUR 2.6 billion of realized losses on Friday, October 24, 2008. The potential loss of EUR 22.8 billion would have likely exceeded Porsche's book value of equity, which was EUR 16.85 billion as of the last reporting date, and therefore would have led to Porsche's insolvency.

Panel B of Table 3 presents the evolution of VW's 1% VaR-prices, and the corresponding total mark-to-market values for the calls and the puts as well as the resulting net mark-to-market value. Based on the 1% VaR-price scenario the total mark-to-market value of Porsche's call options would have further decreased to EUR 1.2 billion. In other words, under this scenario

Porsche's call options would have decreased in value from EUR 20.5 billion on October 17, 2008, to EUR 1.2 billion on October 31, 2008. This is a decrease of EUR 19.3 billion, or 94%, over the course of two weeks. At the same time, the total mark-to-market value of Porsche's put option strategies liabilities would have been EUR 4.6 billion on October 31, 2008. In other words, under this scenario in a two-week period Porsche would have incurred a loss of EUR 26.5 billion – EUR 19.3 billion from the decrease in their call option assets, EUR 4.6 billion from the increase in their put option liabilities, and EUR 2.6 billion of realized losses on Friday, October 24, 2008. The potential loss of EUR 26.5 billion would have exceeded Porsche's book value of equity, which was EUR 16.85 billion as of the last reporting date and would have led to Porsche's insolvency.[31]

[Insert Table 3 here.]

4.3. Probability of default analysis

To provide robustness to the results presented in the previous subsections we next present the results from a standard, academically-established measure of probability of default, namely the distance to default measure of Bharath and Shumway (2008). This measure relies on publicly-available data and can be computed for Porsche and its competitors. We use this measure to assess if an increase in Porsche's probability of default was company-specific or system-wide. 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

$$DD = \frac{ln[(E+F)/F] + r_{i,t-1} - 0.5\sigma^2}{\sigma} \tag{3}$$

[31] To provide further support and robustness of these results we perform the following additional analyses: i) Projected margin calls and liquidity analyses based on VaR prices, and ii) Simulated probability of default analysis. The Projected margin calls and liquidity analyses based on VaR prices evaluate what Porsche's projected margin calls would have been if VW's price continued to decrease after October 24, 2008 (and Porsche did not make the announcement on October 26, 2008), and whether Porsche would have had enough liquidity to meet projected margin calls. The Simulated probability of default analysis assesses for each trading day the cumulative probability of Porsche being unable to meet margin calls or rollover losses resulting from their options holdings based on a Monte Carlo simulation (100,000 simulated price paths) combined with Geometric Brownian Motion with different drift assumptions. These additional analyses confirm the results presented in Section 4.2. For brevity, a description of these additional analyses and the corresponding results are provided in the Section A.5 "Projected margin calls and liquidity analysis based on VaR prices," and in Section A.6 "Simulated probability of default analysis" of the Internet Appendix.

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 σ^2 captures the volatility of the firm's assets. σ is approximated by $(E/(E+F)) * \sigma_E + (F/(E+F)) * (0.05 + 0.25\sigma_E)$, where σ_E is the quarterly percent standard deviation based on the past 12 monthly returns (e.g., Bharath and Shumway, 2008). A firm's probability of default is defined as N(-DD), where N is the cumulative standard normal distribution function.

Fig. 3 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 when we observe a steep upward movement in the probability of default in the second, third, and fourth quarters of 2008, with an increase from 0% to over 95%.[32] We 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 and long-term financial debt.[33] This analysis provides robustness of the previously presented results and shows that Porsche was particularly at risk of default relative to its peers in the industry.

[Insert Fig. 3 here.]

5. Market participants' anticipation of the press release

Over time, market participants should have learned that Porsche's announcements were not fully credible. In the long run, over at least the previous two years, Porsche had repeatedly alternated between denying concrete takeover plans and increasing its stake in VW (see Section 2.1 for an account of Porsche's disclosures regarding its holdings in VW). In this section we

[32] To provide further robustness we also estimated another academically-established measure of probability of default, namely Altman's Z score. Fig. A6 in Section A.8 of the Internet Appendix shows the evolution of Altman's Z over the time period around the short squeeze and confirms the probability of default results.

[33] Porsche's earnings (generated partially from derivatives gains) slightly increased during the first half of 2008. The probability of default measure indicates an increase in Q2 of 2008 as well. We note that Porsche's probability of default takes into account i) the market value of equity, ii) debt, iii) past market return, and iv) volatility of firm assets. According to these metrics, Porsche's riskiness was increasing although the company was generating positive earnings.

assess the extent to which different types of market participants anticipated the publication of the October 26, 2008 press release. We focus this analysis on analysts, controlling shareholders, and informed traders.

5.1. Analysts' price targets

By analyzing the time series evolution of mean and standard deviation of stock analysts' price target estimates for the period of 2005 through 2009 we aim to answer the following questions: (i) did analysts expect the price of VW to increase or decrease before the short squeeze in general and relative to the October 24, 2008 closing price of EUR 210.85 in particular; and (ii) did the press release make it difficult for analysts to determine a new price target estimate.

Fig. 4 (lhs) presents information for aggregate analyst price target forecasts for VW's ordinary and preferred shares for the period of 2005 through 2009. The mean price target estimates for VW's ordinary shares gradually increased from 2005 to 2007. This trend reversed in the second half of 2007. The mean price target estimates were gradually decreasing over the course of 2008 until Porsche's press release, with a mean price target estimate in the first half of October of EUR 134. The high price target estimate (the outlier opinion in the upper part of the distribution) from the middle of August to the middle of October 2008 was EUR 204.75. This price target high was revised downwards to EUR 89.46 shortly before the press release.[34]

[Insert Figure 4 here.]

[34]Using the I/B/E/S Detail History file, we find that the analyst that issued the price target estimate of EUR 204.75 is identified by a Mask Code of 626480. However, the Estimator ID and Name for this analyst are not available. Table A5 in Section A.7 of the Internet Appendix shows the entire price target history for the analyst with Mask Code equal to 626480 (analyst 626480). The first price target estimate recorded by I/B/E/S for analyst 626480 was on July 10, 2006. Since then the analyst has revised the price target for VW several times. On August 15, 2008 the analyst issued a price target for VW of EUR 204.75. On this day the actual closing price for VW was 205.64. Analyst 626480 did not revise the price target estimate of EUR 204.75 again until October 17, 2008, and there was no higher price target for VW during that period. This explains why the I/B/E/S Summary History file indicated EUR 204.75 as the highest price target estimate for the I/B/E/S statistical periods ending September 18, 2008 and October 16, 2008. Table A6 in Section A.7 of the Internet Appendix shows all price target estimates issued during the period October 16, 2008 through October 24, 2008. We see that no other price target estimate came close to the previous highest price of EUR 204.75. The highest price target estimate during that period was EUR 139.15 (as of October 17, 2008), well below the closing price of EUR 358 on the day this estimate was issued as well as below the closing price of EUR 210.85 on October 24, 2008.

Fig. 4 (rhs) plots the standard deviation in price target opinions of analysts for VW (ordinary and preferred), and its competitors Daimler and BMW. The figure shows that experts' opinions were very much aligned up until the first half of 2006. Starting in about the second half of 2006, the dispersion in analyst opinions about VW's price target started to increase and did so until the day of the press release. We interpret this evidence as a disagreement among analysts about the future prospects of VW. Going into October 2008, the price target dispersion for VW was particularly high compared to the price target dispersion of VW's competitors.

After the press release of Porsche, the dispersion in analysts' opinions for VW's ordinary shares tripled implying that skilled stock analysts were unable to narrow down a price target estimate. As we do not observe this kind of pattern for VW's competitors or for VW's preferred shares, we conclude that the press release left skilled analysts in disagreement about what to make of the press release and how to value VW's ordinary shares. The data on analysts' opinions reveal that this uncertainty persisted also through the first half of 2009. It is only after June 2009 that price targets and price target dispersion dropped. By the end of 2009 the wedge in price target estimates between VW ordinary and VW preferred shares had narrowed. Similarly, by the end of 2009 the price target dispersion of VW's ordinary shares had dropped to pre-2007 levels and had converged to the price target dispersion of VW's preferred shares.

5.2. Voting premium

We analyze the difference in VW's preferred and common share prices over time to understand if the stark increase in prices of VW's ordinary shares was due to a fundamental change in VW's value or rather due to the heavy investment of Porsche. In the latter case the increase is due to a voting premium. The value of preferred shares, which offer no voting rights in Germany, can be seen as representative of the fundamental value of a company, absent the benefit of control. Ordinary shares on the other hand have voting rights embedded in their contractual features and hence usually carry a voting premium.

Fig. 1 depicts the evolution of the prices of ordinary and preferred stocks of VW. Starting in about late 2005, the wedge was continuously increasing and more so towards the date of the

October 26 press release. This suggests that VW's share price was reflective of an increasing voting premium. The October 26 press release was followed by a sharp increase in VW's ordinary share price, while the price of the preferred shares slightly decreased. This implies that during the period immediately after the press release investors had to pay a higher voting premium, i.e., a higher price for acquiring voting power in VW. The high level of the voting premium persisted until the middle of August 2009, when Porsche announced that (i) Porsche and VW will form an integrated car group, and (ii) Qatar will purchase the majority of Porsche's options on VW.

5.3. Informed trading

To establish if there was informed trading in VW shares before the press release, we apply a test based on the dynamic return-trading volume relation in the (potential) short squeeze period. This test was introduced by Llorente, Michaely, Saar, and Wang (2002) and later adapted by Allen, Litov, and Mei (2006) to short squeezes and market corners.

Following Allen, Litov, and Mei (2006), we define the short squeeze date as the date when the short sellers seem to have decided to close their short positions,[35] which in this case was the first trading day after the press release, October 27. We also define an event period as well as a pre-event period. The event period is defined as ten days before the short squeeze date to the short squeeze date (included). The pre-event period is defined as 55 trading days before the event period, i.e., [t-65, t-10]. In line with Allen, Litov, and Mei (2006), 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 VW, $R_{i,t}$ 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

[35] Short sellers might decide to close their positions either because the shares that were sold short are called by the stock lender (e.g., Allen, Litov, and Mei, 2006) or because the short sellers realized that there is not enough free-float to cover their shorts. We regard the day of the press release, Sunday, October 26, 2008, as a triggering event because Porsche's surprising announcement seemed to have 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.

an indicator variable with value one in the [t-10, t] period. The coefficient of interest is β_3. According to Allen, Litov, and Mei (2006), if trading on private information was prevalent in the event period, then one would expect to find that β_3 is positive and statistically significant. We perform our estimation for three specifications. Each of the specifications considers different lengths of the event period: period [t-10, t], period [t-5, t], and period [t-20, t].

Panels A and B of Table 4 summarize the results of the dynamic return-trading volume tests for common and preferred shares. We find that β_3 is positive and statistically significant in all three specifications for ordinary shares. This is strong evidence of informed trading in the period leading up to the short squeeze.[36] We do not find any evidence of informed trading in the preferred shares of VW. The reason for this lack of informed trading in preferred shares might relate to the voting premium. As preferred shares offer no voting rights, they may well not be of interest to insider parties who are trying to gain voting control of VW.[37]

[Insert Table 4 here.]

6. Did the press release lead to a short squeeze?

Given that Porsche's liquidity condition was deteriorating and likely leading to default (see Sections 2 and 4), coupled with the fact that market participants seemingly did not anticipate the events surrounding Porsche and VW (see Section 5), it is important to evaluate if Porsche's press release triggered the short squeeze in VW's stock. In this section we analyze the evolution of price, volume, and securities lending market measures. We then describe the dynamics of the

[36] We arrive at this conclusion following the methodological steps described in Llorente, Michaely, Saar, and Wang (2002) and Allen, Litov, and Mei (2006).

[37] To establish robustness of the previously described results, we follow the latest literature on informed trading in stocks. We follow Hendershott, Jones, and Menkveld (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). We measure informed trading using the adverse selection measure proposed in Hendershott, Jones, and Menkveld (2011). Results are presented in Fig. A7 in Section A.9 of the Internet Appendix. In the two weeks before the press release, we observe an increase in VW's adverse selection cost, which lends robustness to the above described findings, which are based on the test presented in Llorente, Michaely, Saar, and Wang (2002).

short squeeze.

6.1. Analyses of price, volume, and securities lending market measures

Allen, Litov, and Mei (2006) suggest a series of tests that are suitable for this analysis. In particular, following them, we analyze abnormal returns, abnormal trading volume, abnormal illiquidity, abnormal price dispersion, and abnormal volatility to assess if these measures suggest a short squeeze following Porsche's October 26 press release. Each measure is constructed by taking the difference between the daily measure during the event periods and the average of the same measure during the pre-event period. For a detailed definition of each of the measures used, see Fig. 5 and 6. As before, our event date is the first trading day after Porsche's press release, Monday, October 27, 2008. For the analysis we define two event periods as well as a pre-event period: event period one, which is ten days before Porsche's press release to the date of the press release (included), followed by event period two, which is the day after the press release to ten days following it. The pre-event period is defined as 55 trading days before the first event period, i.e., [t-65, t-10].

Fig. 5 and 6 present results for the price and volume measures. The evidence based on each of the metrics indicates that VW's common stock was subject to a short squeeze. For example, the cumulative abnormal returns (CARs) for VW's common shares peaked at the day of the press release publication by more than 100% in absolute values (from -52% on Friday, October 24, to 71% on Monday, October 27) and increased slightly further through October 28 and 29. During the remaining trading days of the second event period the cumulative average return steadily declined by more than a third of its previous high.[38] For preferred shares, we find 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 VW's common shares. The evolution of the other metrics confirms the finding for CARs.

[38] If the pre-event period contains abnormal activity, we would expect that this would bias our estimates, since we use the pre-event period to compute the average expected return, which we then subtract from the daily return in the event period. To address this concern, we also computed market adjusted abnormal measures. For example, for abnormal returns these are computed by subtracting the German automotive market average return from the raw returns of VW in the event period. The results are very similar.

[Insert Figure 5 here.]

[Insert Figure 6 here.]

In addition to these price and volume measures, we analyze the securities lending market. If there was a short squeeze, we should find a freezing of trading activity in the securities lending market as shown, for example, by increasing fees on loans, decreasing utilization, increasing average tenure of outstanding loans, and decreasing demand for securities loans for the purposes of short selling VW's stock. The evolution of each of these variables is shown in Fig. 7. The short squeeze in VW's stock is confirmed by the reaction of traders and trading behavior in the securities lending market: fees increased steeply by 47%; the utilization dropped by 17% around the day of the press release; tenure increased by 44%; and the demand for securities loans (value on loan) decreased sharply by 55% around the day of the press release.

Overall, the evidence presented here is consistent with the behavior of cornered stocks described by Allen, Litov, and Mei (2006) and suggests that Porsche's press release triggered the VW short squeeze.

[Insert Figure 7 here.]

6.2. The dynamics of the short squeeze

As shown in Fig. 8, in the three weeks before the October 26 press release, the amount of shorted VW shares fluctuated around 16.5% of VW's shares outstanding (as measured by the ratio of value on loan relative to the market capitalization of VW). Starting on October 13, the amount of shorted VW shares increased from about 16.5% to about 18% on October 20. The amount of shorted VW shares remained at about 18% through October 24, the Friday before the October 26 press release. Along with this increase, the closing price of VW decreased from about EUR 353 on October 13 to EUR 210 on October 24. The fact that the amount of shorted VW shares increased and the price of VW decreased leading up to the short squeeze is in line with Kyle (1984), who predicts that short sellers in particular and market participants more

generally cannot infer from prices that a short squeeze is imminent.[39]

[Insert Figure 8 here.]

On Monday, October 27, the day after Porsche's press release, we observe a drop in the amount of shorted VW shares from about 18% on October 24 to about 9% on October 27. As VW's price continued to rise and break new records, liquidity constrained short sellers closed out their short positions. On October 28, while VW's stock closed at a record high of EUR 919.50, the amount of shorted VW shares dropped further to about 8.5%. Again, this is in line with Kyle (1984) who shows that during a squeeze, short sellers must purchase at increasingly higher prices to exit their short positions.

On October 29, 2008, Porsche made its second announcement early in the day in Frankfurt[42] that it was making available up to 5% of VW's shares to help provide liquidity to the market but at the same it also made clear that it was still committed to pursuing its domination strategy. This posed a dilemma for traders that in the short term supply to the market would increase but in the long term Porsche would purchase more. Prices almost halved in early trading but remained well above the previous Friday closing price. The price closed at EUR 517. It can be seen from Fig. 8 that short sales of VW's shares increased dramatically during the day from about 8.5% to 20.5%. VW's closing price was still at higher levels than prior to the short squeeze and market participants opened new short positions on VW's stock. At the end of the day, about 20.5% of VW's shares outstanding were shorted relative to about 8.5% on the previous day. It seems that the fact that prices were falling persuaded traders that were not liquidity constrained that it would be profitable to continue short selling the stock and for some people to take out new short positions while the stock price was still elevated well above Friday's close and analysts' estimates of fundamental value. The fact that Porsche had changed

[39] Kyle (1984) provides one of the earliest, fully articulated models of a short squeeze. It is a model of squeezes in futures markets but many of his insights are applicable in stock market squeezes. He shows that it usually only becomes apparent that a squeeze is occurring when short sellers try to liquidate their positions. During a squeeze, short sellers must purchase at increasingly higher prices to exit their short positions. Before a squeeze, according to Kyle (1984), the squeezer along with noise traders or hedgers, trades such that short sellers cannot tell from observing the trading process how much a potential squeezer is buying, i.e., the probability of a squeeze is difficult to infer from initial prices before the squeeze.

its announced strategy several times in the previous two years, as described in Section 2.1, may have made its claim to continue pursuing its domination strategy less credible than it otherwise would have been. The influx of new short sales by people taking advantage of their liquidity position to "free ride" the short squeeze triggered and then alleviated by Porsche is not a feature of the analysis provided by Kyle (1984). To our knowledge, it is not something that has been anticipated in the theoretical literature or documented in the empirical literature before. In the subsequent days, short sale positions were reduced and the price fell back but still remained at elevated levels.

7. Did the short squeeze distort market quality and price discovery?

In this section, we describe the extent to which Porsche's short squeeze affected market efficiency, i.e., stock market quality and price discovery for VW and its competitors. To quantify the impact of the short squeeze, we analyze (i) price metrics (e.g., spreads and volatility of returns) and (ii) volume metrics (e.g., trading volume and depth at the best bid and best offer (BBO)). To assess how market quality changed during the short squeeze, we examine the evolution of these metrics over time.[40] Our analysis focuses on the following periods: (i) the period before Porsche's press release (before October 27, 2008), (ii) the period during the VW short squeeze (October 27, 2008 through October 29, 2008), and (iii) the period after Porsche's second press release (after October 29, 2008). To examine how price discovery changed, we examine changes in intraday patterns of these metrics.[41]

The literature on repeated trading and herding in efficient markets explains the difficulties that market participants of all types (unsophisticated and informed) face when evaluating sur-

[40] Price and volume measures are intertwined in that higher quality markets often exhibit lower spreads and volatility as well as higher volumes and depth. Together these metrics provide measures of "market quality" (Harris, 2002). The following papers among others, apply price and volume metrics to assess changes in market quality over time: Bessembinder (2003); Diether, Lee, and Werner (2009); Chordia, Roll, and Subrahmanyam (2011); and O'Hara and Ye (2011).

[41] The following papers, among others, apply similar methodologies: Foster and Viswanathan (1993b); Chan, Christie, and Schultz (1995); Fleming, Ostdiek, and Whaley (1996); and Comerton-Forde, O'Brien, and Westerholm (2007).

prising news. This literature describes that some market participants are faster in evaluating certain surprising news than others. The academic literature refers to these traders as "informed traders." All other traders are referred to as "liquidity traders" or "uninformed traders." The literature suggests that changes in the proportion of informed and liquidity traders leads to changes in spreads, volatility, and volume. First, Glosten and Milgrom (1985) demonstrated that bid-ask spreads are expected to be higher when informed trading is higher due to increased adverse selection risk. Second, volatility is expected to be higher when informed trading is higher. The intuition behind this finding is that volatility is caused by an increase in information being incorporated into prices, which is mainly driven by an increased proportion of informed trading (Foster and Viswanathan, 1990; Holden and Subrahmanyam, 1992; Wang, 1998). While this process is ongoing, prices fluctuate between the previous fundamental value and the new fundamental value. Third, the literature suggests that the relation between volume and informed trading could be either positive or negative. If informed traders are the reason for changes in volume the relation is expected to be positive, but if liquidity traders are the reason for changes in volume the relation is expected to be negative.

Given that Porsche's press release triggered a short squeeze (as argued in Section 6), we hypothesize that this changed the ratio of informed and uninformed market participants in VW's stock during the short squeeze period. In particular, it might be that the short squeeze induced informed traders, who previously did not act on their information, to trade because they were worried that the value of their information would turn out to be obsolete in the future. Alternatively, informed traders might have decided not to trade because the press release left them confused about the fundamental value of VW's stock. These contradicting views imply that the proportion of informed traders changes during the short squeeze to either increase or decrease. Based on the literature referenced above, we hypothesize that the change in the magnitude of informed trading leads to a change in spreads, volatility, and trading volume during the short squeeze period, and with a reversion to pre-squeeze levels after the short squeeze period. To test the extent to which the short squeeze impacted market quality of the German automotive market more generally, we also examine changes in market quality for VW's competitors.

To examine changes in price discovery over the relevant periods, we analyze intraday patterns in spreads, volatility, and volume measures. Strategic behavior models propose that the timing of trading by informed and liquidity traders causes systematic intraday trading patterns, which in turn lead to distinct intraday patterns in spreads, volatility, and trading volume. Different strategic behavior models predict different intraday patterns. Two possible patterns have emerged.

One part of the theoretical strategic trading literature suggests that the proportion of informed traders decreases throughout the day because informed traders enter the market early and herd at the open to exploit their informational advantage (e.g., Holden and Subrahmanyam, 1992; Park and Sabourian, 2011; Park and Sgroi, 2012). Based on this theory, we should observe price discovery to happen in stages, with wider spreads and higher levels of volatility and volume at market open and a subsequent decrease in these measures throughout the rest of the trading day.

The other group of papers on theoretical strategic trading suggests that the proportion of informed traders is high at the open and at the close of trading. Informed traders enter the market early to exploit their informational advantage, but they also return to the market to trade at the close to profit from the high trading activity at the close and potential divergence of prices from the fundamental value (e.g., Admati and Pfleiderer, 1988; Foster and Viswanathan, 1993a, 1994, 1996; Wang, 1998). If this prediction holds true, we should observe a U-shaped pattern in the speed of price discovery over the course of a trading day and therefore a U-shaped pattern in spreads, volatility, and volume.

We hypothesize that the short squeeze changed intraday trading behavior of market participants, and thereby the price discovery process in VW's stock. For example, it is possible that short sellers that had previously considered themselves to be informed, were confused by Porsche's largely unexpected announcement and unsure about the true value of VW. We expect to find that the intraday patterns and dynamics that governed price discovery before Porsche's press release were changed during the short squeeze period. We assess the extent to which the short squeeze distorted price discovery in the German automotive sector by examining changes in price discovery patterns for VW's competitors. In the subsections below, we describe the

testing methodology that we apply to analyze changes in (i) market quality and (ii) intraday trading patterns (price discovery), and provide interpretations of the results.

7.1. Market quality: Methodology

To test how market quality changed over time, we differentiate between the following time periods: 1) *Pre-SSqueeze* is defined as four weeks (20 trading days) before the short squeeze started, i.e., before October 27, 2008;[42] 2) *SSqueeze* is defined as the short squeeze period, which is from October 27, 2008 through October 29, 2008; and 3) *Post-SSqueeze* is defined as four weeks (20 trading days) after October 29, 2008. We restrict the sample to four weeks around the event days to avoid an overlap with the week during which Lehman Brothers filed for bankruptcy.[43] We estimate the following regression model:

$$Y_{i,t} = \alpha + \beta_1 SSqueeze + \beta_2 Post\text{-}SSqueeze + \epsilon_{i,t}, \tag{5}$$

where $Y_{i,t}$ represents one of the price and volume metrics of interest. Table 5 provides definitions and summary statistics for these variables. i is a firm index and t denotes time in minutes. $SSqueeze$ is a dummy taking the value of one if a trading day is during the short squeeze period, which is from October 27 through October 29, 2008. $Post\text{-}SSqueeze$ is a dummy taking the value of one if the trading day is after October 29, 2008. This model is estimated separately for VW's ordinary shares[44] and VW's competitors. The coefficient α measures the average level of a given metric in the *Pre-SSqueeze* period. The coefficient β_1 measures the change in the average level of a given metric from the *Pre-SSqueeze* period to the *SSqueeze* period. The coefficient β_2 measures the change in the average level of a given metric from the *Pre-SSqueeze* period into the *Post-SSqueeze* period. Statistical inference is based on HAC standard errors,

[42] In robustness estimations we define the *Pre-SSqueeze* period as 55 trading days before the event period. The results are quantitatively and qualitatively very similar to the reported results (untabulated).

[43] The results described below are robust to changing the time windows analyzed to two and three weeks around the event period.

[44] We concentrate this analysis on VW's ordinary shares since they carry voting rights and were the target of the short squeeze.

i.e., standard errors robust to heteroscedasticity and serial correlation.

[Insert Table 5 here.]

7.2. Market quality: Results

Panel A of Table 6 presents the results for VW; Panel B for VW's competitors. For VW we observe that relative bid-ask spreads were on average 18 basis points (b.p.) before the short squeeze period and increased by 11 b.p. during the short squeeze period. This is an increase of 61%. Spreads decreased after the short squeeze period, but remained 4 b.p. higher compared to the period before the short squeeze. Volatility, was on average 0.0028 before the squeeze period.[45] During the short squeeze period, volatility increased by 0.0054, which is an increase of 193%. After the squeeze period, volatility decreased by 0.0002 compared to the period before the short squeeze. Trading volume was on average 4,500 shares per minute before the short squeeze. It increased by 2,320 shares per minute during the short squeeze period, which represents an increase of 51%. It dropped by 2,860 shares after the squeeze period compared to the period before the short squeeze. Before the squeeze period, depth at the BBO lived predominantly on the bid side. The average bid quote size per minute was 11,200 shares; the ask quote size was 2,200 shares. This represents an average order imbalance of 500%. During the squeeze period, this imbalance increased to 1,800%, i.e., the average one-minute bid quote size increased to 13,000 shares; the average one-minute ask quote size decreased to 690 shares. This evidence corroborates the severity of the short squeeze, which was followed by a dry-up in supply and an increase in demand of VW's shares, which in turn resulted in a spike of VW's price. After the short squeeze period, order imbalance remained skewed towards the bid side, but decreased to 400%. Trading volume initiated from sell orders versus buy orders remained relatively balanced in the period before the short squeeze. During the short squeeze period trading volume initiated by buy orders increased much more than trading volume initiated by sell orders. After the short squeeze period, trading volume initiated from the buy orders and

[45] We measure volatility as the rolling standard deviation of realized one-minute returns over 15 minutes. We also estimated all regression models with a measure for volatility over 30-minute non-overlapping windows. Results are qualitatively and quantitatively very similar (not tabulated).

sell orders decreased to about 1,200 shares per minute.

[Insert Table 6 here.]

Panel B of Table 6 presents evidence for VW's competitors. For VW's competitors we observe that relative bid-ask spreads were on average 19 b.p. before the short squeeze period and increased by 2 b.p. during the short squeeze period. This is an increase of 10%. Spreads decreased after the short squeeze period by 2 b.p. compared to the period before the short squeeze. Volatility was on average 0.0022 before the squeeze period and increased during the short squeeze period by 0.0009, which is an increase of 41%. After the squeeze period, volatility decreased by 0.0004 compared to the period before the short squeeze. Trading volume remained the same during the short squeeze period and decreased after the short squeeze. Bid and ask quote sizes, and signed trading volume decreased both during and after the short squeeze.

Overall, we interpret the evidence presented in this section as deterioration in the market quality of VW's stock during the short squeeze period. Furthermore, the evidence is consistent with a deterioration in the market quality of VW's competitors during the short squeeze period.

7.3. Intraday trading patterns: Methodology

To examine how price discovery changed, we assess the intraday patterns in the price and volume variables used in the previous section. In particular, we adopt an approach similar to Foster and Viswanathan (1993a), Chan, Christie, and Schultz (1995), and Comerton-Forde, O'Brien, and Westerholm (2007). We examine what the intraday patterns of these variables are, i.e., the trading patterns at market open, during regular business hours, and at market close. We then examine if these intraday trading patterns changed during and after the short squeeze.

To test for the shape and changes of intraday patterns, we differentiate between the following time periods:[46] 1) we define "early in the trading day" as the first 30 minutes of the trading

[46] VW's ordinary shares are traded on the German stock exchange Xetra. Xetra currently is and was in 2008 a limit order book market with opening, mid-day, and closing call auctions. XETRA matches orders based on price and time priority. In 2008, the operating hours were 9:00 a.m. to 5:30 p.m. CET (Dimpfl and Peter, 2014).

day after market open, i.e., 9:00 a.m. through 9:30 a.m., which includes a daily opening auction (*Before 9:30*) Central European Time (CET); 2) we define "during the trading day" as the period from 9:31 a.m. CET through 5:00 p.m. CET, including the midday auction (*9:31 – 17:00*); and 3) we define "close of trading" as the time after 5:00 p.m. CET, i.e., the last 30 minutes before market close, including the closing auction (*After 17:00*). To establish intraday variation we employ a regression model whereby the price and volume metrics described above are regressed on a constant and indicator variables for the intraday periods:

$$Y_{i,t} = \alpha + \beta_1 D_1 + \beta_2 D_2 + \epsilon_{i,t}, \tag{6}$$

where $Y_{i,t}$ represents one of the metrics of interest, defined in the caption of Table 5. i is a firm index and t denotes time in minutes. D_1 is a dummy taking the value of one if the trading day time is during the period *9:31– 17:00*. D_2 is a dummy taking the value of one if the trading day time is *After 17:00*. This regression is estimated separately for (1) the event windows of interest (i.e., *Pre-SSqueeze*, *SSqueeze*, and *Post-SSqueeze*) and (2) VW and its competitors. The coefficient α measures the average level of a given metric for the trading day period *Before 9:30*. The coefficient β_1 measures the change in the average level of a given metric from the trading day period *Before 9:30* to the trading day period *9:31 – 17:00*. The coefficient β_2 measures the change in the average level of a given metric from the trading day period *Before 9:30* to the trading day period *After 17:00*.[47]

Every trading session starts, ends, and is interrupted by call auctions. Midday auctions usually take place around 1:00 p.m. CET. All auctions operate under similar conditions and only differ in auction duration. During an auction, only indicative prices and volumes are published to market participants. The opening auction lasts ten minutes; the midday auction is in effect for two minutes; and the closing auction lasts five minutes. All auctions have a random end of 30 seconds.

[47]For ease of interpretation, we analyze the regression model described above for the three event windows separately. To provide robustness of the results from regression model 6 and to assess the statistical significance of changes in intraday patterns over time, we also employ a regression model in which each metric of interest is regressed on (1) a constant and additional indicator variables for the intraday periods, (2) indicator variables for the event windows of interest, and (3) their interactions. The results from this "fully-interacted" model for VW are provided in Table A7 and results for VW's competitors are provided in Table A8 in Section A.10 of the Internet Appendix. The results are qualitatively and quantitatively very similar to the results from Model 6 and provide support that changes over the time periods are statistically significant.

7.4. Intraday trading patterns: Results

Table 7 presents the results for VW. Panels A, B, and C report coefficient estimates for the periods before, during, and after the short squeeze, respectively. The results in Panel A show that - before the short squeeze period - bid-ask spreads were largest during market open and decreased over the course of the trading day. The coefficient during the beginning of the day period (*Before 9:30*) is statistically significant 0.0029, i.e., 29 b.p. The coefficient for the middle of the trading day (*9:31 - 17:00*) is statistically significant -0.0011, i.e., spreads were 11 b.p. lower than spreads during the beginning of the day. The coefficient for the market close period (*After 17:00*) is statistically significant -0.0013, i.e., spreads were 13 b.p. lower than spreads during the beginning of the day. This evidence indicates that - before the short squeeze period - spreads experienced a reversed J-shape pattern over the course of a trading day, with largest spreads at the beginning of the day and smallest spreads at market close. Volatility followed a similar intraday pattern. Volatility was largest at market open (significant coefficient of 0.0062), decreased during the middle of the trading day (significant coefficient of -0.0036) and at market close (significant coefficient of -0.0034). These results are consistent with previous studies on intraday patterns and suggest that the amount of price discovery is highest at market open.[48] Volume and depth measures, on the other hand, followed an intraday U-shape pattern. Trading volume was relatively large during market open (estimated coefficient of 6,700), decreased during the day (estimated coefficient of -3,426), and increased to its highest level at market close (estimated coefficient of 12,970). Signed trading volume and depth at the BBO exhibited the same U-shape pattern, with the exception of ask quote size which was steadily increasing throughout the day. Furthermore, ask quote size estimates are much smaller than the bid quote size estimates, which is consistent with dry-up in supply and the increase in demand for VW's shares in the weeks leading up to the short squeeze.

[Insert Table 7 here.]

[48] See, for example, Comerton-Forde, O'Brien, and Westerholm, 2007.

Panel B of Table 7 contains results for VW's stock during the short squeeze period. For this period, we observe that intraday patterns in spreads and volatility change shape from a reversed J-shape pattern to a U-shape pattern. For spreads, the coefficient for the beginning of the day period is statistically significant 0.0093, i.e., spreads increased from 29 b.p. before the short squeeze period to 93 b.p. during the short squeeze period, a three-fold increase. For the middle of the trading day we find a statistically significant coefficient of -0.0064, i.e., during the middle of the trading day spreads were smaller than at the beginning, but - when compared to the results presented in Panel A - still on an elevated level relative to the period before the short squeeze. For the market close we find an insignificant coefficient, which means that spreads at the market close were not significantly different from spreads at the open i.e., spreads increased toward market close relative to the level of spreads during the middle of the trading day. Volatility followed a similar intraday pattern, with a relatively large coefficient estimate of 0.0117 at the beginning of the day compared to the pre-squeeze period. Volatility decreased during the middle of the trading day (significant coefficient of -0.0040). At market close volatility increased above volatility at market open (significant coefficient of 0.0018). Volatility still exhibited a U-shape pattern.

The measures of bid size and buy volume follow a reverse J-shape pattern during the short squeeze period, where they used to follow a U-shape pattern before the short squeeze period. Sell volume continued to follow a U-shape pattern, whereas ask size was highest during the middle of the trading day. The changes in intraday patterns of the price and volume metrics described above are indicative of changes in price discovery for VW during the squeeze. If market participants were confused by Porsche's announcement, it took them longer to react to and trade based on the new information.[49] Finally, Panel C of Table 7 contains results for the regression specification that assesses intraday variations after the short squeeze period. For this period, intraday price discovery patterns largely reverted back to the patterns that we observe

[49]Based on the strategic trading models explained above (e.g., Foster and Viswanathan, 1994, 1996; Wang, 1998), this implies that informed traders preferred to trade later in the day and there was a shift in price discovery towards the end of the day. This is also confirmed by estimating an alternative price discovery measure, namely the weighted price contribution. For brevity, the results of this measure are reported in Fig. A8 of the Internet Appendix, and confirm that price discovery in VW tended to move later in the day right after the Porsche press release.

in the period before the short squeeze.

Table 8 contains results for VW's competitors. The results in Panel A show that intraday patterns for VW's competitors were the same as for VW's stock before the short squeeze. The results in Panel B show that (i) price and volume measures increased in levels during the short squeeze period relative to before, only ask size slightly decreased, and (ii) volume measures slightly changed its intraday patterns compared to before, i.e., before the short squeeze volume measures were largest at market close and during the short squeeze period there was no statistically significant difference between measures at market close relative to market open. This implies that price discovery shifted during the short squeeze period for VW's competitors from market close to be more equally distributed between market open and market close.

[Insert Table 8 here.]

8. Conclusion

The episode of October 2008 during which VW briefly became the most valuable company in the world by market capitalization is an interesting and important one. The consensus of analyst reports at the time saw the voting stock of VW on a path down to EUR 140 per share or even less in the foreseeable future. VW's ordinary stock was overvalued compared to its peers and consequently sold short by arbitrageurs. The market environment at the time was 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. Given this environment, there were low chances of the stock price for VW ordinary shares staying at its still overvalued level, with no fundamental data supporting these prices. Porsche had significant derivatives holdings on VW's stock and had effectively insured more than 50% of the voting stock of VW against falling stock prices by selling cash-settled put options. Liquidity and solvency analyses show that against the background of the credit crisis, Porsche lacked the funds to back up its contractual derivatives obligations

that came under mounting pressure in October 2008. This provided an incentive for Porsche to manipulate VW's stock and save itself from insolvency. In many countries such as the U.S., this kind of abuse would be quickly punished. However, this example illustrates that in Germany, there is a lack of effective enforcement and this did not occur.

We use the VW short squeeze that resulted from Porsche's press release on October 26, 2008, as an important event that likely surprised many market participants, to investigate the impact that such a short squeeze had on stock market quality and price discovery.

While stock price manipulations such as squeezes and corners have been outlawed in the U.S. since 1934, legal limitations have only been introduced and enforced in many European countries in recent years. We use the German financial market system as a unique setting representing a market with imperfect disclosure requirements, low shareholder protection, and most importantly weak enforcement of securities laws. We show that such an environment does not effectively prevent market-distorting events, such as short squeezes, from happening. This has important public policy implications. Going forward, the European Union will only be able to develop the Capital Markets Union with well-functioning and efficient capital markets if prohibitions of market-distorting events such as stock price manipulations are effectively enforced. The fact that they have not been enforced in the EU's most important country economically, namely Germany, suggests that it is necessary to implement significant changes. In particular, rather than remaining a national competency, enforcement of regulations needs to become the full responsibility of an EU level body, specifically, ESMA.

Appendix: Tables and Figures

Fig. 1 Evolution of VW's price and trading volume: January 2005 – December 2009: This figure depicts the evolution of price and trading volume for VW's ordinary (blue) and preferred (red) shares over the period January 2005 through December 2009. The figure also provides a timeline of Porsche's announcements and actions in relation to the acquisition attempt of VW.

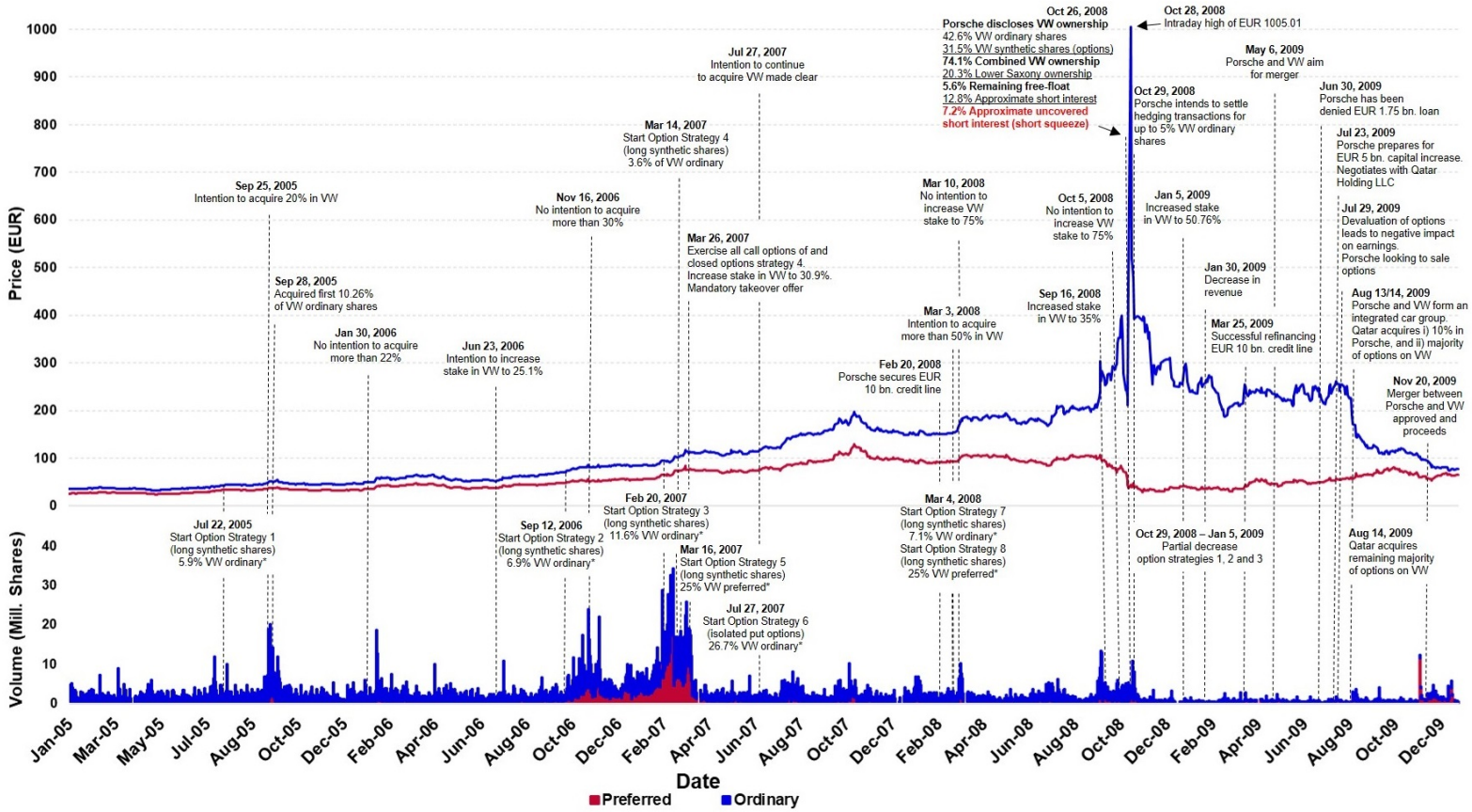


Table 1 Summary of Porsche's option strategies: This table summarizes Porsche's option strategies written on VW's shares as of October 24, 2008.

Strategy	Date Opened	Strategy Type	Underlying Shares	Quantity as of 10/24/2008	Strike Price (€)	Rollover Frequency/Date	Settlement
1	07/22/2005	Long Calls/Short Puts	VW ordinary	17,327,856	Price at every rollover date	Weekly/Fridays	Cash
2	09/12/2006	Long Calls/Short Puts	VW ordinary	20,423,797	85	Monthly/End of month	Cash
3.1	02/20/2007	Long Calls/Short Puts	VW ordinary	34,098,744	93	Weekly/Wednesdays	Cash
3.2	02/20/2007	Short Puts	VW ordinary	closed (21,220,900 before closing)	101	Weekly/Wednesdays	Cash
4	03/14/2007	Long Calls/Short Puts	VW ordinary	closed (10,500,000 before closing)	101	Monthly/End of month	Cash/Physical
5	03/16/2007	Long Calls/Short Puts	VW preferred	26,309,570	60	Monthly/End of month	Cash
6	07/27/2007	Short Puts	VW ordinary	78,591,400	120	Monthly/End of month	Cash
7	03/04/2008	Long Calls/Short Puts	VW ordinary	20,795,080	120	Monthly/End of month	Cash
8	03/04/2008	Long Calls/Short Puts	VW preferred	26,309,570	70	Monthly/End of month	Cash

Fig. 2 Evolution of quarterly liquidity metrics for the German automobile industry: **Current ratio**: We define the current ratio as current assets divided by current liabilities. **Quick ratio**: We define the quick ratio as cash 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: VW, Daimler, and BMW. The period covered is 2005 through 2009.

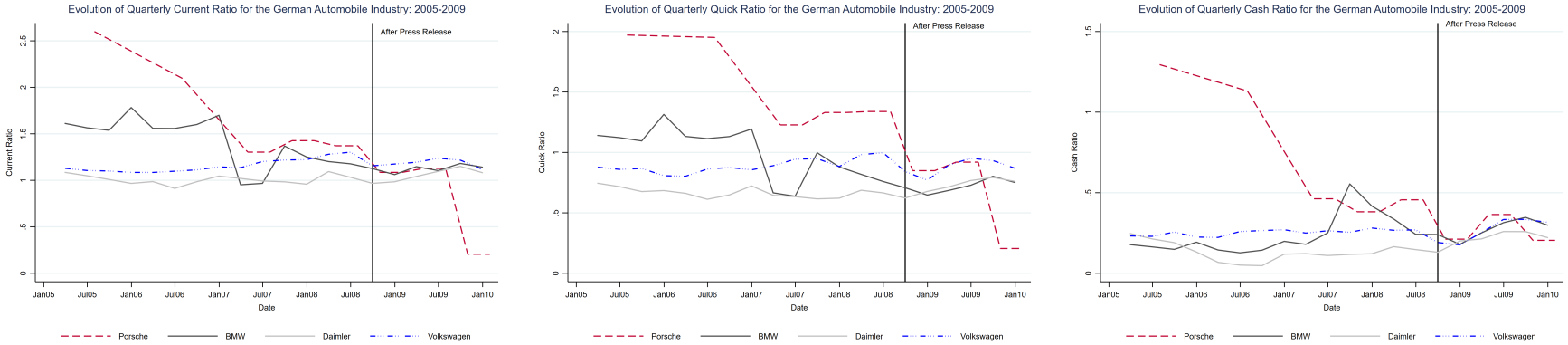


Table 2 Mark-to-market estimates of Porsche's option strategies and margin requirements: This table presents total mark-to-market estimates (MtM) as well as margin requirements for Porsche's option strategies. The period covered is October 13, 2008 through October 31, 2008. MtM values were estimated applying the numerical valuation procedure outlined in Barone-Adesi and Whaley (1987) using information from Table 1. Daily liquidity locked in margins (Margins) was obtained from the Indictment of the public prosecutor, October 6, 2015, LG Stuttgart 13 KLs 159 69207/09. Daily margin requirements (Δ Margins) were estimated as $\text{Margins}_t - \text{Margins}_{t-1}$. All figures are in EUR. Prices are closing prices.

Date	Price Ordinary	Price Preferred	Total MtM Calls Asset (A) (Mill.)	Total MtM Puts Liability (L) (Mill.)	Net MtM A-L (Mill.)	Margins (Mill.)	Δ Margins (Mill.)	Margins/Net MtM
10/13/2008	353.06	77.53	20,303	244	20,059	2,796	-	13.94%
10/14/2008	352.10	78.89	20,251	211	20,040	2,741	-55	13.68%
10/15/2008	390.93	83.55	23,912	32	23,880	3,076	335	12.88%
10/16/2008	398.84	78.87	24,397	30	24,367	3,079	3	12.63%
10/17/2008	358.00	76.49	20,534	77	20,457	3,175	96	15.52%
10/20/2008	277.09	72.66	13,946	1,465	12,481	4,872	1,697	39.03%
10/21/2008	242.75	69.60	11,226	2,092	9,134	5,648	776	61.83%
10/22/2008	243.00	64.15	11,065	2,196	8,869	5,436	-211	61.30%
10/23/2008	229.00	52.90	9,861	2,882	6,979	6,290	854	90.14%
10/24/2008	210.85	43.98	8,484	3,661	4,823	4,268	-2,023	88.48%
10/27/2008	471.00	37.66	32,585	1,438	31,147	1,997	-2,271	6.41%
10/28/2008	919.50	45.08	74,135	1,048	73,087	1,997	0	2.73%
10/29/2008	517.00	39.69	36,845	1,332	35,513	4,129	2,132	11.63%
10/30/2008	500.00	42.05	35,271	1,209	34,062	4,026	-103	11.82%
10/31/2008	475.10	48.21	32,962	884	32,078	3,941	-85	12.29%

Table 3 Scenario analysis based on VaR prices: The panels below present total mark-to-market (MtM) estimates applying two scenarios: (i) 5% VaR prices in Panel A, and (ii) 1% VaR prices in Panel B. The period covered is the week of October 27, 2018 through October 31, 2008, i.e., the week when the short squeeze took place. The estimation of VaR prices is outlined in Equation 2. MtM values were estimated applying the numerical valuation procedure outlined in Barone-Adesi and Whaley (1987) using information from Table 1. To estimate VaR prices, we use the following inputs: the closing price of VW's ordinary shares on October 24, 2008, which was EUR 210.85; the closing price of VW's preferred shares on that date, which was EUR 43.98; the standard deviation of daily returns over the 30 days preceding October 24, which was 9.21% for ordinary shares and 5.29% for preferred shares. All figures are in EUR.

Panel A: 5% VaR

Date	VaR Price Ordinary	VaR Price Preferred	Total MtM Calls Asset (A) (Mill.)	Total MtM Puts Liability (L) (Mill.)	Net MtM A-L (Mill.)
10/27/2008	178.91	40.15	6,131	1,923	4,208
10/28/2008	165.68	38.56	5,099	2,209	2,890
10/29/2008	155.53	37.35	4,320	2,439	1,881
10/30/2008	146.97	36.32	3,679	2,643	1,036
10/31/2008	139.43	35.42	3,104	2,801	303

Panel B: 1% VaR

Date	VaR Price Ordinary	VaR Price Preferred	Total MtM Calls Asset (A) (Mill.)	Total MtM Puts Liability (L) (Mill.)	Net MtM A-L (Mill.)
10/27/2008	165.68	38.56	5,106	2,223	2,883
10/28/2008	146.97	36.32	3,700	2,749	951
10/29/2008	132.61	34.60	2,645	3,234	-589
10/30/2008	120.51	33.15	1,845	3,848	-2,003
10/31/2008	109.84	31.87	1,162	4,623	-3,461

Fig. 3 Probability of default: The probability of default measure is constructed following Bharath and Shumway (2008)'s Equation 12. In particular, $DD = \frac{ln[(E+F)/F]+r_{i,t-1}-0.5\sigma^2}{\sigma}$, where E equals the market value of company's equity (prccd×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 σ^2 captures the volatility of the firm's assets. σ is approximated by $(E/(E+F)) * \sigma_E + (F/(E+F)) * (0.05 + 0.25\sigma_E)$, where σ_E is the quarterly percent standard deviation based on the past 12 monthly returns. The probability of default is then defined as N(–DD), where N is the cumulative standard normal distribution function. We have plotted the evolution of the probability of default for Porsche and its peer group: VW, Daimler, and BMW. The period covered is Q1 2007 through Q3 2009.

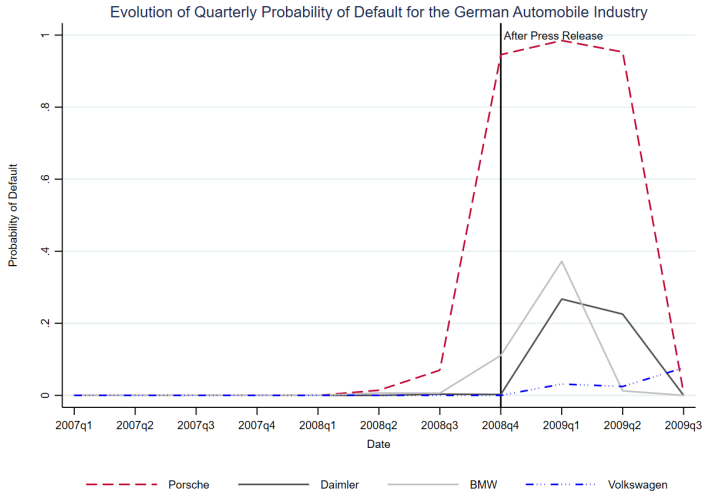


Fig. 4 Evolution of VW's price taget (in EUR): 2005-2009: This figure plots the evolution of monthly average price target estimates of stock analysts. The shaded areas in blue and red around the average price targets of ordinary and preferred shares denote 95% confidence intervals. The period covered is 2005 through 2009. **Evolution of price target dispersion: 2005-2009:** This figure plots the evolution of the monthly dispersion in analysts' price target estimates (an estimate of how much analysts differ in terms of their opinion on the value of a stock). The period covered is 2005 through 2009. For both figures, we use data from the I/B/E/S Summary History file.

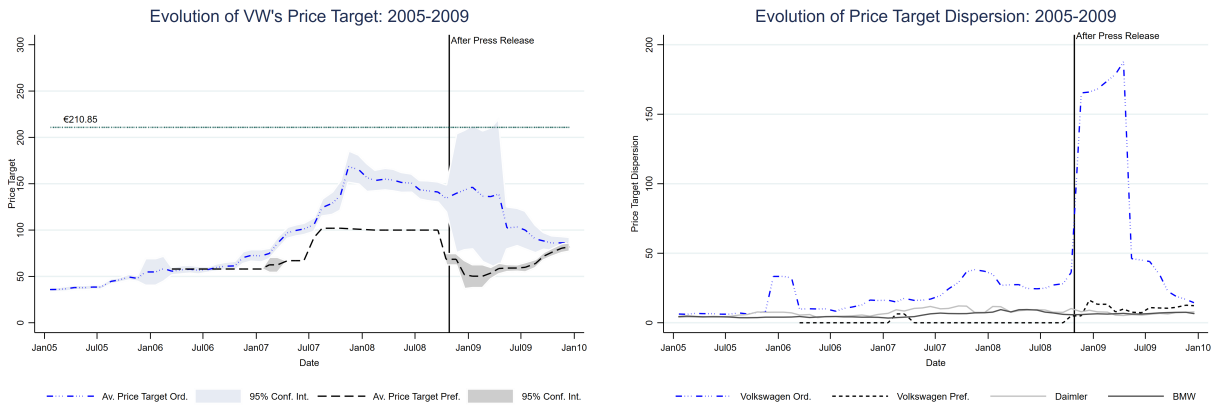


Table 4 Dynamic return-trading volume relationship test for common and preferred shares: We present the results of the regression $R_{i,t+1} = \alpha_i + \beta_1 R_{i,t} + \beta_2 R_{i,t} \times V_{i,t} + \beta_3 R_{i,t} \times V_{i,t} \times D_i + \epsilon_{i,t+1}$, where i indexes the stock of VW, $R_{i,t}$ 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 short squeeze date t. In columns two and three, as a robustness test, we define the period around the short squeeze date t as [t-5, t] and [t-20, t], respectively. We are interested in testing whether the coefficient β_3 of the interaction term, $R_{i,t} \times V_{i,t} \times D_i$, is positive and statistically significant (see Allen, Litov, and Mei, 2006). t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Common Shares

Variables	$D_{t-10,t}$	$D_{t-5,t}$	$D_{t-20,t}$
$Return_t$	2.330***	3.460***	2.173**
	(2.818)	(2.927)	(2.630)
$Volume_t \times Return_t$	-0.220***	-0.301***	-0.205***
	(-3.052)	(-2.855)	(-2.848)
$Volume_t \times Return_t \times D_i$	0.043***	0.035**	0.039**
	(2.759)	(2.131)	(2.462)
Constant	0.009	0.007	0.009
	(1.389)	(1.026)	(1.269)
Observations	63	63	63
R^2	0.186	0.146	0.166

Panel B: Preferred Shares

Variables	$D_{t-10,t}$	$D_{t-5,t}$	$D_{t-20,t}$
$Return_t$	8.594*	8.429*	9.429**
	(1.889)	(1.819)	(2.088)
$Volume_t \times Return_t$	-0.650*	-0.633*	-0.708**
	(-1.922)	(-1.840)	(-2.090)
$Volume_t \times Return_t \times D_i$	0.028	0.023	0.016
	(1.101)	(0.936)	(0.546)
Constant	-0.006	-0.006	-0.006
	(-0.736)	(-0.716)	(-0.676)
Observations	51	51	51
R^2	0.123	0.116	0.106

Fig. 5 Cumulative abnormal return: We show the cumulative abnormal return for VW's common (left-hand side) and preferred (right-hand side) stock around the short squeeze (event date) [t-10, t+10]. Abnormal returns are defined as the difference between the daily return in the event period and the pre-event [t-65, t-10] average daily return. In the figures, we have accumulated the abnormal returns across the event 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. **Cumulative abnormal trading volume (standardized):** We show the cumulative abnormal trading volume for VW's common (left-hand side) and preferred (right-hand side) stock around the event date [t-10, t+10]. Abnormal trading volume is defined as the difference between daily trading volume in the event period and the pre-event [t-65, t-10] average daily trading volume. We standardize this variable with the standard deviation of the pre-event period daily volume. In the figure, we have accumulated the abnormal trading volume across the event 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 VW's common (left-hand side) and preferred (right-hand side) 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), and $R_{i,t}$ is the daily stock return (see Amihud (2002)). **Daily price dispersion:** Daily price dispersion as a percentage of closing price for VW's common (left-hand side) and preferred (right-hand side) stock is the difference between the high and low prices within a given trading day as a percentage of the closing price.

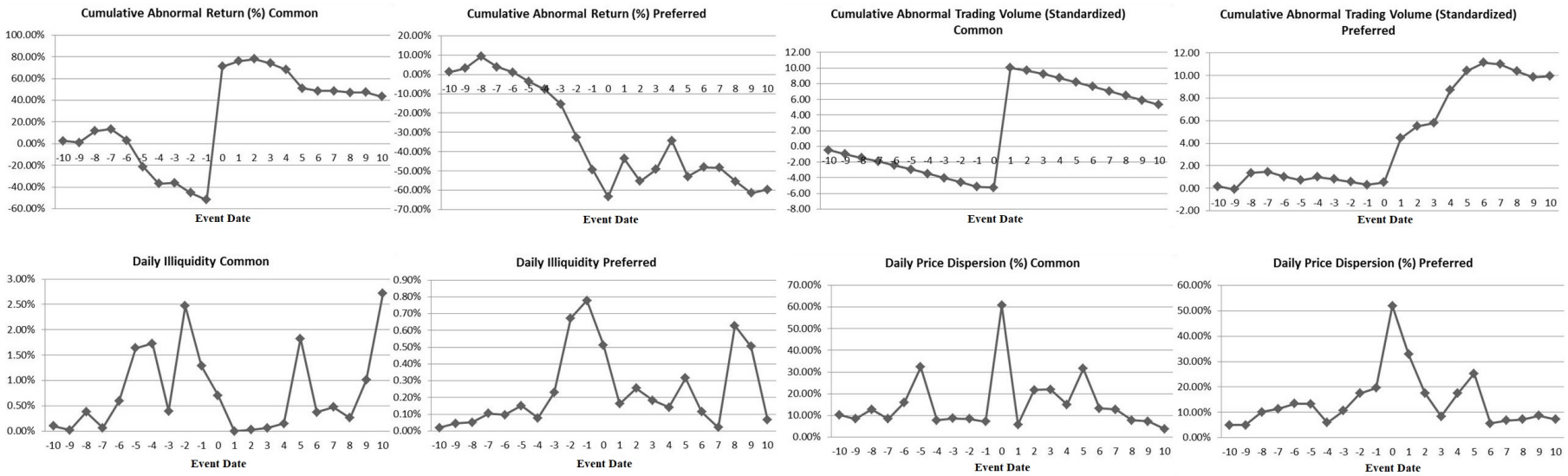


Fig. 6 Daily volatility: We define the daily volatility measure for VW's common (left-hand side) and preferred (right-hand side) stock as the standard deviation of intraday returns (on a minute by minute basis). Abnormal volatility is defined as the difference between daily volatility in the event period and the pre-event [t-65, t-10] average daily volatility.

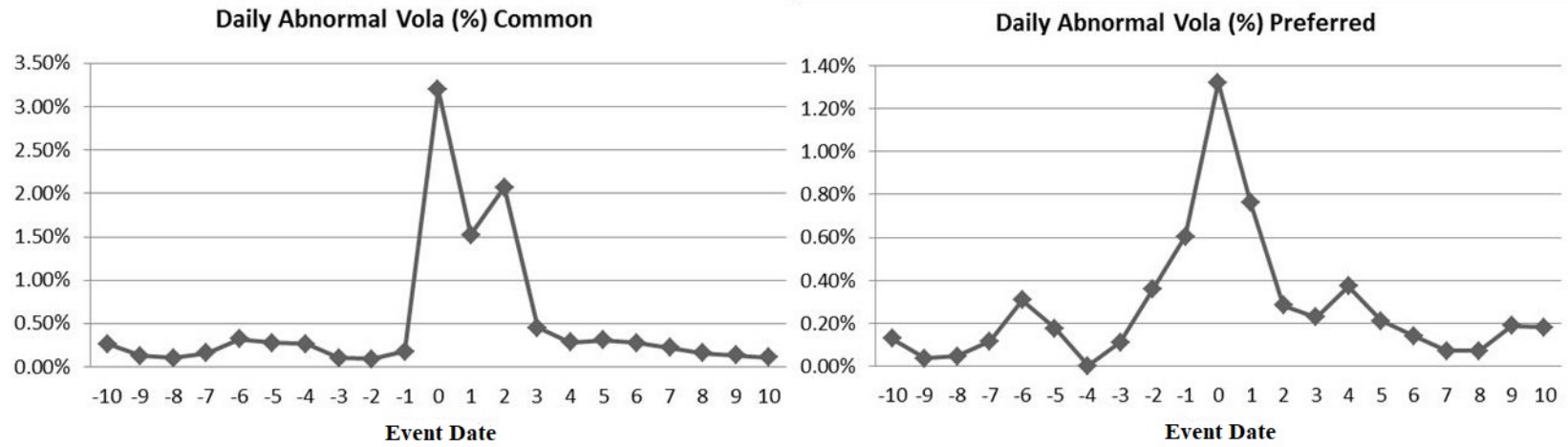
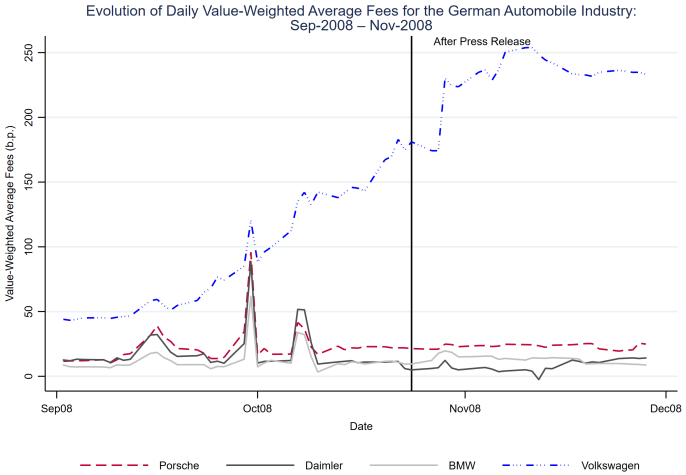
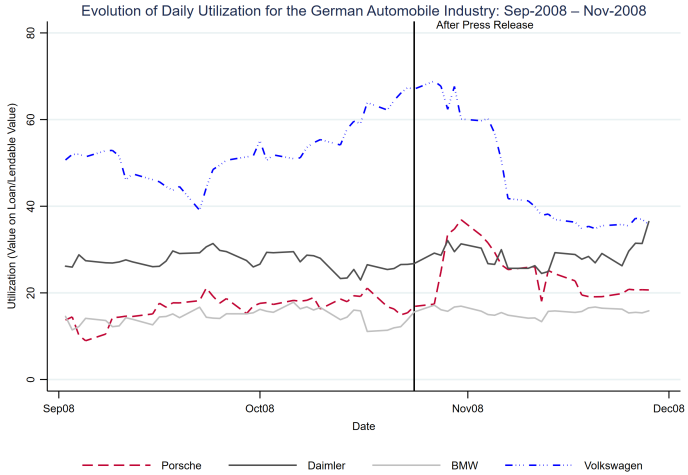
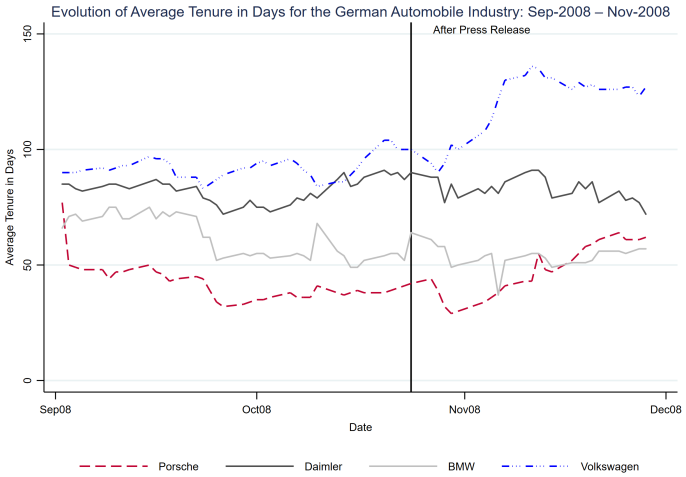


Fig. 7 Value-weighted average fees: This graphs shows the value-weighted average fees on securities loans of the German automotive industry for the time period of September to November 2008 (y-axis is in basis points). **Utilization:** This graphs shows the utilization of securities loans of the German 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 (y-axis is in days). **Value on loan:** This graph represents the demand for securities loans and shows the total value of open securities loans relative to a company's market capitalization for the German automotive industry for the time period of September to November 2008.







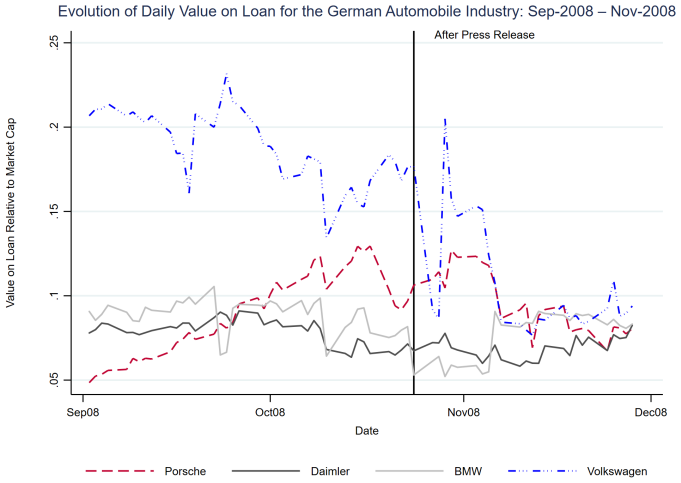


Fig. 8 Evolution of Daily Value on Loan and VW Price: This graph represents value on loan relative to market capitalization for the German automotive industry and VW's price (closing values) for the period around the short squeeze, i.e., October 08, 2008 - November 08, 2008.

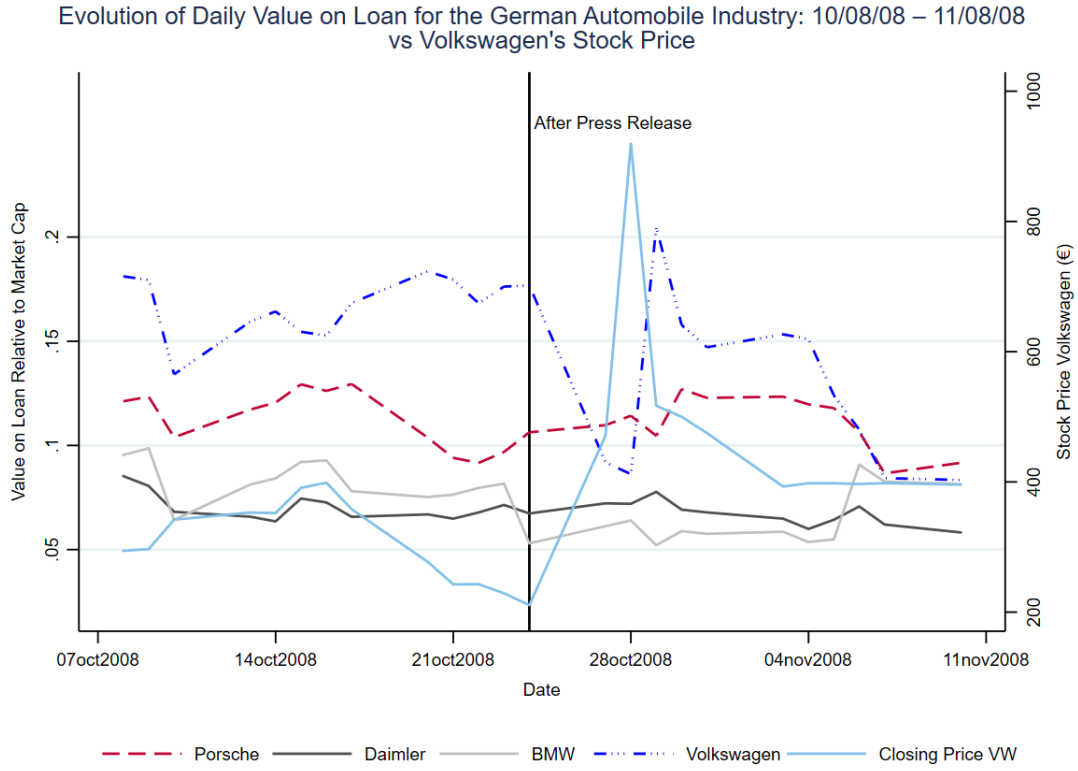


Table 5 Descriptive statistics: This table presents descriptive statistics for VW in panel A. Descriptive statistic for VW's competitors (Daimler, Porsche and BMW) are presented in panel B. We present descriptive statistics for the following variables: 1.) Spread is the relative spread measured as: $\frac{(Ask_{i,t}-Bid_{i,t})}{m_{i,t}}$, where: $m_{i,t} = \frac{(Ask_{i,t}+Bid_{i,t})}{2}$; 2.) Volatility is the rolling standard deviation of realized returns over a window of fifteen minutes; 3.) Volume is the total trading volume; 4.) Bid Size is the total number of shares quoted at the bid; 6.) Ask Size is the total number of shares quoted at the ask; 5.) Buy Volume is the number of shares traded into buy-side trading volume; 6.) Sell Volume is the number of shares traded into sell-side trading volume. To differentiate between buy- and sell-side, we apply the algorithm proposed by Lee and Ready (1991). The data cover the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short squeeze period (inclusive). The data frequency is on the minute level. Data come from TickData Inc.

Panel A: VW

	Obs	Mean	Std. Dev.	Min	Max	P1	P25	P50	P75	P99
Spread	18689	.0021	.0018	0	.036	.0001	.0009	.0016	.0027	.0087
Volatility	21577	.003	.0028	0	.0285	.0005	.0014	.0022	.0035	.0151
Volume	21713	3296.169	23290.53	0	1659085	0	543	1356	3012	21960
Bid Size	21624	7962.934	12877.35	0	456255	116	2175	4577	8902.5	56313
Ask Size	19871	1556.102	2348.018	1	47376	29	360	831	1788	11187
Buy Volume	9479	2317.681	3058.887	1	59817	44	566	1341	2845	14802
Sell Volume	10050	2341.696	3112.815	3	40758	35	583	1379.5	2916	15753

Panel B: VW's Competitors

	Obs	Mean	Std. Dev.	Min	Max	P1	P25	P50	P75	P99
Spread	59305	.0018	.0016	0	.0327	.0001	.0009	.0014	.0022	.0081
Volatility	65299	.0021	.0014	0	.0239	.0006	.0012	.0017	.0024	.0074
Volume	65695	11294.01	99048.42	0	1.10e+07	0	1502	4451	10210	68682
Bid Size	64891	30187.28	48619.65	0	3940434	187	6625	17813	36429	193830
Ask Size	61930	9361.189	13149.22	1	443865	127	2370	5504.5	11346	62082
Buy Volume	30311	8444.251	11475.7	1	170710	50	1750	4814	10481	57648
Sell Volume	29809	8830.781	12563.03	1	289860	82	1894	4890	10668	63138

Table 6 Market quality tests: This table reports the results from the market quality regression estimation described in Equation 5. The dependent variables are defined in Table 5. Panel A presents results for VW ordinary shares; panel B presents results for VW's competitors: Daimler, Porsche and BMW. The data set covers the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short squeeze period. The data frequency is on the minute level. We define the period before the short squeeze (Pre-SSqueeze) as the four weeks (20 trading days) preceding October 27, 2008. We define the short squeeze period (SSqueeze) as October 27, 2008 through October 29, 2008. We define the period after the short squeeze (Post-SSqueeze) as the four weeks (20 trading days) after October 29, 2008. t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data come from TickData Inc.

Panel A: VW

	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
Post-SSqueeze	0.0004***	-0.0002***	-2,858.7401***	-7,222.6674***	-1,228.3990***	-1,919.0313***	-2,059.4017***
	(15.980)	(-5.873)	(-8.705)	(-42.484)	(-37.031)	(-31.544)	(-35.531)
SSqueeze	0.0011***	0.0054***	2,317.6175***	1,728.3640***	-1,515.7435***	1,015.4803***	536.6491***
	(10.192)	(42.110)	(3.689)	(3.926)	(-35.838)	(7.406)	(4.325)
Pre-SSqueeze	0.0018***	0.0028***	4,480.3721***	11,227.4041***	2,202.9793***	3,175.2276***	3,230.4372***
	(113.410)	(114.574)	(16.152)	(71.236)	(73.539)	(57.766)	(60.500)
Observations	18,689	21,577	21,713	21,624	19,871	9,479	10,050
Adjusted R^2	0.024	0.232	0.005	0.084	0.072	0.113	0.115

Panel B: VW's Competitors

	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
Post-SSqueeze	-0.0002***	-0.0004***	-6,129.5081***	-11,334.4893***	-2,644.8122***	-4,014.2284***	-4,465.9519***
	(-11.483)	(-28.000)	(-5.808)	(-25.425)	(-21.470)	(-26.283)	(-26.529)
SSqueeze	0.0002***	0.0009***	-1,517.6042	-7,325.0634***	-1,357.0999***	-762.6419***	-1,361.8168***
	(5.241)	(16.612)	(-0.867)	(-12.705)	(-5.702)	(-3.194)	(-5.577)
Pre-SSqueeze	0.0019***	0.0022***	14,253.9139***	35,956.9668***	10,668.4475***	10,330.3847***	10,938.2812***
	(177.239)	(190.340)	(15.461)	(96.126)	(113.250)	(78.990)	(75.104)
Observations	59,305	65,299	65,695	64,891	61,930	30,311	29,809
Adjusted R^2	0.003	0.052	0.001	0.013	0.009	0.029	0.029

Table 7 Intraday variation in spreads, volatility, and trading activity for VW: This table reports the results from the intraday variation regression estimation described in Equation 6. The dependent variables are defined in Table 5. The data set covers the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short squeeze period. The data frequency is on the minute level. Panel A reports regression results for the period before the short squeeze. We define the period before the short squeeze as the four weeks (20 trading days) preceding October 27, 2008. Panel B reports regression results for the short squeeze period. We define the short squeeze period as October 27, 2008 through October 29, 2008. Panel C reports regression results for the period after the short squeeze. We define the period after the short squeeze as the four weeks (20 trading days) after October 29, 2008. t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data come from TickData Inc.

Panel A: Pre-SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0013***	-0.0034***	12,970.1791***	-774.5999	679.0832***	258.6863	50.3180
	(-10.537)	(-17.701)	(2.999)	(-0.539)	(4.266)	(0.553)	(0.132)
9:31 - 17:00	-0.0011***	-0.0036***	-3,426.8786***	-5,545.4088***	469.6758***	-1,731.0916***	-1,735.4631***
	(-10.208)	(-20.076)	(-6.510)	(-5.063)	(5.140)	(-4.620)	(-5.498)
Before 9:30	0.0029***	0.0062***	6,700.8306***	16,159.4364***	1,747.5378***	4,701.8194***	4,761.1938***
	(26.648)	(34.454)	(12.906)	(14.892)	(20.432)	(12.682)	(15.312)
Observations	9,151	10,053	10,113	10,082	9,649	4,500	5,041
Adjusted R^2	0.029	0.116	0.020	0.011	0.001	0.025	0.022

Panel B: SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0041	0.0018**	-15,891.6476	-14,726.0300***	-117.5839	-2,488.8667***	-3,897.3333
	(-1.287)	(2.323)	(-1.597)	(-2.822)	(-0.750)	(-3.013)	(-1.274)
9:31 - 17:00	-0.0064**	-0.0040***	-25,154.9367***	-17,852.3802***	257.0546*	-3,080.7501***	-5,978.8980**
	(-2.096)	(-8.109)	(-2.912)	(-3.536)	(1.722)	(-4.001)	(-2.234)
Before 9:30	0.0093***	0.0117***	30,170.1081***	29,743.0833***	444.1765***	7,189.8000***	9,654.2500***
	(3.032)	(24.310)	(3.494)	(5.904)	(3.042)	(9.473)	(3.611)
Observations	826	1,426	1,439	1,427	1,035	486	533
Adjusted R^2	0.055	0.100	0.073	0.063	0.003	0.022	0.050

Panel C: Post-SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0019***	-0.0030***	6,898.4272**	3,674.8724***	550.1060***	1,342.9400***	1,222.7831***
	(-13.481)	(-13.665)	(2.368)	(7.435)	(5.747)	(7.629)	(7.195)
9:31 - 17:00	-0.0015***	-0.0038***	-542.5481***	-697.2514***	169.8060***	83.9809	-120.8256
	(-13.196)	(-20.092)	(-2.723)	(-2.634)	(3.637)	(1.090)	(-1.511)
Before 9:30	0.0037***	0.0061***	1,686.5645***	4,405.0733***	792.9532***	1,104.7449***	1,206.0604***
	(32.414)	(32.613)	(8.507)	(17.138)	(17.907)	(15.283)	(15.702)
Observations	8,712	10,098	10,161	10,115	9,187	4,493	4,476
Adjusted R^2	0.043	0.185	0.010	0.025	0.005	0.028	0.043

Table 8 Intraday variation in spreads, volatility, and trading activity for VW's competitors: This table reports the results from the intraday variation regression estimation described in Equation 6. The dependent variables are defined in Table 5. The data set covers the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short squeeze period. The data frequency is on the minute level. Panel A reports regression results for the period before the short squeeze. We define the period before the short squeeze as the four weeks (20 trading days) preceding October 27, 2008. Panel B reports regression results for the short squeeze period. We define the short squeeze period as October 27, 2008 through October 29, 2008. Panel C reports regression results for the period after the short squeeze. We define the period after the short squeeze as the four weeks (20 trading days) after October 29, 2008. t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data come from TickData Inc.

Panel A: Pre-SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0011***	-0.0015***	54,553.1764***	18,455.7122***	4,354.0810***	4,328.2109***	4,494.1824***
	(-14.069)	(-17.580)	(3.825)	(8.578)	(7.108)	(4.452)	(3.964)
9:31 - 17:00	-0.0010***	-0.0019***	-6,666.0071***	-1,316.8985	1,032.6999**	-2,815.0865***	-3,736.3439***
	(-14.717)	(-24.537)	(-6.026)	(-0.870)	(2.576)	(-4.051)	(-5.171)
Before 9:30	0.0028***	0.0039***	16,737.0537***	36,030.7124***	9,499.4955***	12,587.2296***	13,942.3713***
	(41.900)	(51.427)	(15.546)	(24.646)	(24.439)	(18.446)	(19.684)
Observations	27,907	30,355	30,538	30,252	29,174	14,321	14,208
Adjusted R^2	0.018	0.088	0.014	0.006	0.004	0.016	0.019

Panel B: SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0013***	-0.0048***	34,151.5751	-2,180.9479	1,076.3162	-2,233.1441	-2.8017
	(-5.937)	(-13.034)	(1.421)	(-0.747)	(1.119)	(-1.531)	(-0.002)
9:31 - 17:00	-0.0013***	-0.0055***	-13,461.5722***	-12,104.8607***	1,746.8878**	-5,756.0015***	-8,353.9148***
	(-7.033)	(-16.117)	(-4.499)	(-5.029)	(2.112)	(-4.405)	(-6.712)
Before 9:30	0.0033***	0.0082***	22,546.3527***	39,483.7668***	7,693.3652***	14,872.0659***	17,003.1600***
	(17.467)	(24.169)	(7.547)	(16.697)	(9.711)	(11.519)	(13.802)
Observations	4,191	4,534	4,563	4,543	4,407	2,158	2,207
Adjusted R^2	0.025	0.234	0.022	0.014	0.000	0.023	0.090

Panel C: Post-SSqueeze	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
After 17:00	-0.0009***	-0.0012***	35,182.9669***	21,208.6766***	5,094.6437***	5,111.7078***	5,820.2369***
	(-16.754)	(-20.358)	(4.368)	(14.652)	(10.849)	(8.906)	(9.433)
9:31 - 17:00	-0.0009***	-0.0017***	-2,631.2359***	2,178.2754***	2,070.6568***	-1,262.5775***	-533.5637*
	(-18.345)	(-30.363)	(-5.855)	(2.924)	(9.074)	(-3.812)	(-1.814)
Before 9:30	0.0026***	0.0033***	8,242.0373***	21,443.9641***	5,891.9970***	7,089.6398***	6,585.5024***
	(53.454)	(60.996)	(18.598)	(30.589)	(27.749)	(21.993)	(23.348)
Observations	27,207	30,410	30,594	30,096	28,349	13,832	13,394
Adjusted R^2	0.024	0.156	0.019	0.014	0.005	0.037	0.030

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Internet Appendix to Market efficiency and limits to arbitrage: Evidence from the Volkswagen short squeeze

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(*Not for Publication*)

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A.1. Case study: Tesla Inc.

This section describes a recent prominent example of the enforcement of the SEC Act when the SEC investigated and prosecuted Tesla and Elon Musk for using messaging services to drive up Tesla's stock price and allegedly "squeeze" short sellers. This contrasts with the enforcement of manipulation cases in Germany such as the one described in the paper.

In 2018, stock analysts and investors increasingly began to question Tesla's ability to meet its previously announced production targets and its ability to earn sufficient cash to sustain its operations and pay its existing debt.[5] By August 2018, more than USD 13 billion worth of Tesla shares were being "shorted."[5] Elon Musk repeatedly alleged that Tesla has been unfairly targeted by this negative press and more importantly by short sellers. He publicly speculated that short sellers would be "burned."[5] For example, on May 4, 2018, Musk tweeted, "Oh and uh short burn of the century coming soon. Flamethrowers should arrive just in time."[5] Following this tweet, on June 17, 2018, Musk tweeted that short sellers "have about three weeks before their short position explodes."[5]

On August 7, 2018, during trading hours, Elon Musk surprised investors when he tweeted to his more than 22 million Twitter followers that he was considering taking Tesla private at USD 420 per share, which was about a 20% premium over the stock's trading price earlier that day.[4];[5] Mr. Musk continued to tweet that day with what the SEC has alleged amounts to additional materially false and misleading statements. For example, he tweeted that "[i]nvestor support is confirmed" and that the "[o]nly reason why this [investor support] is not certain is that it's contingent on a shareholder vote."[5]

Investors reacted instantaneously to Musk's tweets. On the same day, the stock price closed at a premium of 10.98% relative to the previous day's close.[5] According to the public press, this increase in Tesla's stock price led to a loss of about USD 1.3 billion for short sellers.[43] The tweet also seems to have encouraged more trading activity in Tesla's options, driving volume up by more than twice the daily average after the tweet went public.[43] Figure A1 depicts the evolution of Tesla's share price and short interest for the period of July 1, 2018 through October 1, 2018. The figure shows that short sellers reduced their positions around Mr. Musk's tweet.

In particular, from the last recorded short interest data point at the end of July 2018, before the announcement was made, through the next recorded data point in middle of August 2018, there is a reduction in short interest of 2,268,961 shares,[4] or 15% of the average daily trading volume.[5]

Regulators reacted swiftly. A week after the tweet was made, on August 14, 2018, the SEC started an official investigation into the matter by sending a subpoena to Tesla seeking information from each of Tesla's directors.[4] The DOJ followed with a criminal investigation.[44] On August 23, 2018, Mr. Musk told Tesla's board of directors that he had decided not to follow through with the going-private proposal. On the next day, he ended the speculation regarding Tesla going private by publishing a tweet that stated that he "believe[d] the better path is for Tesla to remain public."[44]

A settlement proposal was reached between the SEC and Tesla less than two months after the initial tweets on August 7. On September 29, 2018, the SEC announced that Tesla's CEO Elon Musk had proposed to settle a fraud suit by agreeing to pay a USD 20 million fine.[45] In addition, the proposal indicated that he would step down as the chairman of Tesla's board and would be replaced by an independent chairman.[6;45] On October 16, 2018, a U.S. federal judge approved the proposed settlement between Tesla, Mr. Musk, and the SEC.[46] The final settlement agreement put forward that the company would pay a USD 20 million penalty.[47] Furthermore, the regulators have enforced governance changes at Tesla that require the company to hire two additional directors and to set up a new committee of independent directors, as well as to adopt controls over Mr. Musk's communications.[47]

These timely regulatory actions quickly restored market confidence and relate to an increased activity of short sellers. Figure A1 shows that short sellers increased their positions from the middle of August until the end of September by 913,341 shares sold short,[7] or 9% of the average

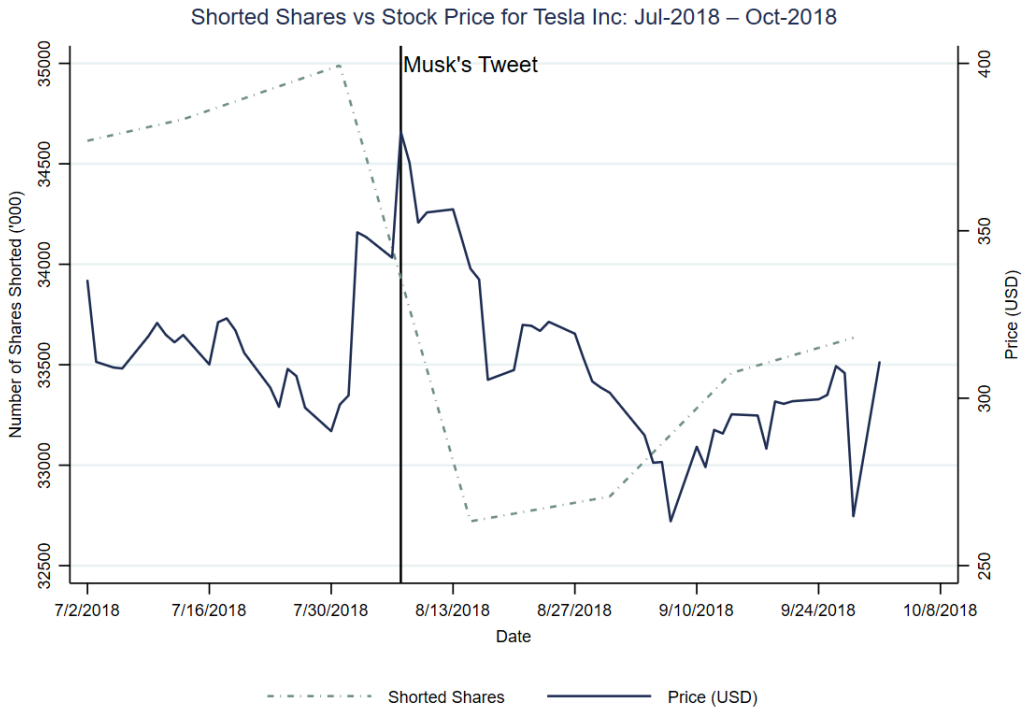
[4]Official data per Nasdaq retrieved as of October 10, 2018 indicate that as of settlement date July 31, 2018, a total of 34,989,543 of Tesla's shares were sold short. Furthermore, as of settlement date August 15, 2018 a total of 32,720,582 of Tesla's shares were sold short. Nasdaq, Inc. short interest is available by issuer for the past 12 months and updated twice a month. See, Nasdaq Short Interest Data (Link).

[5]Official data per Nasdaq retrieved as of October 10, 2018 indicate that as of August 15, 2018 the average daily share volume was 15,118,819. See, Nasdaq Short Interest Data (Link).

[6]Elon Musk will be ineligible to be reelected chairman for three years, but can keep the CEO position.

[7]Official data per Nasdaq retrieved as of October 10, 2018 indicate that as of August 15, 2018, a total of 32,720,582 of Tesla's shares were sold short. Furthermore, as of September, 29, 2018 a total of 33,633,923 of

Fig. A1 Tesla's stock price and short interest over time: This figure shows the evolution of Tesla's short interest (left-hand side) and stock price (right-hand side) during the period July 1, 2018 through October 1, 2018.



daily share volume.[8] To put this number into perspective, short sellers increased their aggregate short positions by USD 242 million when using Tesla's stock market price as of September, 28 2018.[9] Overall, the evidence suggests that the quick and efficient enforcement resolution system in the U.S. restored the confidence in Tesla's market.

Tesla's shares were sold short. See, Nasdaq Short Interest Data (Link).

[8]Official data per Nasdaq retrieved as of October 10, 2018 indicate that as of September 28, 2018 the average daily share volume was 10,345,288. See, Nasdaq Short Interest Data (Link).

[9]We calculate the short interest dollar value by applying Tesla's closing stock market price as of September, 28 2018 of USD 265 to both the short interest as of August 15, 2018 and the short interest as of September, 28 2018.

A.2. The BaFin's regulatory investigations: 2006 - 2018

This section provides an overview of the Bafin's market manipulation investigations and enforcement actions over the period of 2006 to 2018.

The public information that the BaFin provides through their website and their annual reports, is not granular enough to allow us to assess if any of the market manipulation investigations involved an attempted corner on the long side or another type of trade-based manipulation related to a takeover attempt. We have reviewed all "Measures & sanctions" disclosed on the BaFin's website, both non-anonymized and anonymized. All of these sanctions relate to either (i) non-compliance of financial reporting requirements (29%) or (ii) omissions or delay of disclosures of financial reporting requirements (71%). Furthermore, we have reviewed all of the BaFin's annual reports for the period of 2006 through 2018 for information on market manipulation investigations. Table A1 provides statistics on the number of (i) new investigations, (ii) pending investigations, and (iii) closed investigations by the BaFin into alleged market manipulation by year. As described in Section 1 of the main body of the paper and shown in this table, from 2016 to 2018, the BaFin started 647 new investigations into alleged market manipulation, of which it passed on 304 cases to public prosecutors.[10] Of those, 21 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 for the period 2016 to 2018 - conditional on having been investigated by the BaFin - is 3%.

While the BaFin provides detailed statistics on the number of (1) new investigations, (2) discontinued investigations, and (3) pending investigations per year, the BaFin only describes at a high level the types of market manipulations underlying these statistics. For example, in its 2018 Annual Report, the BaFin describes that "most of [its market manipulation investigations] were triggered by suspicious transaction and order reports."[11] Of the 3,104 "suspicious

[10] The BaFin Annual Reports, 2016 - 2018.
[11] 2018 Annual Report, p. 131.

transaction and order reports" that the BaFin received, 77% "related to alleged market manipulation."[12] The remaining 23% relate to alleged insider trading cases. For the alleged market manipulation cases, the BaFin states that most "cases involved trade-based manipulation."[13] However, when referring to trade-based manipulation, the BaFin only points to "pre-arranged trades and wash sales, where the buyer and seller are the same person" and does not mention any other types of trade-based manipulation.[14]

[12] 2018 Annual Report, p. 131.
[13] See, e.g., 2018 Annual Report, p. 131.
[14] See, e.g., 2018 Annual Report, p. 131.

Table A1 The BaFin's Market Manipulation Investigations: 2006 - 2018: This table presents information about the number of market manipulation investigations reported by the BaFin in its 2006 - 2018 annual reports. The symbol * represents an estimate since the BaFin changed its "risk-based investigation approach" in 2018 and does not report the total number of pending investigations in its 2018 Annual Report.

			Closed Investigations				
Period	**Pending Prior Period**	**New**	Discontinued	Passed to Public Prosecutor	Settled	**Total Closed**	**Pending Period End**
2018	441	149	84	77	4	81	425*
2017	398	226	56	121	6	127	441
2016	279	272	40	106	7	113	398
2015	237	256	44	160	10	170	279
2014	208	224	33	156	6	162	237
2013	208	218	66	142	10	152	208
2012	115	250	30	121	6	127	208
2011	90	166	30	104	7	111	115
2010	71	116	29	62	6	68	90
2009	100	150	115	60	4	64	71
2008	97	77	42	32	0	32	100
2007	103	61	41	22	4	26	97
2006	n/a	60	30	15	5	20	103

A.3. Porsche's plan to take over Volkswagen: The legal landscape

This section provides a summary of legal and institutional details on Germany's takeover regulation.[15]

Threshold and the timing for providing disclosure of large block holdings

As discussed in Section 2, the German Securities Trading Act (Wertpapierhandelsgesetz – WpHG) requires disclosure of shareholdings upon exceeding (or falling below) the following thresholds of holdings in voting rights in the target company: 3%, 5%, 10%, 15%, 20%, 25%, 30%, 50%, and 75%.[48] Changes in holdings of the voting rights must be reported to the issuing company and to the German Federal Financial Supervisory Authority (the BaFin or Supervisory Authority) "without undue delay and at the latest within four trading days."[48] The notification period "begins when the party subject to the notification requirement learns or [...] must have learned, that its percentage of voting rights has reached, exceeded or fallen below the respective thresholds. With regard to the beginning of the period, [the] presumption [is] that the shareholder learns of this no later than two trading days after reaching, exceeding or falling below the specified thresholds."[48] The issuer must subsequently publish the received notification "without undue delay, but no later than three trading days following receipt of the notification" from the shareholder.[49]

Under the German Securities Trading Act, Section 33, the threshold and the timing for providing disclosure of block holdings does not depend on the stated purpose of the holding. Under the German Securities Trading Act, Section 33, disclosure is only subject to reaching or falling below the above-mentioned thresholds. However, according to the German Securities Trading Act, Section 43, once a party reaches the threshold of 10% of holdings in voting rights in the target company, it has to "inform an issuer [...] of the goals pursued by purchasing the

[15] We thank Christina Queisser for her time, valuable comments, and suggestions.

voting rights and the source of the funds used to purchase the voting rights."[50] With respect to "the goals pursued by purchasing the voting rights, the party subject to the notification requirement must disclose whether:

- the investment serves to implement strategic objectives or to generate trading profits;
- it plans to acquire further voting rights within the next twelve months by means of a purchase or by other means;
- it intends to exert influence on the appointment or removal of members of the issuer's administrative, managing and supervisory bodies; and
- it intends to achieve a material change in the company's capital structure, in particular as regards the ratio between equity and debt and the dividend policy."[50]

Hence, under the German Securities Trading Act the threshold and the timing for providing disclosure of block holdings does not depend on the stated purpose of the holding.

Rules around mandatory takeover offers

According to the Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz - WpÜG), a mandatory offer has to be made upon exceeding the shareholding threshold of 30%.[16] A shareholder that exceeds this shareholding threshold is – under German law – considered to take control of the target company.[51] Upon reaching this threshold, the Securities Acquisition and Takeover Act requires two steps. First, the block holder must disclose that it has exceeded the 30% threshold "without undue delay and within seven calendar days at the

[16]The Securities Acquisition and Takeover Act "distinguishes between three different types of offer, namely takeover offers, mandatory offers and simple purchase offers. Takeover offers are voluntary and aim at the initial acquisition of control, being defined as the ownership of 30% or more of the voting rights in the target. A mandatory offer must be made if the 30%-threshold is reached or exceeded by other means than a public offer or in connection with a public offer, either directly or by way of attribution of voting rights. As voluntary takeover offers are less regulated – for example because the offer may be subject to more conditions – and hence more flexible, takeovers are usually structured as voluntary takeover offers. Voluntary takeover offers and mandatory offers both have to be made for all the target shares not already held by the bidder (and the persons acting in concert with it). Whereas in the case of a simple purchase offer (or partial offer) the bidder only seeks to acquire less than 30% of the voting rights or reinforce a controlling (30% or more) interest it already holds, e.g., following a previous takeover offer." See, "Public Takeovers in Germany," Cameron McKenna, available at (Link).

latest" by publishing "that fact [...] stating the extent of his percentage of voting rights."[52] After the disclosure has been made, the offeror "must submit an offer document to the Supervisory Authority and publish an offer [...] within four weeks of publication of the attainment of control of a target company."[52]

According to the Securities Acquisition and Takeover Act, the "offeror must offer the shareholders of the target company adequate consideration."[53] The "consideration must be equal to the higher of the volume-weighted average stock exchange price of the target shares, calculated for the three months prior to the publication of the offer announcement, and the highest price paid or agreed by the bidder during the six months prior to the publication of the offer document."[54]

As discussed above, according to the Securities Acquisition and Takeover Act, the offeror must submit an offer document to the Supervisory Authority and publish an offer within four weeks of publication of the attainment of control of a target company.[17] Following the submission of the offer document, the Supervisory Authority verifies that the information is consistent with the requirements of the Securities Acquisition and Takeover Act. The Supervisory Authority has a period of ten working days to complete its examination.[55] Within this period, it is entitled to either permit or prohibit the publication of the offer document.[55] If the offer document is incomplete or otherwise fails to comply with the provisions of the Securities Acquisition and Takeover Act, the Supervisory Authority may grant the offeror an additional five working days to make corrections.[55]

The offeror must publish the offer document on the internet without undue delay once the Supervisory Authority grants permission.[56] Furthermore, the offeror must either publish the entire offer document in the electronic Federal Gazette (elektronischer Bundesanzeiger) or make it available for distribution free of charge at a suitable agency in Germany.[56] All shareholders

[17] The law requires that the offer document is prepared in German. It must provide information regarding the offer (offeror, type and amount of consideration), the shares (in the case of an exchange offer), the financing of the offer, the offeror's financial position, financial performance and earnings position after the offer, the offeror's stake in the target company and the offeror's intentions with regard to the future business of the target company and its employees. In the case of takeover bids and mandatory offers, shareholders of a target company should be able to decide based on the information given in the offer document if they want to accept or decline the offer. See, Section 11 of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link).

should be able to take note of the offer document. The offeror also has a duty to transmit the offer document to the board of management of the target company and the employees of the offeror, if possible via the competent works council, without undue delay following its publication.[56]

The acceptance period commences upon publication of the offer document. The period for acceptance of the offer may be no less than four weeks and no more than ten weeks.[18] The offeror has to publish the acceptance rate of the offer on the internet and in the electronic Federal Gazette frequently – weekly until the start of the final week of the acceptance period and daily in the final week.[18] Furthermore, the offeror must publish the outcome of the offer without undue delay following the end of the acceptance period.[18] The offer process ends when the acceptance period is over and the consideration offered is exchanged for the shares.

Treatment of minority shareholders in takeovers

According to the Securities Acquisition and Takeover Act, if the offeror acquirers 95% of the voting rights in the target, the remaining shares can be acquired from the minority shareholders in a "takeover squeeze-out." In a takeover squeeze-out, minority shareholders are forced to sell their shares for adequate compensation. The adequacy of the compensation must be verified by an independent, court-appointed auditor. The minimum price rules are the same as described above under the details on the "consideration value."[19]

Requirements and restrictions if offer fails

[18] Sections 16 and 23 of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link). If an offeror holds at least 95% of the voting share capital, ordinary shareholders of the target company may accept the offer within three months after the end of the acceptance period. Preference shareholders are also entitled to this sell-out right if the offeror holds at least 95% of the target company's share capital following a takeover bid or mandatory offer.

[19] See, Sections 39a, 39b, and 39c of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link). The squeeze-out requires a resolution of the general meeting of the target company which is passed with the votes of the majority shareholder. It becomes effective upon registration in the commercial register. Minority shareholders can delay registration by filing actions against the squeeze-out resolution. Actions against the adequacy of the compensation are, however, dealt with in separate proceedings after registration and effectiveness of the squeeze-out. See, Sections 39a, 39b, and 39c of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link).

According to the Securities Acquisition and Takeover Act, if the offer fails, the offeror is prohibited from submitting a new offer for the period of one year.[57] Upon written application, the Supervisory Authority may exempt the offeror from the prohibition if the target company consents to such exemption.

A.4. Press announcements on October 26, 2008 and October 29, 2008

This section presents the original press releases of Porsche from October 26 and October 29, 2008. The press releases are referenced multiple times in the body of the paper and the Internet Appendix and are listed here for the convenience of the reader.

Fig. A2 Press release of Porsche on October 26, 2008

News archive 2008

Porsche heads for domination agreement

Interest in Volkswagen increased to 42.6 percent

Stuttgart, 26 October 2008. Due to the dramatic distortions on the financial markets Porsche Automobil Holding SE, Stuttgart, has decided over the weekend to disclose its holdings in shares and hedging positions related to the takeover of Volkswagen AG, Wolfsburg. At the end of last week Porsche SE held 42.6 percent of the Volkswagen ordinary shares and in addition 31.5 percent in so called cash settled options relating to Volkswagen ordinary shares to hedge against price risks, representing a total of 74.1 percent. Upon settlement of these options Porsche will receive in cash the difference between the then actual Volkswagen share price and the underlying strike price in cash. The Volkswagen shares will be bought in each case at market price.

Assuming the economic framework conditions are suitable, the aim is to increase to 75 percent in 2009, paving the way to a domination agreement. The intention to increase the Volkswagen stake to above
50 percent in November/December 2008 remains unchanged.

Porsche has decided to make this announcement after it became clear that there are by far more short positions in the market than expected. The disclosure should give so called short sellers - meaning financial institutions which have betted or are still betting on a falling share price in Volkswagen - the opportunity to settle their relevant positions without rush and without facing major risks.

In addition, the EU commission will - according to media reports over the weekend - sometime soon qualify the new draft of the VW Act tabled by the Federal Government as not complying with EU law. It is therefore to be expected that a new lawsuit will be filed with the European Court of Justice.

Also as a reason for today's step served the fact, that the families Porsche and Piëch, who own all Porsche ordinary shares, have expressed their unconditioned and undivided backing of the steps taken by the members of Porsche SE's board of management Dr. Wendelin Wiedeking and Holger Härter. As reported, both families clearly expressed last week their support for a domination of the Volkswagen group by Porsche.

GO

10/26/2008

Fig. A3 Press release of Porsche on October 29, 2008

News archive 2008

Short Sellers Responsible for Extreme Price Movements in Volkswagen Ordinary Shares

Partial Settlement of Hedging Transactions Planned

Stuttgart, 29 October 2008. Porsche Automobil Holding SE, Stuttgart, has information that speculative short sellers have had to buy Volkswagen ordinary shares in order to fulfil their delivery obligations. In the very recent past, this resulted in a massive increase in the stock exchange price of the Volkswagen shares, which at one stage exceeded Euro 1,000 per Volkswagen ordinary share.

In order to avoid further market distortions and the resulting consequences for those involved, Porsche SE intends - depending on the state of the market - to settle hedging transactions in the amount of up to five per cent of the Volkswagen ordinary shares. This may result in an increase in the liquidity of the Volkswagen ordinary shares.

Porsche SE denies all responsibility for these market distortions and for the resulting risks to which the short sellers have exposed themselves. Porsche wishes to point out that the applicable capital markets law provisions have been complied with at all times. Porsche has not been active in the market during this share price movements. Allegations of price manipulation by Porsche are therefore without any foundation whatsoever.

Porsche remains committed to its goal of increasing its stake in Volkswagen to up to 75% and thus intends to continue to acquire Volkswagen ordinary shares, on and off the stock exchange, at prices which are economically justifiable.

The German Federal Agency for Financial Services Supervision (BaFin) was informed by Porsche in advance about the measure being contemplated and its publication.

K-GO

10/29/2008

A.5. Projected margin calls and liquidity analysis based on VaR prices

This section describes in detail the methodology underlying the "Projected margin calls and liquidity analysis based on VaR prices." In particular, we analyse what Porsche's projected margin calls would have been if VW's price continued to decrease after October 24, 2008 and Porsche did not make the announcement on October 26, 2008. Next, we assess if Porsche's liquidity at the time would have been sufficient to cover the projected margin calls.

To analyze if Porsche's liquidity would have been sufficient to cover further margin calls if VW's price continued to decrease after October 24, 2008 we combine the VaR price analysis with information about Porsche's margin requirements from the relevant court documents. According to the indictment, when the price falls below a threshold value, a margin payment is requested.[1] The threshold value for strategies 2, 3, and 7 was 1.4 times the strike of the respective strategy. The threshold value for strategies 5 and 8 was 1.3 times the strike of the respective strategy.[20] For strategy 1, we apply a threshold value of 0.9 times the strike of strategy 1.[21] It is our understanding, based on the relevant court documents we reviewed, that the margin payments were then based on the difference between the closing stock price on the previous rollover date and the current stock price.[22] To provide robustness, we estimate the margin requirements based on margin rules for exchange traded options. In particular, we apply the rules provided by the Chicago Board Options Exchange (Cboe).[58] The Cboe margin rules are as follows: "[f]or each short option, 100% of option market value plus 20% of underlying security/index value less out-of-the-money amount, if any, to a minimum of option mkt. value plus 10% of underlying security/index value for calls; 10% of the put exercise price for puts." Following the Cboe guidance we apply a conservative approach and estimate margin requirements for each strategy as "option mkt. value plus 10% of the put exercise price for puts."

[20] No margins were required for strategy 6.

[21] The threshold value of 0.9 corresponds to a base margin of 10%. This is consistent with the rules governing options trading on the Eurex exchange.

[22] We note that margin requirements are often negotiated between the two contracting parties, may vary from brokerage firm to brokerage firm, and are often subject to change.

To determine whether Porsche would have had sufficient liquidity to cover margin calls we estimate Porsche's liquidity as of October 24, 2008 to be EUR 2,635 mill. = 326 mill. [(4,594 mill. cash - 4,268 mill. locked in margins)] + 1,021 mill. [remainder from an existing 10-billion Euro credit line] + 88 mill. [securities of other companies held by Porsche (short term assets)] + 1,200 mill. [investment funds of Porsche].[59]

Panels A and B of Table A2 show projected daily margin requirements based on the margin rules outlined in the relevant court documents for 5% VaR prices and 1% VaR prices, respectively. Panels A and B of Table A3 show projected daily margin requirements based on the Cboe margin rules for 5% VaR prices and 1% VaR prices, respectively. The total projected margin requirements figures are based on the sum of the individual projected margin requirements related to each of Porsche's option strategies.

The tables also shows Porsche's liquidity net of total margins on each day, which is computed as the difference between Porsche's total available liquidity as of October 24, 2008 (EUR 2,635 million) and the cumulative projected margin requirements. For example, in Panel A of Table A2, under the 5% VaR price scenario, Porsche's available liquidity on October 30, 2008 is assumed to be EUR 2,635 million,[23] the total cumulative margin calls on the same day are EUR 2,838 million, and the resulting liquidity net of margin calls is EUR -203 million (EUR 2,635 million - EUR 2,838 million). Similarly, in Panel B of Table A2, under the 1% VaR price scenario Porsche's available liquidity on October 30, 2008 is EUR 2,635 million, the total cumulative margin calls on the same day are EUR 4,427 million and the resulting liquidity net of margin calls is EUR -1,792 million (EUR 2,635 million - EUR 4,427 million). The evidence presented in Panels A and B of Table A3, which assumes Cboe's margin rules, indicates that the liquidity net of margin calls would have been negative even earlier: on Monday, October 27, 2008. Based on the VaR analysis it is likely that Porsche would have been in default on October 30 at the latest because its net liquidity on that day would have been negative. Given that Porsche itself utilized VaR methods according to their own annual report, it is likely they were aware of this fact.

[23] This is based on the assumption that Porsche's liquidity level from October 24, 2008, would have not changed and remained at EUR 2,635 million.

Table A2 Margin calls and liquidity analysis based on VaR prices using rules outlined in court documents: This table presents projected margin calls and Porsche's liquidity net of margins calls based on VaR prices for the week starting October 27, 2008, i.e., the week when the short squeeze took place. VaR prices are computed as described in Equation 2. According to relevant court documents, strategies 6 did not require margin payments in October 2008; strategy 4 was discontinued on March 26, 2007. Panel A presents estimates based on 5% VaR prices and Panel B based on 1% VaR prices. To estimate VaR prices, we use the following inputs: the closing price of VW's ordinary shares on October 24, 2008, which was EUR 210.85; the closing price of VW's preferred shares on that date, which was EUR 43.98; the standard deviation of daily returns over the 30 days preceding October 24, which was 9.21% for ordinary shares and 5.29% for preferred shares. As of this date, we estimate Porsche's liquidity at EUR 2,635 million. All figures are in EUR. Margin and liquidity figures are in millions.

Panel A: 5% VaR

Time horizon	**Oct. 27**	**Oct. 28**	**Oct. 29**	**Oct. 30**	**Oct. 31**
VaR price ordinary	178.91	165.68	155.53	146.97	139.43
VaR price preferred	40.15	38.56	37.35	36.32	35.42
Margin calls strategy one	-553	-783	-959	-1,107	-1,238
Margin calls strategy two	-	-	-	-	-
Margin calls strategy three	-	-	-	-	-
Margin calls strategy four	n/a	n/a	n/a	n/a	n/a
Margin calls strategy five	-101	-142,416	-174	-201	-225
Margin calls strategy six	n/a	n/a	n/a	n/a	n/a
Margin calls strategy seven	-	-939	-1,150	-1,328	-1,485
Margin calls strategy eight	-101	-142	-174	-201	-225
Total margins	-755	-2,007	-2,458	-2,838	-3,173
Liquidity net of total margins	**1,880**	**628**	**177**	**-203**	**-538**

Panel B: 1% VaR

Time horizon	**Oct. 27**	**Oct. 28**	**Oct. 29**	**Oct. 30**	**Oct. 31**
VaR price ordinary	165.68	146.97	132.61	120.51	109.84
VaR price preferred	38.56	36.32	34.60	33.15	31.87
Margin calls strategy one	-783	-1,107	-1,356	-1,566	-1,750
Margin calls strategy two	-	-	-	-	-2,063
Margin calls strategy three	-	-	-	-413	-776
Margin calls strategy four	n/a	n/a	n/a	n/a	n/a
Margin calls strategy five	-142	-201	-247	-285	-319
Margin calls strategy six	n/a	n/a	n/a	n/a	n/a
Margin calls strategy seven	-939	-1,329	-1,627	-1,879	-2,101
Margin calls strategy eight	-142	-201	-247	-285	-319
Total margins	-2,007	-2,838	-3,476	-4,427	-7,327
Liquidity net of total margins	**628**	**-203**	**-841**	**-1,792**	**-4,692**

Table A3 Margin calls and liquidity analysis based on VaR prices using Cboe maring rules: This table presents projected margin calls and Porsche's liquidity net of margins calls based on VaR prices for the week starting October 27, 2008, i.e., the week when the short squeeze took place. VaR prices are computed as described in Equation 2. We compute margin requirements following the rules outlined by Cboe (Link). In particular, Cboe states that "For each short option, 100% of option market value plus 20% of underlying security/index value less out-of-the-money amount, if any, to a minimum of option mkt. value plus 10% of underlying security/index value for calls; 10% of the put exercise price for puts." Following the Cboe guidance we apply a conservative approach and estimate margin requirements for each strategy as "option mkt. value plus 10% of the put exercise price for puts." According to relevant court documents, strategies 6 did not require margin payments in October 2008; strategy 4 was discontinued on March 26, 2007. Panel A presents estimates based on 5% VaR prices and Panel B based on 1% VaR prices. To estimate VaR prices, we use the following inputs: the closing price of VW's ordinary shares on October 24, 2008, which was EUR 210.85; the closing price of VW's preferred shares on that date, which was EUR 43.98; the standard deviation of daily returns over the 30 days preceding October 24, which was 9.21% for ordinary shares and 5.29% for preferred shares. As of this date, we estimate Porsche's liquidity at EUR 2,635 million. All figures are in EUR. Margin and liquidity figures are in millions.

Panel A: 5% VaR

Time horizon	**Oct. 27**	**Oct. 28**	**Oct. 29**	**Oct. 30**	**Oct. 31**
VaR price ordinary	178.91	165.68	155.53	146.97	139.43
VaR price preferred	40.15	38.56	37.35	36.32	35.42
Margin calls strategy one	-971	-1,163	-1,325	-1,472	-1,603
Margin calls strategy two	-174	-174	-174	-174	-174
Margin calls strategy three	-317	-317	-317	-322	-319
Margin calls strategy four	n/a	n/a	n/a	n/a	n/a
Margin calls strategy five	-680	-722	-754	-781	-805
Margin calls strategy six	n/a	n/a	n/a	n/a	n/a
Margin calls strategy seven	-251	-254	-254	-254	-251
Margin calls strategy eight	-970	-1,011	-1,043	-1,070	-1,094
Total margins:	-3,363	-3,641	-3,868	-4,073	-4,245
Liquidity net of total margins:	**-728**	**-1,006**	**-1,233**	**-1,438**	**-1,610**

Panel B: 1% VaR

Time horizon	**Oct. 27**	**Oct. 28**	**Oct. 29**	**Oct. 30**	**Oct. 31**
VaR price ordinary	165.68	146.97	132.61	120.51	109.84
VaR price preferred	38.56	36.32	34.60	33.15	31.87
Margin calls strategy one	-1,168	-1,475	-1,721	-1,931	-2,116
Margin calls strategy two	-174	-174	-174	-174	-174
Margin calls strategy three	-317	-317	-317	-369	-384
Margin calls strategy four	n/a	n/a	n/a	n/a	n/a
Margin calls strategy five	-722	-781	-826	-864	-898
Margin calls strategy six	n/a	n/a	n/a	n/a	n/a
Margin calls strategy seven	-256	-277	-308	-366	-472
Margin calls strategy eight	-1,011	-1,070	-1,116	-1,154	-1,187
Total margins:	-3,647	-4,093	-4,461	-4,857	-5,230
Liquidity net of total margins:	**-1,012**	**-1,458**	**-1,826**	**-2,222**	**-2,595**

A.6. Simulated probability of default analysis

This section describes in detail the methodology underlying the "simulated probability of default" analysis. Specifically, we analyze the probability of default of Porsche on a daily level by assessing the impact of Porsche's option strategies. In particular, we take into account different price paths, projected margin calls and rollover losses, as well as the co-variance between ordinary and preferred shares. The simulated probability of default analysis assesses for each trading day the cumulative probability of Porsche being unable to meet margin calls and rollover losses resulting from their options strategies. This measure builds on Vasicek (2002), who estimates the amount of capital necessary to support a loan portfolio.

To simulate Porsche's probability of default, we generate 100,000 daily price paths for VW's ordinary and preferred shares using a Monte Carlo simulation combined with Geometric Brownian motion (GBM). In particular, we focus on the days after October 24, 2008 and simulate stock price paths for VW for the coming trading days (i.e., we put ourselves in the shoes of Porsche's management on October 24, 2008, and consider various VW price scenarios for the following trading days of October 27, 2008, through 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 liquidity. We estimate Porsche's total available liquidity as of October 24,2008 to be 2,635,097,229 = 326,222,639 [(4,594,122,639 cash - 4,267,900,000 locked in margins)]+ 1,020,874,590 [remainder from an existing 10-billion euro credit line] + 88,000,000 [securities of other companies held by Porsche AG (short term assets)] +1,200,000,000 [Investment funds of Porsche AG].[1] The number of defaults on each day divided by the total number of simulated price paths provides the simulated probability of default. For example, if we find that Porsche defaults 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 for that particular price path at a later date.

The first step involves simulating 100,000 price paths using the Monte Carlo simulation

methodology with GBM. We apply the following assumptions:

1. The price of VW's ordinary and preferred shares follow a correlated GBM.
2. Activities outside the options strategy do not have an effect on Porsche's liquidity.
3. Volatility is constant.
4. Correlation is constant.
5. Drift is constant.

The first assumption is frequently used in the literature, as the GBM is a standard process to model the stock prices of a public company. The main reason we apply this process is that the prices cannot become negative. The drawback is that the model does not consider the presence of fat tails and skewness, since it assumes a log-normal distribution. As for the second assumption, the period analyzed presents a particularly volatile time for the financial industry. It included the default of Lehman Brothers and the resulting credit crunch in both the U.S. and Europe. We can therefore reasonably assume that Porsche would not have had access to any additional outside liquidity. The third assumption is a conservative approach to actual volatility given the fact that the analyzed time period included both the 2007-2008 financial crisis and the VW short squeeze.

In order to compute the variance-covariance matrix, we use the multivariate GARCH-model following Ledoit, Santa-Clara, and Wolf (2003). We set the drift equal to the average daily return over the last six trading days. This drift is negative and designed to mimic the fact that during the week preceding October 24, 2008, there was downward pressure on VW's ordinary and preferred shares. We also perform robustness tests in which we apply additional drift assumptions. For example, we set the drift equal to zero. This assumption is in line with the fact that we are conducting the analysis over a short-term horizon and we are using daily returns. This should mimic the situation in which prices do not follow any trend. We also set the drift equal to the average daily return over the preceding six months and also the preceding one year. The drifts in these cases are positive for the ordinary shares and negative for the preferred shares. These additional drift assumptions capture the long-term trend in VW's share prices.

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

In addition to rollover gains and losses, Porsche also faced margin calls. These were activated by Porsche's option counterparty, Maple Bank, when VW's stock price fell below a certain threshold.[24] 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 VW'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 next rollover date. As a robustness, we apply margin estimation rules as outlined by the Cboe (Link).

Finally, the last step in our simulation involves computing the probability of default. We check for each price 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.

We next discuss the results for the main case, i.e., a drift equal to the average return over the last six trading days, and the robustness cases, i.e., price simulations assuming i) zero drift, ii) a drift equal to the average return over the preceding six months, and iii) a drift equal to the average return over the preceding one year. For the main case the first thousand simulated prices for the ordinary shares are plotted in Figure A4 and for preferred shares in Figure A5.

[24] Detailed information about the respective thresholds of Porsche's different option strategies can be found in the Indictment of the public prosecutor, October 6, 2015, LG Stuttgart 13 KLs 159 69207/09.

The black bold line denotes the initial value, which is the price as of October 24, 2008. A visual inspection shows that all simulated price paths are below the price for ordinary and preferred shares as of October 24, 2008. This evidence is in line with the declining VaR prices we observe in the analyses presented in Subsections 4.2 and A.5. Panel A in Table A4 documents the simulated probability of default results for the main case and the robustness cases. In the scenario with a drift equal to the average return over the last six trading days, Porsche would have been in default with a probability of 55% on October 29, and with a probability of 100% on the next day. The scenario with price simulations assuming zero drift shows that Porsche would have been in default on November 3, 2008 with probability close to one. The scenarios that assume a drift equal to the average return over the preceding six months, or a drift equal to the average return over the preceding one year deliver very similar results, i.e., with high likelihood Porsche would have been in default on November 3, 2008. Panel B in Table A4 documents the simulated probability of default results for the main case and the robustness cases applying the Cboe margin methodology. The results indicate that Porsche would have been in default with a probability of 100% on October 27 under all drift assumptions. All in all, 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.

Fig. A4 First 1000 simulations with drift being set to the sample average of the returns over the last six trading days: This figure plots simulated prices for 1000 simulations for ordinary shares on the y-axis. The x-axis denotes the number of days over which each simulation is performed. The drift is set to the sample average of the returns over the last six trading days. The black horizontal line denotes the initial value, which is the price as of October 24, 2008, i.e., EUR 210.85.

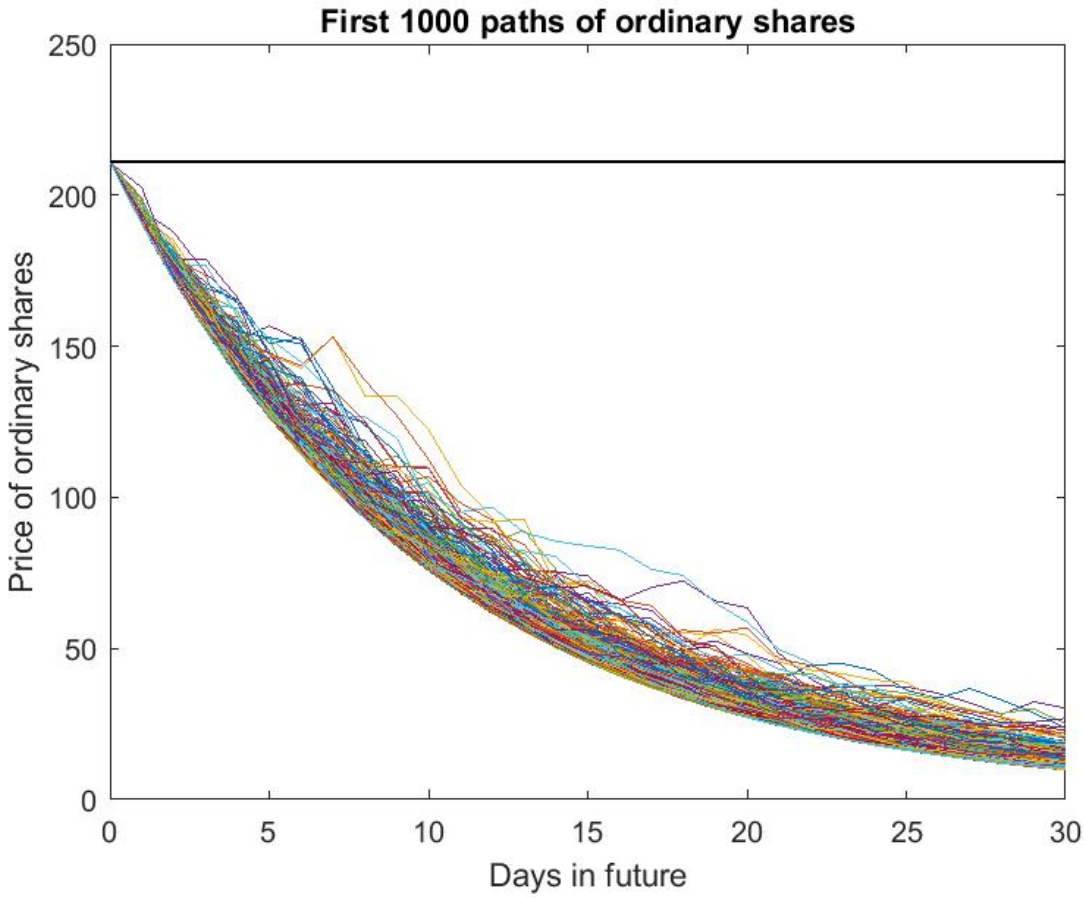


Fig. A5 First 1000 simulations with drift being set to the sample average of the returns over the last six trading days: This figure plots simulated prices for 1000 simulations for preferred shares on the y-axis. The x-axis denotes the number of days over which each simulation is performed. The drift is set to the sample average of the returns over the last six trading days. The black horizontal line denotes the initial value, which is the price as of October 24, 2008, i.e., EUR 43.98.

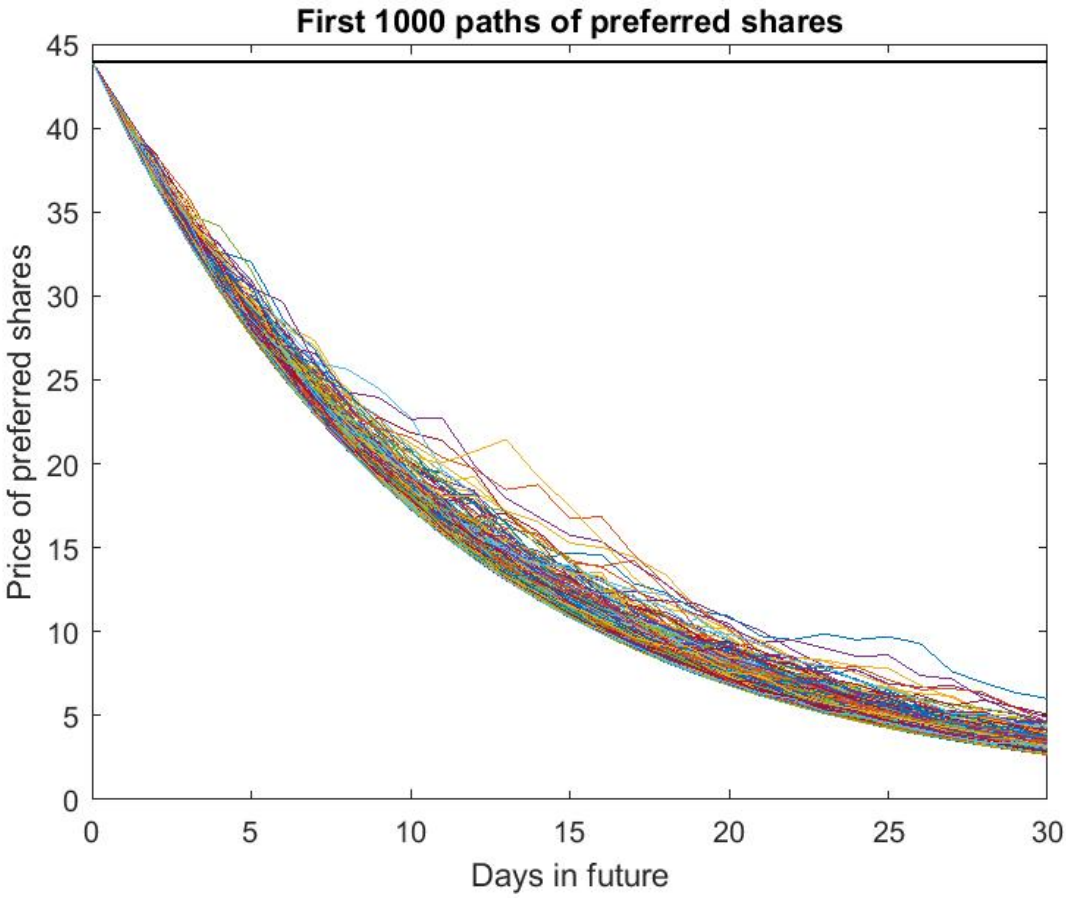


Table A4 Simulated probability of default: This table presents the simulated probability of default for the period 10/27-11/03. "Average six day drift" assumes a drift of the average daily return over the six trading days preceding and including October 24, 2008. "Zero drift" assumes no drift. "Average six month drift" and "Average one year drift" are scenarios that assume a drift equal to the average return over the preceding six months, or a drift equal to the average return over the preceding one year, respectively. The simulated probability of default is computed as described in the preceding section in the Internet Appendix.

Panel A: Probability of default based on the court documents margin requirements methodology

Time period	**10/27**	**10/28**	**10/29**	**10/30**	**10/31**	**11/03**
Average six day drift	0	0	0.55	1	1	1
Zero drift	0	0	0	0	0	0.97
Average six month drift	0	0	0	0	0	0.96
Average one year drift	0	0	0	0	0	0.96

Panel B: Probability of default based on the Cboe margin requirements estimation methodology

Time period	**10/27**	**10/28**	**10/29**	**10/30**	**10/31**	**11/03**
Average six day drift	1	1	1	1	1	1
Zero drift	1	1	1	1	1	1
Average six month drift	1	1	1	1	1	1
Average one year drift	1	1	1	1	1	1

A.7. Analyst price target forecasts and dispersion

This section provides additional details on the entire history of price target forecasts submitted by the analyst with Mask Code 626480, i.e., the analyst that maintained the highest price target forecast of EUR 204.75 during the period August 15, 2008 through October 16, 2008. It also summarizes information about all price target estimates submitted during the period October 16, 2008 through October 24, 2008, i.e., the days before the short squeeze.

Table A5 I/B/E/S individual analyst price target forecasts for VW: This table presents the entire history of price target forecasts submitted by the analyst with Mask Code 626480, i.e., the analyst that maintained the highest price target forecast of EUR 204.75 during the period August 15, 2008 through October 16, 2008. Data are obtained from the I/B/E/S Detail History file.

Announcement Date	Price Target (€)	Actual Price (€)
07/10/2006	57.65	54.11
10/30/2006	76.53	77.40
11/16/2006	109.33	85.50
03/14/2007	119.27	101.33
07/25/2007	149.09	121.99
09/20/2007	183.88	154.02
10/29/2007	238.55	187.63
01/07/2008	206.74	148.88
01/29/2008	168.97	156.40
03/14/2008	173.94	157.15
06/12/2008	173.94	173.92
08/15/2008	204.75	205.64
10/17/2008	89.46	358.00

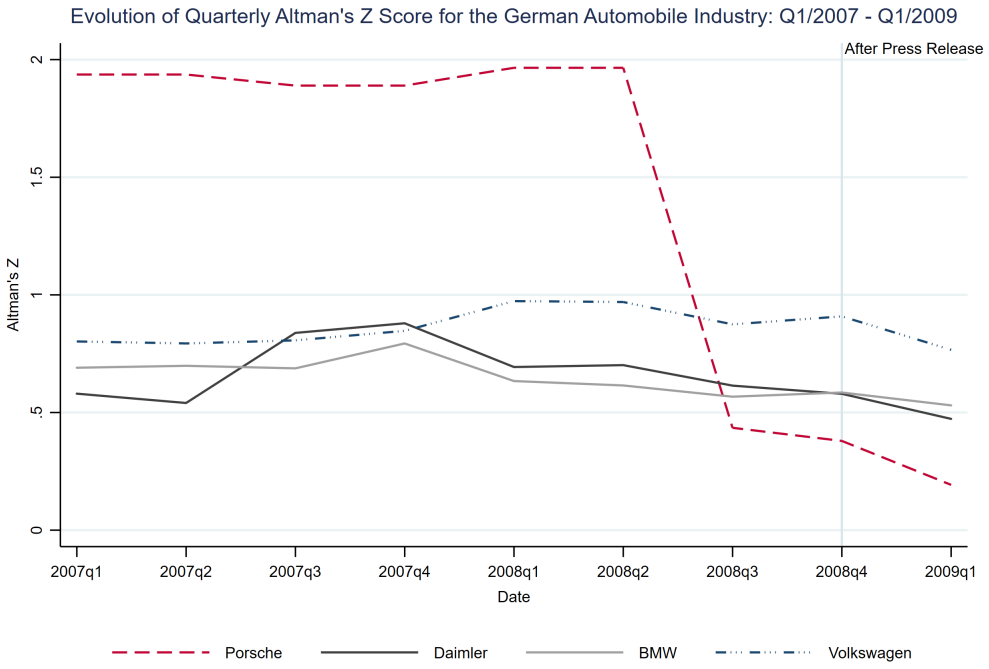
Table A6 Price targets during the days before the short squeeze: This table presents information about all price target estimates submitted during the period October 16, 2008 through October 24, 2008, i.e., the days before the short squeeze. Data are obtained from the I/B/E/S Detail History file.

Announcement Date	Mask Code	Estimator ID	Name	Price Target	Actual Price
10/16/2008	604552	PRMDN070	PERMDENIED	68.58	398.84
10/17/2008	54707	METZLER	PIEPER	139.15	358.00
10/17/2008	626480	PRMDN050	PERMDENIED	89.46	358.00
10/20/2008	578458	PRMDN063	PERMDENIED	69.58	277.09
10/22/2008	45845	BHFBANK	DENNINGHOFF	86.47	243.00
10/22/2008	121576	OPPENGER	BREITSPRECHER	89.46	243.00

A.8. Altman's Z

This section provides a robustness estimation related to the analysis of Porsche's probability of default (see Section 4.3).

Fig. A6 Robustness: 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, 2013). Lower values represent an increased probability of default. Compustat does not report Sales and EBIT figures for Porsche starting in 2009. After reviewing Porsche's financial statements for the relevant period, this is likely due to the fact that Porsche increased its stake in VW in the beginning of 2009 over 50%, and therefore, they started consolidating VW's results (e.g., Sales and EBIT), which, in turn, distorts the presentation of Porsche's own financial performance. Due to the missing Compustat data items, the relevant figures have been carried forward to Q1 2009.



A.9. Insider trading: Sensitivity tests to Section 5.3

This section describes the sensitivity test outlined in Section 5.3, footnote 37. To establish robustness of the results described in Section 5.3, we follow the latest literature on informed trading in stocks. More specifically, we follow the paper of Hendershott, Jones, and Menkveld (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). Using the methodology proposed in Hendershott, Jones, and Menkveld (2011), we measure informed trading in VW's shares and VW's competitors using effective half-spreads, 5-minute realized spreads, and 5-minute price impacts. All of these proxies are share volume-weighted to account for the differences in trading volumes across the different automobile stocks. Effective half-spreads are measured as follows for stock i and trade t:

$$espread_{i,t} = \frac{q_{i,t}(p_{i,t} - m_{i,t})}{m_{i,t}} \tag{7}$$

$q_{i,t}$ is a 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 quotes).

Revenues to liquidity providers are estimated using 5-minute realized spreads. We follow Hendershott, Jones, and Menkveld (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:

$$rspread_{i,t} = \frac{q_{i,t}(p_{i,t} - m_{i,t+5min})}{m_{i,t}} \tag{8}$$

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

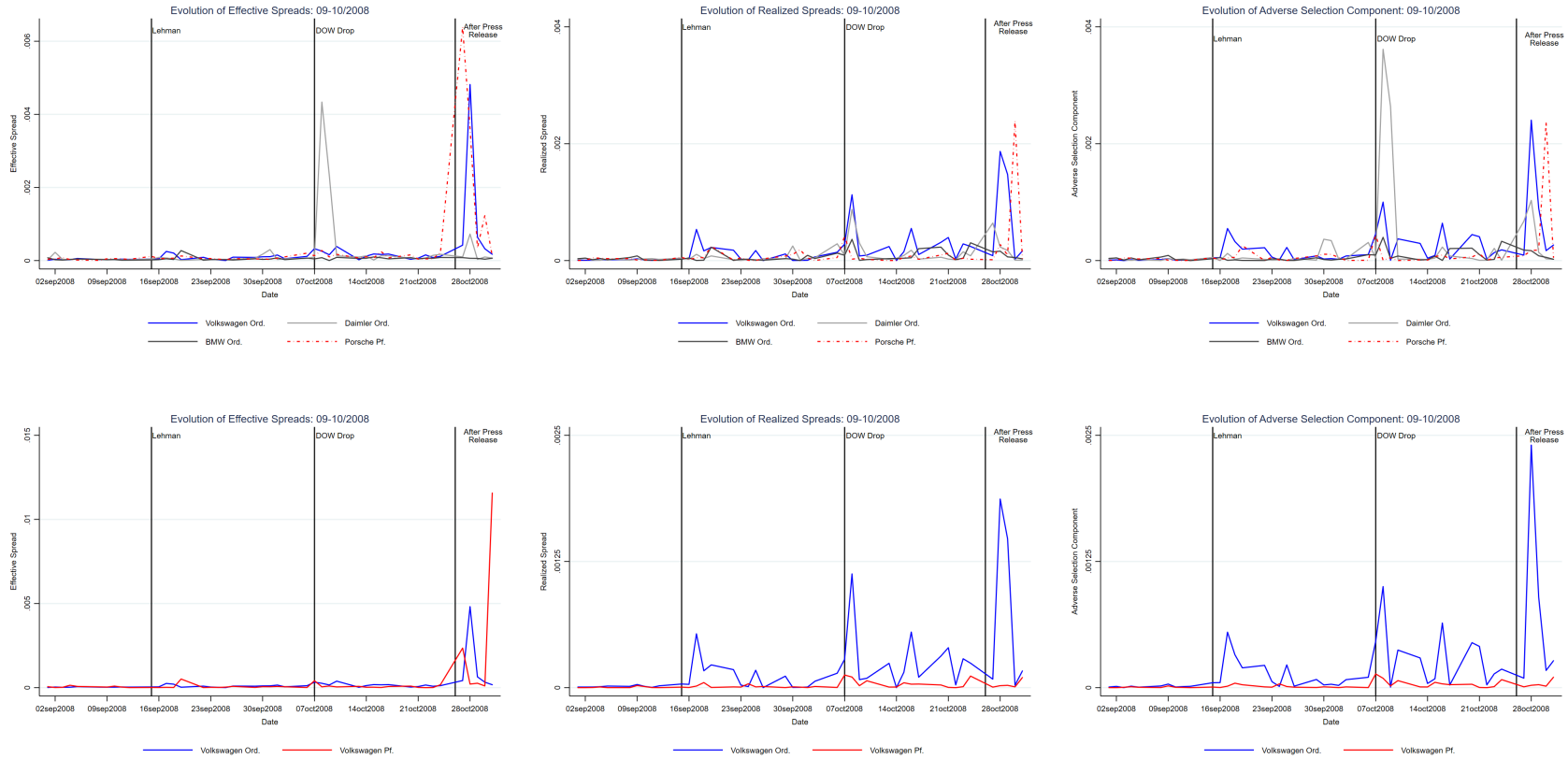
$$advselection_{i,t} = \frac{q_{i,t}(m_{i,t+5min} - m_{i,t})}{m_{i,t}} \tag{9}$$

In case a liquidity demander does not suffer from adverse selection and estimates the price movement correctly, the wedge between $m_{i,t+5min}$ 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 A7 plots the measures of informed trading. Generally, before the press release of Porsche, the measures are in line with what Hendershott, Jones, and Menkveld (2011) find for modern financial markets. Effective spreads are on average 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' 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 informed trading. For Daimler we find a significant increase in effective spreads and adverse selection costs (about a 300% increase); for all other companies we find a non-significant increase. For the press release of Porsche with respect to the domination of VW shares, we find a significant increase in effective spreads, realized spreads, and adverse selection costs for VW and Porsche. Effective spreads at VW increase significantly - about 400% 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% already in the week of October 24, 2008. Note that adverse selection cost was already on an elevated level for VW ***before*** the press release. In fact, in the two weeks before the press release we observe an increase in VW's adverse selection cost of 40% on average, which lends robustness to the results described in Section 5.3, which are based on the measure of Llorente, Michaely, Saar, and Wang (2002). We do not observe this to happen at any of the other companies.

Fig. A7 Robustness: 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 VW 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: $espread_{i,t} = \frac{q_{i,t}(p_{i,t}-m_{i,t})}{m_{i,t}}$. $q_{i,t}$ is the 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). Realized spreads are defined as: $rspread_{i,t} = \frac{q_{i,t}(p_{i,t}-m_{i,t+5min})}{m_{i,t}}$. Gross losses to liquidity demanders due to adverse selection are measured as: $advselection_{i,t} = \frac{q_{i,t}(m_{i,t+5min}-m_{i,t})}{m_{i,t}}$.



A.10. Price discovery: Fully-interacted model and WPC analysis

This section presents additional robustness estimations for the results presented in Section 7.

Table A7 Robustness: Intraday Variation in Spreads, Volatility, and Trading Activity for VW. Fully Interacted Model:

To provide robustness of the results from Model 6 and to assess the statistical significance of changes in intraday patterns over time in the metrics of interest, we also employ a regression model in which each metric is regressed on (1) a constant and additional indicator variables for the intraday periods and (2) indicator variables for the event windows of interest and (3) their interactions. This "fully-interacted" model, can be summarized by the following regression equation:

$$\begin{aligned} Y_{i,t} = \alpha &+ \beta_1 D_1 + \beta_2 D_2 + \beta_3 SSqueeze + \beta_4 SSqueeze \times D_1 + \beta_5 SSqueeze \times D_2 \\ &+ \beta_6 Post\text{-}SSqueeze + \beta_7 Post\text{-}SSqueeze \times D_1 + \beta_8 Post\text{-}SSqueeze \times D_2 + \epsilon_{i,t}, \end{aligned}$$

where $Y_{i,t}$ represents one of the metrics defined in Table 5. i is a firm index and t denotes time in minutes. The dummy variables D_1, D_2, $SSqueeze$, and $Post\text{-}SSqueeze$ are defined in equations 5 and 6. The data-set covers the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short-squeeze period. The t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Spread	(2) Volatility	(3) Volume	(4) Bid Size	(5) Ask Size	(6) Buy Volume	(7) Sell Volume
Post-SSqueeze x After 17:00	-0.0005***	0.0004	-6,071.75	4,449.47***	-128.97	1,084.25**	1,172.46***
	(-2.899)	(1.414)	(-1.164)	(2.927)	(-0.694)	(2.168)	(2.806)
Post-SSqueeze x 9:31 - 17:00	-0.0004**	-0.0001	2,884.33***	4,848.15***	-299.86***	1,815.07***	1,614.63***
	(-2.473)	(-0.505)	(5.124)	(4.302)	(-2.922)	(4.745)	(4.958)
Post-SSqueeze	0.0008***	-0.0001	-5,014.26***	-11,754.36***	-954.58***	-3,597.07***	-3,555.13***
	(4.924)	(-0.366)	(-9.022)	(-10.540)	(-9.911)	(-9.522)	(-11.098)
SSqueeze x After 17:00	-0.0028	0.0052***	-28,861.82***	-13,951.43***	-796.66***	-2,747.55***	-3,947.65
	(-0.869)	(6.527)	(-2.661)	(-2.580)	(-3.567)	(-2.900)	(-1.284)
SSqueeze x 9:31 - 17:00	-0.0053*	-0.0004	-21,728.05**	-12,306.97**	-212.62	-1,349.65	-4,243.43
	(-1.730)	(-0.728)	(-2.513)	(-2.384)	(-1.216)	(-1.580)	(-1.579)
SSqueeze	0.0064**	0.0055***	23,469.27***	13,583.64***	-1,303.36***	2,487.98***	4,893.05*
	(2.083)	(10.694)	(2.715)	(2.638)	(-7.710)	(2.952)	(1.822)
After 17:00	-0.0013***	-0.0034***	12,970.17***	-774.59	679.08***	258.68	50.31
	(-10.536)	(-17.700)	(2.998)	(-0.539)	(4.266)	(0.553)	(0.132)
9:31 - 17:00	-0.0011***	-0.0036***	-3,426.87***	-5,545.40***	469.67***	-1,731.09***	-1,735.46***
	(-10.207)	(-20.074)	(-6.510)	(-5.063)	(5.139)	(-4.620)	(-5.497)
Before 9:30	0.0029***	0.0062***	6,700.83***	16,159.43***	1,747.53***	4,701.81***	4,761.19***
	(26.645)	(34.452)	(12.905)	(14.891)	(20.431)	(12.680)	(15.310)
Observations	18,689	21,577	21,713	21,624	19,871	9,479	10,050
Adjusted R^2	0.063	0.335	0.025	0.101	0.074	0.136	0.137

Table A8 Robustness: Intraday Variation in Spreads, Volatility, and Trading Activity for VW's competitors. Fully Interacted Model:

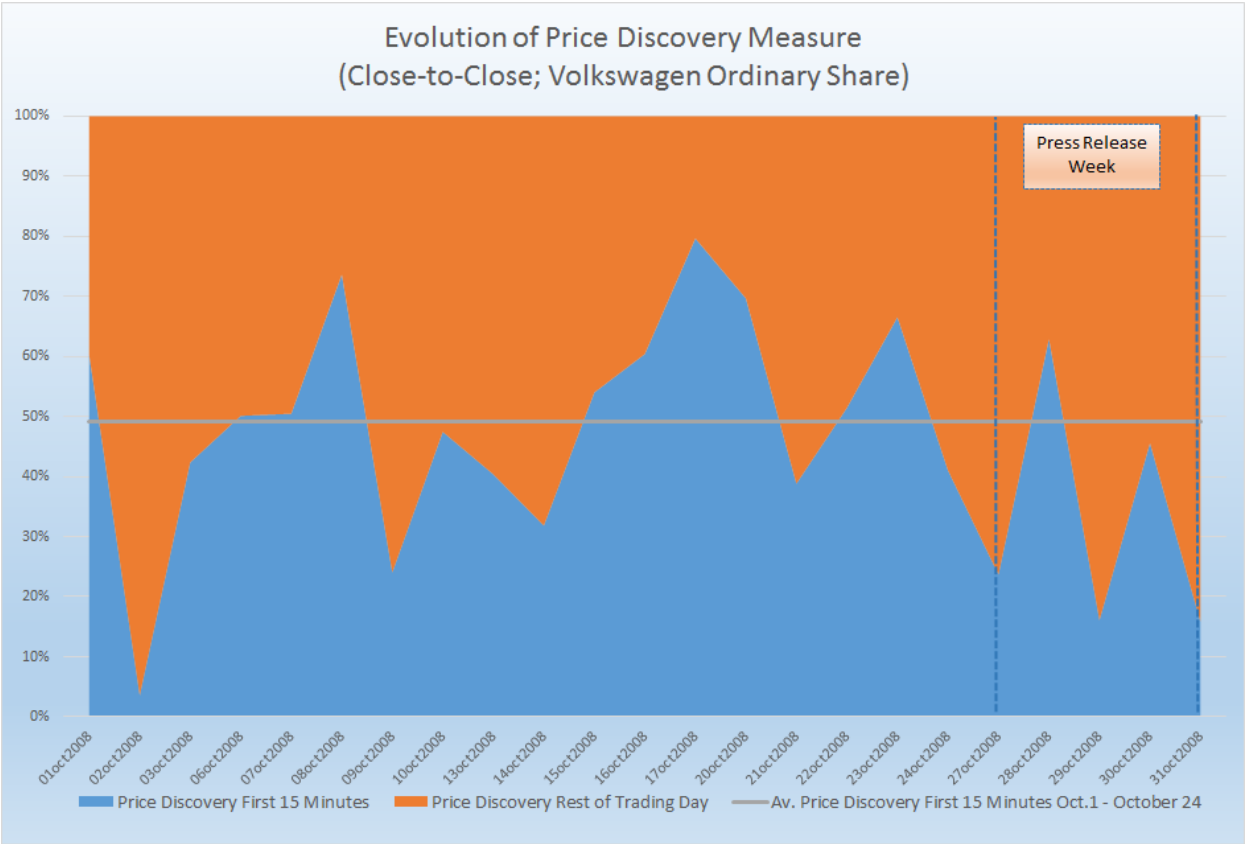
To provide robustness of the results from Model 6 and to assess the statistical significance of changes in intraday patterns over time in the metrics of interest, we also employ a regression model in which each metric is regressed on (1) a constant and additional indicator variables for the intraday periods and (2) indicator variables for the event windows of interest and (3) their interactions. This "fully-interacted" model, can be summarized by the following regression equation:

$$\begin{aligned} Y_{i,t} = \alpha &+ \beta_1 D_1 + \beta_2 D_2 + \beta_3 SSqueeze + \beta_4 SSqueeze \times D_1 + \beta_5 SSqueeze \times D_2 \\ &+ \beta_6 Post\text{-}SSqueeze + \beta_7 Post\text{-}SSqueeze \times D_1 + \beta_8 Post\text{-}SSqueeze \times D_2 + \epsilon_{i,t}, \end{aligned}$$

where $Y_{i,t}$ represents one of the metrics defined in Table 5. i is a firm index and t denotes time in minutes. The dummy variables D_1, D_2, $SSqueeze$, and $Post\text{-}SSqueeze$ are defined in equations 5 and 6. The data-set covers the period September 29, 2008 through November 26, 2008, i.e., four weeks before and four weeks after the short-squeeze period. The t-statistics are based on HAC standard errors and are reported in parentheses below the coefficient estimates. The symbols ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Spread	(2) Volatility	(3) Volume	(5) Bid Size	(6) Ask Size	(7) Buy Volume	(8) Sell Volume
Post-SSqueeze x After 17:00	0.0001	0.0003***	-19,370.20	2,752.96	740.56	783.49	1,326.05
	(1.439)	(2.731)	(-1.183)	(1.062)	(0.960)	(0.694)	(1.027)
Post-SSqueeze x 9:31 - 17:00	0.0001	0.0002**	4,034.77***	3,495.17**	1,037.95**	1,552.50**	3,202.78***
	(1.349)	(2.366)	(3.379)	(2.071)	(2.250)	(2.017)	(4.105)
Post-SSqueeze	-0.0003***	-0.0006***	-8,495.01***	-14,586.74***	-3,607.49***	-5,497.58***	-7,356.86***
	(-3.170)	(-6.354)	(-7.296)	(-8.997)	(-8.145)	(-7.284)	(-9.649)
SSqueeze x After 17:00	-0.0003	-0.0033***	-20,401.60	-20,636.66***	-3,277.76***	-6,561.35***	-4,496.98**
	(-1.082)	(-8.738)	(-0.730)	(-5.689)	(-2.876)	(-3.745)	(-2.359)
SSqueeze x 9:31 - 17:00	-0.0003*	-0.0036***	-6,795.56**	-10,787.96***	714.18	-2,940.91**	-4,617.57***
	(-1.694)	(-10.301)	(-2.131)	(-3.795)	(0.777)	(-1.988)	(-3.210)
SSqueeze	0.0005**	0.0043***	5,809.29*	3,453.05	-1,806.13**	2,284.83	3,060.78**
	(2.432)	(12.251)	(1.830)	(1.242)	(-2.048)	(1.565)	(2.155)
After 17:00	-0.0011***	-0.0015***	54,553.17***	18,455.71***	4,354.08***	4,328.21***	4,494.18***
	(-14.069)	(-17.580)	(3.825)	(8.578)	(7.108)	(4.452)	(3.964)
9:31 - 17:00	-0.0010***	-0.0019***	-6,666.00***	-1,316.89	1,032.69**	-2,815.08***	-3,736.34***
	(-14.717)	(-24.537)	(-6.026)	(-0.870)	(2.576)	(-4.051)	(-5.171)
Before 9:30	0.0028***	0.0039***	16,737.05***	36,030.71***	9,499.49***	12,587.22***	13,942.37***
	(41.900)	(51.427)	(15.546)	(24.646)	(24.439)	(18.445)	(19.683)
Observations	59,305	65,299	65,695	64,891	61,930	30,311	29,809
Adjusted R^2	0.024	0.184	0.016	0.021	0.013	0.050	0.053

Fig. A8 Robustness: Price discovery process for Volkswagen ordinary shares: This figure plots the evolution of the price discovery measure "weighted price contribution" (WPC) for the ordinary shares of VW for the period of October 2008. The WPC is plotted for two distinct sub periods of a given trading day: 1.) the first 15 minutes after market open (blue area), and 2.) the rest of the trading day, i.e., including both regular and after-hours trading (orange area). For each day and each time period i, the WPC is defined as: $\text{WPC}_{i,VW} = \frac{|\text{ret}_{i,VW}|}{|\text{ret}_{VW}|}$ where $\text{ret}_{i,VW}$ is the return during period i, and ret_{VW} is the close-to-close return for Volkswagen.



A.11. Legal and Other Source Notes for Paper and Internet Appendix

This section lists the legal sources referenced by the notation [1], [2], and so on in the main body of this paper as well as in the Internet Appendix. Standard explanatory footnotes are referenced in the usual way in the main body of the paper.

[1] Indictment of the public prosecutor, October 6, 2015, LG Stuttgart 13 KLs 159 69207/09.
[2] "Hedge funds make £18bn loss on VW," BBC News, October 29, 2008 (Link).
[3] "European Securities and Markets Authority, Annual report on administrative and criminal sanctions and other administrative measures under MAR, ESMA70-156-2005, 12 December 2019," available at (Link).
[4] "SEC sends Subpoena to Tesla in a Probe Over Musk Tweets," Wall Street Journal, August 15, 2018 (Link)
[5] Complaint "United States Securities And Exchange Commission vs. Elon Musk," September 27, 2018, ¶2.
[6] "Tesla call options soar on Musk tweet, short-sellers hit," Reuters, August 7, 2018 (Link).
[7] "DOJ Opened Probe of Tesla After Musk's Going-Private Tweet," Wall Street Journal, September, 18, 2018 (Link).
[8] "Elon Musk will be ineligible to be reelected chairman for three years, but can keep the CEO position." See, "Elon Musk to step down as chair of Tesla board, settles with SEC for USD 20 million," CBS News, September 29, 2018 (Link).
[9] "Wirecard made this short seller right but not rich," Financial Times, July 15, 2020 (Link).
[10] "Wirecard's Former CEO Markus Braun Is Arrested," Wall Street Journal, June 23, 2020 (Link).
[11] See, e.g., 2005/2006 Porsche Annual Report, p. 34.
[12] OLG Stuttgart, Beschl. 18. August 2014, 1 Ws 68/14, BeckRS 2014, 16657. See also "Der Fall Porsche: 'Marktmanipulation' und die Frage des hinreichenden Tatverdachts" (Link).
[13] The link to the German version of the announcement on September 25, 2005 can be found here (Link).
[14] The link to the English version of the announcement on March 26, 2007 can be found here (Link).
[15] "As Giant Rivals Stall, Porsche Engineers a Financial Windfall," Wall Street Journal, November 8, 2018 (Link).
[16] The link to the English version of the announcement on March 3, 2008 can be found here (Link).
[17] The link to the English version of the March 10, 2008 announcement is here (Link).
[18] A copy of the announcement on October 26, 2008 is included in Section A.4 of the Internet Appendix. The link to the English version is also here (Link).
[19] A copy of the announcement on October 29, 2008 is included in Section A.4 of the Internet Appendix. The link to the English version can be found here (Link).
[20] "Squeezy money - How Porsche fleeced hedge funds and roiled the world's financial markets," The Economist, October 30, 2008(Link).
[21] "Trading calendar 2008," Xetra (Link).
[22] "Porsche prepares sale of options," Porsche SE, July 29, 2009 (Link).
[23] "Porsche cannot escape general downward trend," Porsche SE, January 30, 2009 (Link).
[24] "Has Porsche Bitten Off More than It Can Chew?," Spiegel Online, April 20, 2009 (Link).
[25] "Porsche intends to obtain a credit rating from two internationally recognized agencies. The company believes that this will further improve its refinancing possibilities" in "Porsche posts substantially increased profits," Porsche SE, March 31, 2009 (Link).
[26] Indictment of the public prosecutor, December 17, 2012, LG Stuttgart 159 Js 69207/09.
[27] "Porsche secures ten billion credit line," Porsche SE, March 25, 2009 (Link).
[28] "Porsche not Applying to KfW for a New Loan - Alternative Financing Possibilities Being Considered," Porsche SE, June 30, 2009 (Link).
[29] "Porsche Supervisory Board decides capital increase of Euros 5 billion," Porsche SE, July 23, 2009 (Link).
[30] "Porsche Supervisory Board supports negotiations with Qatar," Porsche SE, July 23, 2009 (Link).
[31] 2013 Porsche Annual Report.
[32] "Creation of an integrated car manufacturing group intended," Porsche SE, May 6, 2009 (Link).
[33] "Porsche Automobil Holding SE: Basic Agreement between Porsche SE and Volkswagen AG on the foundation of an integrated car group," Porsche SE, August 13, 2009 (Link).

[34] "Porsche Supervisory Board agrees on the contracts of implementation - Intensive negotiations with Volkswagen concluded successfully," Porsche SE, November 20, 2009 (Link).
[35] 2009 VW Annual Report.
[36] 2012 VW Annual Report.
[37] 2019 Porsche Half-Yearly Financial Report.
[38] Judgment, March 18, 2016, LG Stuttgart 13 KLs 159 Js 69207/09.
[39] Judgement (in re: credit fraud), LG Stuttgart 11 KLs 159 Js77250/11, BeckRS 2014, 03776.
[40] "Razzia bei Porsche," Frankfurther Allgemeine Zeitung, August 20, 2009, (Link).
[41] 2007/2008 Porsche Annual Report, pp. 176-177.
[42] "Porsche To Profit From Volkswagen Squeeze," Forbes, October 29, 2008 (Link).
[43] "Tesla call options soar on Musk tweet, short-sellers hit," Reuters, August 7, 2018 (Link).
[44] "DOJ Opened Probe of Tesla After Musk's Going-Private Tweet," Wall Street Journal, September, 18, 2018 (Link).
[45] "Elon Musk to step down as chair of Tesla board, settles with SEC for USD 20 million," CBS News, September 29, 2018 (Link).
[46] "Federal Judge Approves Elon Musk, Tesla Settlements With SEC," Wall Street Journal, October 16, 2018 (Link).
[47] "Elon Musk's climbdown set to bring relief to Tesla investors," Financial Times, September 28, 2018 (Link).
[48] Section 33 of the German Securities Trading Act (Wertpapierhandelsgesetz – WpHG), available at (Link).
[49] Section 40, ibid, available at (Link).
[50] Section 43, ibid, available at (Link).
[51] Section 29 of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link).
[52] Section 35, ibid, available at (Link).
[53] Section 31, ibid, available at (Link).
[54] "Public Takeovers in Germany," Cameron McKenna, available at (Link).
[55] Sections 14 and 15 of the German Securities Acquisition and Takeover Act (Wertpapiererwerbs- und Übernahmegesetz – WpÜG), available at (Link).
[56] Section 10, ibid, available at (Link).
[57] Section 26 , ibid, available at (Link).
[58] "Strategy-based Margin," Cboe, available at (Link).
[59] LG Stuttgart 13. Große Strafkammer 13 KLs 159 Js 69207/09.