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Firms and Collective Reputation: The Volkswagen Emission Scandal as a Case Study

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Firms and Collective Reputation: The Volkswagen Emissions Scandal as a Case Study

Abstract

This paper uses the 2015 Volkswagen emissions scandal as a natural experiment to provide causal evidence that group reputation externalities matter for firms. Our estimates show statistically and economically significant declines in the U.S. sales and stock returns of, as well as public sentiment towards, BMW, Mercedes-Benz, and Smart as a result of the Volkswagen scandal. In particular, the scandal reduced the sales of these non-Volkswagen German manufacturers by approximately 76,000 vehicles over the following year, leading to a loss of approximately \$3.7 billion of revenue. Volkswagen's malfeasance materially harmed the group reputation of "German car engineering" in the United States.

JEL-Codes: D120, D900, F230, L140, L620.

Keywords: automobiles, collective reputation, country reputation, difference-in-differences, event study, Google trends, firm reputation, natural experiment, reputation externalities, Twitter sentiment, Volkswagen emissions scandal.

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1 Introduction

A group’s collective reputation can influence the outcomes for its members independently of their individual characteristics or behavior. In a seminal paper, [Tirole \(1996\)](#) develops a theoretical framework for modeling collective reputation showing how stereotypes can arise through history dependence so that an original sin by elder group members can have long-lasting effects on a group. [Tadelis \(1999\)](#), writing in the large theoretical literature on firm reputation, highlights the importance of names as intangible assets conveying reputation. In this paper, we combine these two perspectives and investigate empirically a case in which firms have a collective reputation by virtue of their association with a particular country.

Despite the theoretical interest in the issue, there is limited empirical evidence that group reputation and reputational externalities matter economically at the level of the firm.¹ This evidence is limited by many obstacles. First is the scarcity of large and prominent shocks that directly implicate only a subset of group members so that the existence of reputational spillovers on the other group members can be demonstrated. Second is the difficulty of identifying natural and reputationally salient groups of firms. Third is the rarity of direct measures of group reputation, which requires researchers to make indirect inferences about the effects of reputation. To overcome these issues, we use the 2015 Volkswagen (VW) emissions scandal as a natural experiment, which directly implicated VW but not the other German automakers. We study the scandal’s effects on their vehicle sales, stock returns, and social media sentiment. In doing so, we provide empirical support for the theoretical literature and the existence of group reputation externalities in an important setting.

On September 18, 2015, the U.S. Environmental Protection Agency (EPA) served a Notice of Violation to the VW Group alleging that approximately 500,000 VW and Audi diesel-engine cars sold between 2009 and 2015 in the United States contained a defeat device that allowed these cars to comply with emissions regulations in the test box, while having higher on-road emissions.² This date marks the public eruption of one of the major

¹There is a growing empirical literature on reputation management on online platforms (e.g., [Mayzlin et al. \(2014\)](#), [Fan et al. \(2016\)](#) and [Li et al. \(2016\)](#)), but it does not generally focus on collective reputation or reputational externalities. There is an agricultural economics literature with an emphasis on group reputation effects of regional appellations such as Bordeaux Wines ([Castriota and Delmastra \(2014\)](#) and [Landon and Smith \(1998\)](#)), but it typically does not include causal or quasi-experimental analysis. As [Castriota and Delmastra \(2014\)](#) state: “Despite the ubiquity of the concept, the economic literature concerning collective reputation is still in its infancy. [...] to our knowledge, there is no work that has tested the determinants of the process of collective reputation building.” [Noskoy and Tadelis \(2015\)](#) provide a field experiment with an online platform that also includes an emphasis on causal analysis of reputational spillovers.

²The Volkswagen Group consists of Volkswagen proper plus Audi and Porsche.

industrial scandals in recent history, with a prolonged legal fallout in the United States.

Several features of the scandal make it an appealing natural experiment: (1) For the general public the scandal was a clear surprise in September 2015, and it immediately generated extensive media coverage. There was also no concurrent notion in the public that the non-Volkswagen German car manufacturers—BMW, Mercedes-Benz, and Smart—were manipulating vehicle emissions.³ (2) The German auto manufacturers featured the notion of “German car engineering” prominently in their U.S. advertising, creating a natural reputational group. Additionally, we show that pre-scandal trends in reputation and business outcomes appear to have been similar among automakers from all countries, suggesting that non-German automakers can serve as a control group for understanding the effects of a German-specific shock. (3) Individual automotive makes are salient to consumers, enabling us to use novel company-specific data on U.S. social-media sentiment and internet searches to directly establish the existence of reputational externalities.

Adding to its appeal as a natural experiment, the scandal occurred within an important setting: (4) The car manufacturing industry is large and important in Germany. In 2014, the year prior to the scandal, cars amounted to 18 percent of Germany’s total exports according to the German Federal Statistical Office ([Destatis \(2015\)](#)), and were thus Germany’s largest export category. Also as of 2014, Germany captured by far the largest share of world car exports in UN trade statistics ([United Nations \(2017\)](#)), with 22.7 percent in dollar and 18.5 percent in unit terms, followed by Japan with, respectively, 12.5 percent and 10.7 percent. (5) German vehicles are a large share of the U.S. market: in 2014 German car manufacturers comprised 8.1 percent of all U.S. light vehicle sales, making Germany the second-largest source for foreign-branded vehicles. (6) The scandal’s reputational consequences were amplified by the damage the excess emissions caused to the public. [Oldenkamp et al. \(2016\)](#) estimate that the excess emissions caused by VW diesel cars cost 45,000 disability adjusted life years, with a value of life lost of approximately \$39 billion.⁴ We add to this a calculation of the economic damage for the other German car manufacturers. Finally, (7) the scandal also sparked a widespread public discussion regarding the mechanism at the center of our paper: country-related reputational spillovers. Our paper provides numbers to this debate.

³On September 22, 2015, CNN published ([Petroff \(2015\)](#)): “But before you start worrying about the complete collapse of the German auto industry, it’s worth repeating that – at least for now – the scandal is limited to Volkswagen. Other German automakers such as Daimler, which owns Mercedes-Benz, and BMW have said they’re not affected.” Only in the summer of 2017, after our study period, was it suggested that Mercedes-Benz had also manipulated emissions ([Zeit Online \(2017\)](#)), although Mercedes-Benz never admitted wrongdoing in the United States.

⁴[Barrett et al. \(2015\)](#) estimate 59 premature deaths and a social cost of \$450 million; [Holland et al. \(2016\)](#) estimate similar numbers.

We find that the VW scandal caused a loss of 76,000 vehicle sales worth roughly \$3.7 billion of revenue for the non-VW German car manufacturers along with a decline in their stock returns relative to expected market outcomes. We reach these conclusions using a difference-in-differences approach (e.g., [Angrist and Krueger \(1999\)](#)) that compares how key outcomes changed over time for the treated group, non-VW German car manufacturers, versus a control group of non-German car manufacturers. The differential responses to the scandal provide causal evidence on the scandal's economic consequences.

Our interpretation of these results is that the scandal harmed the collective reputation of German automakers in the United States. To support this interpretation, we proceed in several steps: First, we provide suggestive evidence that German car manufacturers constitute a reputationally salient group under the umbrella of "German engineering." Second, we document that the scandal reduced the sales of each non-VW German automaker individually. Third, we document a deterioration in positive public sentiment toward the non-VW German automakers in the social media data.⁵ Fourth, we show that the results are not primarily driven by diesel cars, despite the scandal's origins in the diesel market. Fifth, we use internet search data to argue that consumers did not engage in increased information-seeking regarding the non-VW German automakers, which is inconsistent with suspicions of malfeasance similar to VW's.

Our results thus substantiate the opening claim in [Tirole \(1996\)](#) that: "Collective reputations play an important role in economics and the social sciences. Countries, ethnic, racial or religious groups are known to be hard-working, honest, corrupt, hospitable or belligerent." Further, we show that the actions of one member of a group can materially damage the group's reputation, producing reputation externalities from the standpoint of individual firms. We are not aware of any systematic investigation into the reputational spillover effects of major corporate scandals and their economic consequences, and thus hope that this paper fills this lacuna in the literature.

Our study is also related to four additional strands of literature: First, a recent literature in international macroeconomics, for instance [di Giovanni and Levchenko \(2012\)](#), [di Giovanni et al. \(2014\)](#) and [di Giovanni et al. \(2015\)](#), emphasizes granularity and the importance of large international firms; our results suggest that misbehavior at such firms can damage the collective reputation of particular national powerhouse industries. Second, the international economics literature has examined the extent to which taste shocks for domestic versus foreign goods can explain the comovement of international business cycles ([Stockman and Tesar \(1995\)](#)). Our results suggest that the misbehavior of large multina-

⁵The economic and reputational spillovers from the scandal on the non-VW German car manufacturers are separate from the deterioration in economic outcomes and reputational measures for VW itself.

tional firms might generate such taste shocks through reputational spillovers. Third, our results provide a case study for the recent macroeconomic literature on customer capital; our evidence shows how customer capital can decline through reputational spillovers and quantifies the economic consequences of such a loss (Drozd and Nosal (2012) and Gourio and Rudanko (2014)). Fourth, in what Berry et al. (1995) call the “characteristics approach” to demand estimation, researchers must specify what properties of products enter into consumers’ preferences. Our results suggest that country of origin might be an important such attribute, consistent with an existing marketing literature.⁶

Section 2 provides a more detailed timeline of the VW emissions scandal and describes the scandal’s effect on VW. It also introduces our main data sources. Section 3 quantifies the economic fallout from the scandal for the other German car manufacturers, focusing on their vehicle sales and also examining their stock returns. Section 4 interprets this economic fallout as evidence for the existence of reputational spillovers to the non-VW German car manufacturers. A final section 5 concludes.

2 The VW Emissions Scandal as a Natural Experiment

In this section, we describe the timeline of the VW emissions scandal in detail, and argue that it represents a natural experiment with which to study the economic effects of reputation. We show that the scandal was largely unanticipated, both in the media and by stock market participants. We also document that the scandal was widely covered in the media and that Volkswagen’s sales growth, stock price and reputation declined substantially in the scandal’s aftermath.

2.1 Timeline of the Scandal

In May 2014, West Virginia University’s Center for Alternative Fuels Engines and Emissions found discrepancies between high on-road emissions by VW diesel cars and earlier test results. The U.S. Environmental Protection Agency’s (EPA) replication of the tests led VW to order a voluntary recall of diesel cars in December 2014, citing a need to recalibrate engines. In May 2015, the California Air Resources Board (CARB) conducted new tests, and again the on-road emissions failed to match the test-box results for VW diesel cars. In

⁶This marketing literature has devoted substantial attention to “Country of Origin” (COO) effects on corporate reputation, as summarized in Newburry (2012), who states: “While COO has been studied extensively with respect to firm products, the impact of country on a firm’s overall reputation and the dimensions forming a country’s reputation are less well understood.” In addition, Newburry (2012) calls for more causal analyses of how firms can shape a country’s reputation and vice versa.

July 2015, the agencies informed VW about these tests and threatened not to certify the 2016 diesel cars. On September 3, 2015, VW admitted to the EPA and CARB that they had used a defeat device in their software which regulated emissions and produced fake test results in the test box (see [Breitinger \(2016\)](#) for a more complete timeline). The scandal entered its public phase on September 18, 2015, when the EPA served a Notice of Violation to the Volkswagen Group.

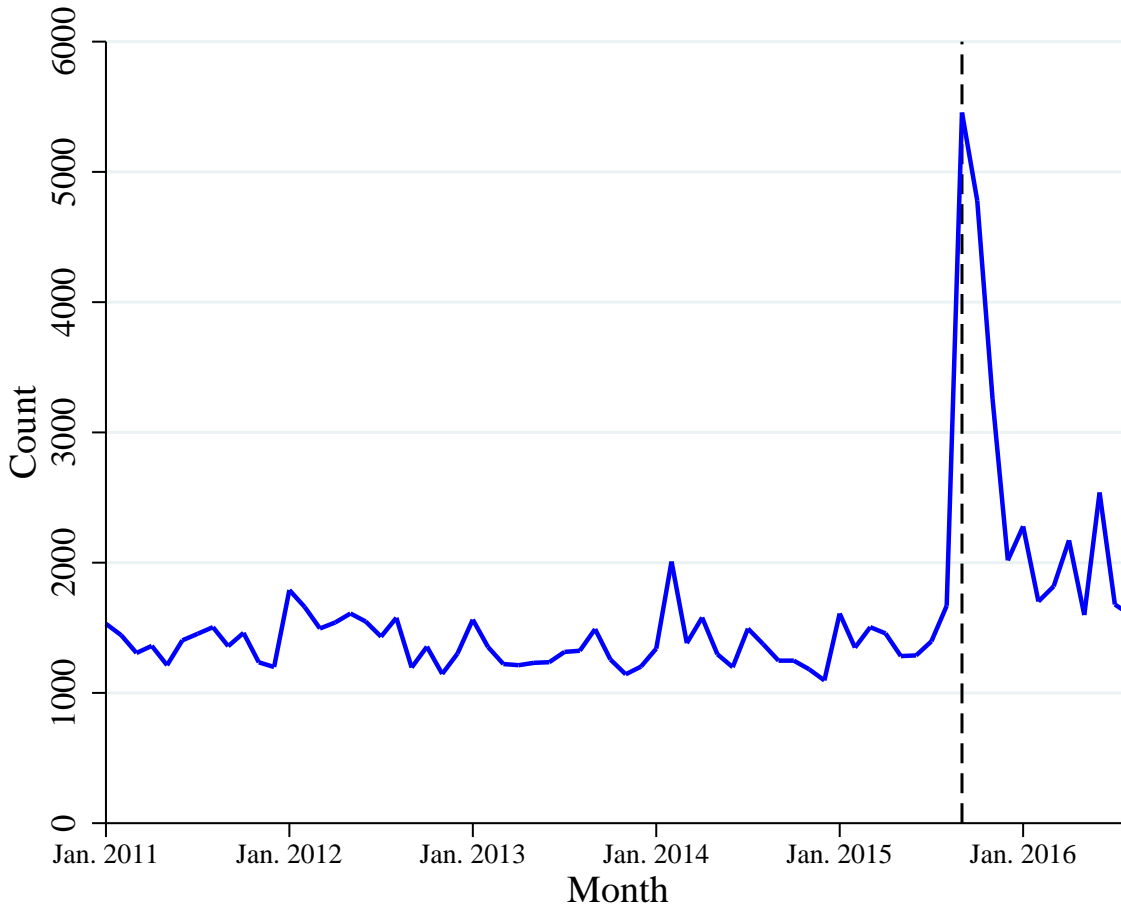
Volkswagen's culpability quickly became a matter of public knowledge: on September 20, two days after the start of the scandal, Volkswagen admitted publicly to the deception and issued an apology. VW Chief Executive Officer Martin Winterkorn resigned three days later. On September 28, German authorities opened a fraud investigation of the former CEO, and in October they authorized a police raid on the VW headquarters. The U.S. Congress called the VW U.S. CEO Michael Horn to testify on October 8, 2015, and he formally resigned his post in early March 2016. In anticipation of the fines and settlements associated with the scandal, VW set aside more than \$18 billion in fiscal year 2015. The scandal's legal resolution in the United States began in April 2016. On July 26, 2016, VW and a U.S. court agreed on a civil settlement amounting to \$15 billion.

Major news outlets across many countries covered the scandal and its aftermath. On September 19, the morning after the scandal, the front page of the New York Times read: "U.S. Orders Major VW Recall Over Emissions Test Trickery." The Wall Street Journal used a more accusatory tone: "Volkswagen Faked EPA Exhaust Test, U.S. Alleges." Spiegel Online and Zeit Online, the online platforms of two major German newspapers, frequently reported about the scandal. The scandal quickly spilled over into popular culture. On September 22, 2016, VW was awarded the satirical Ig Noble Prize in chemistry ([Improbable Research \(2016\)](#)), and on October 13, 2015, Paramount Pictures and Leonardo DiCaprio's production company announced that they had secured the rights to shoot a film about the scandal ([Breitinger \(2016\)](#)).

2.2 The Scandal's Effect on Volkswagen and Its Reputation

We quantify the immediate and longer-term media prominence of the scandal using data from the Newsbank news aggregator on print media mentions of "Volkswagen" in the United States. This database covers roughly 5,000 U.S. newspapers, newswires, journals, and magazines. Figure 1 shows that mentions of "Volkswagen" spiked after the scandal, more than tripling from the preceding months to 5,500 in September 2015. This suggests that the scandal came as a complete surprise to the general public. Media interest in Volkswagen remained elevated for most of the following year.

Figure 1: Monthly Print Media Mentions of “Volkswagen” in the United States



Note: Dashed line shows the date of the Volkswagen emissions scandal, dated September 2015. Data come from the Newsbank news aggregator, which covers roughly 5,000 U.S. newspapers, newswires, journals, and magazines. Time period covered is January 2011 to August 2016.

Economic consequences quickly followed suit. Table 1 displays U.S. light vehicle sales statistics over the period of January 2011 to August 2016, split into a pre-scandal period through August 2015 and a post-scandal period beginning September 2015. Volkswagen’s light vehicle sales declined by an average of 3,000 units per month in the 12 months following the scandal relative to the pre-scandal average. Volkswagen’s average 12-month natural log sales growth, $\ln \text{Sales}_t - \ln \text{Sales}_{t-12}$, was -0.12 in the year following the scandal, compared to 0.07 prior to the scandal.⁷ By contrast, the sales of all automakers increased by an average of 7,000 units per month and make relative to the pre-scandal average, and their post-scandal log sales growth averaged 0.05.

⁷The VW Group shows increases in its average number of vehicle sales by month-make in the post-scandal period relative to the pre-scandal period; this is explained by an increasing trend in vehicles sold over the entire time period. More informative and relevant for our paper is the switch from positive average growth rates for VW Group before the scandal (0.12) to negative average growth rates after the scandal (-0.01).

Table 1: U.S. Light Vehicle Sales – Descriptive Statistics

	Average Vehicle Sales by Make-Month	Average 12-month Log Sales Growth by Make-Month	Number of Make-Months
<i>All Makes</i>			
Whole Sample	34,622	0.10	2,798
Pre-Scandal	33,567	0.11	2,378
Post-Scandal	40,595	0.05	420
<i>Volkswagen</i>			
Pre-Scandal	29,751	0.07	68
Post-Scandal	26,481	-0.12	12
<i>VW Group</i>			
Pre-Scandal	14,982	0.12	204
Post-Scandal	15,891	-0.01	36

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Volkswagen Group is defined as Volkswagen, Audi, and Porsche. Pre-scandal period is January 2011 to August 2015; post-scandal period is September 2015 to August 2016. Sales are measured in units sold. Data come from Ward’s Automotive.

To construct these statistics, we obtain light vehicle sales data at the unit level from WardsAuto, one of the premier automotive industry publications. WardsAuto receives these unit-level sales data from all car manufacturers in the United States. It is thus in principle a complete count of light vehicle sales in the United States. The car manufacturers themselves use Ward’s data for their own analyses. In addition, the official U.S. car sales statistics in the national accounting data are based on the same data we use. An individual observation underlying the statistics in table 1 contains identifiers for the vehicle make (e.g., Honda or Volkswagen), the vehicle model (e.g., Civic or Jetta), and the vehicle powertype (e.g., gas or diesel). The data set contains 37 makes, listed in appendix table A.1, and 357 distinct models. We identify six makes as of German origin: Audi, BMW, Mercedes-Benz, Porsche, Smart, and Volkswagen.⁸

Along with the adverse attention in the media and its reduced sales, VW’s stock price declined precipitously following the EPA’s announcement; the visually evident discontinuity on September 18 in figure 2 suggests that the scandal came as a surprise to market participants. Volkswagen’s end-of-day stock price fell by 33 percent in the two trading

⁸Mini, the present-day incarnation of a line manufactured by the British Motor Corporation and its successors between 1959 and 2000, is currently owned by BMW. Given its historical association with Britain, we classify Mini as not of German origin. We consider alternative classifications in appendix B.1.

days following the scandal.⁹ The stock price subsequently recovered some of its losses over the rest of the year, but at the end of August 2016 it remained 24 percent lower than its pre-scandal closing price.

Figure 2: End-of-Day Stock Price for Volkswagen Group



Note: Dashed line shows the date of the Volkswagen emissions scandal, dated September 2015. End-of-day price shown for Volkswagen ADR listed on U.S. stock exchanges. Data come from the Bloomberg database. Time period covered is January 2011 to August 2016.

Finally, we use novel sentiment measures from Networked Insights to measure the scandal's effect on Volkswagen's reputation. Networked Insights is a data analytics company, founded in 2006, that provides a platform for real-time semantic analyses of social media posts; its primary clients are consumer-facing companies that use the platform to manage their brands. We focus on sentiment data from Twitter, an online social media networking service where some 300 million active monthly users share short messages. The sentiment measures in our data set are calculated from a 10 percent random sample from Twitter.

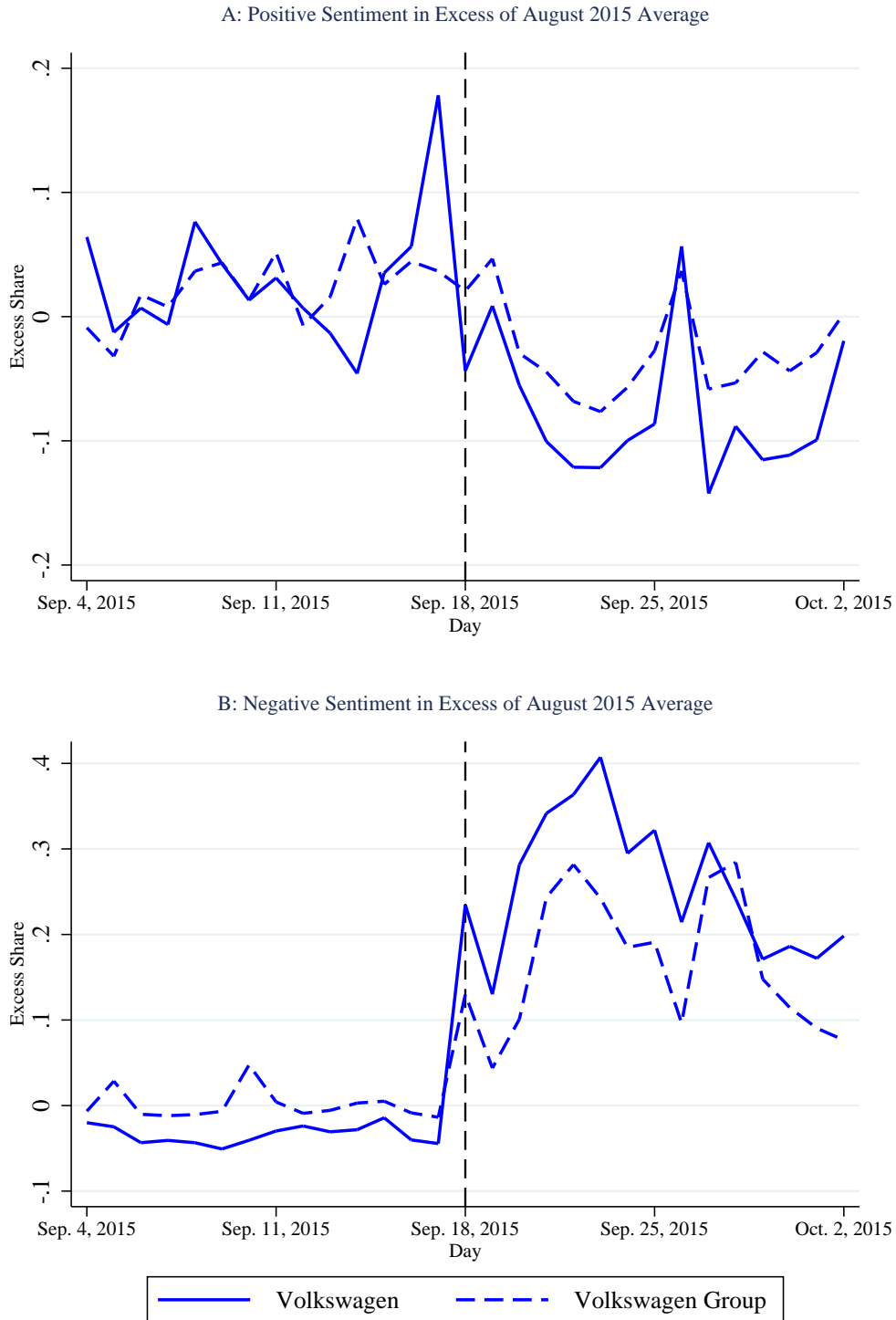
⁹To focus on the effects within the United States and to avoid currency effects from the euro-based VW listing on the Frankfurt Stock Exchange, we use the price of the VW American Depository Receipt (ADR) traded on U.S. markets. ADRs are issued by a U.S. depository bank and entitle the owner to shares in an international security; they are priced and pay dividends in U.S. dollars, and are traded through broker-dealers.

Networked Insights categorizes tweets as displaying positive, neutral, or negative sentiment toward the mentioned company. Posts are excluded from the analysis if they are not written in English or if the user accounts are associated with locations outside the United States. Networked Insights also constructs brand identifiers. An identifier for Volkswagen, for instance, is meant to collate mentions of “Volkswagen,” “VW,” “#Volkswagen,” and the like. Given the size of the underlying data set, Networked Insights only retains the past 13 months of data. We requested the data in September 2016, so our time series begins on August 10, 2015. We first create average daily sentiment shares (positive/negative/neutral) for August 2015 for each vehicle make in our data. We then construct sentiment shares in excess of this August baseline for each day.

Figure 3 displays these sentiment metrics for VW and the VW group two weeks before and after the scandal: positive sentiment toward VW declined following the scandal, while negative sentiment spiked. Panel A shows a decrease in positive sentiment toward VW, from an average of 3 percentage points higher than its August baseline in the two weeks prior to the scandal to an average of 8 percentage points below in the two weeks following the scandal. Panel B displays an even sharper increase in negative sentiment toward VW: from an average of 3 percentage points below to an average of 26 percentage points above.¹⁰ The results for the entire Volkswagen group (which includes Audi and Porsche) are similar. Together, these two panels suggest that Volkswagen’s reputation suffered in the aftermath of the September 18 EPA announcement.

¹⁰The pre-scandal and post-scandal means are statistically different at the 1 percent significance level for both positive and negative sentiment.

Figure 3: Daily Twitter Sentiment Towards Volkswagen



Note: Dashed vertical lines show the date of the Volkswagen emissions scandal, dated September 18, 2015. Sentiment shares are normalized by subtracting the average sentiment share from August 10 to August 31, 2015. We show a window of ± 14 days around September 18, 2015. Volkswagen Group is defined as Volkswagen, Audi, and Porsche. Data come from Networked Insights.

3 The Scandal’s Economic Effects on BMW, Mercedes-Benz, and Smart

In this section, we show that the Volkswagen emissions scandal had *economically* important spillovers on the other German auto manufacturers (BMW, Mercedes-Benz, and Smart). First, we present our main result, that the scandal substantially reduced the U.S. sales growth of the other German auto manufacturers relative to their non-German counterparts. Second, we show that those German auto manufacturers’ U.S. stock returns fell immediately after the scandal relative to the returns of non-German auto manufacturers. In the ensuing section 4, we interpret these economic spillovers as reflective of *reputational* spillovers to the non-VW German car manufacturers.

We estimate the causal effects of the scandal on non-VW German auto manufacturers using a standard difference-in-differences regression specification:

$$y_{it} = \alpha + \beta_i + \gamma_t + \delta T_{it} + \varepsilon_{it}, \tag{1}$$

where y_{it} is an outcome of interest for an individual vehicle make or company i at time t ; β_i an individual-specific fixed effect; γ_t a time fixed effect; and T_{it} is an indicator taking value one for the German manufacturers on and after the scandal date, and zero otherwise. We exclude the Volkswagen Group from the sample to focus the analysis on the economic consequences of reputation for German automakers not directly implicated by the scandal, that is, reputational externalities. The coefficient of interest, δ , captures the differential impact of being a non-VW German auto manufacturer after the scandal. To interpret the estimated coefficient as a causal effect, we invoke and support the so-called “parallel trends” assumption.

3.1 Sales Growth

To study the scandal’s spillovers on vehicle sales, we define the outcome variable in equation (1) as the 12-month growth rate of unit sales, expressed in log points: $\ln \text{Sales}_{it} - \ln \text{Sales}_{it-12}$. The unit of observation is the vehicle make-month (e.g., Honda in January 2016), and the sample period is January 2011 to August 2016. In this setting, β_i is a make fixed effect, capturing potentially unobserved heterogeneity at the make level. γ_t is a fixed effect for each month in the sample, capturing seasonality in car sales and the potential impacts of time-varying gasoline and diesel prices. We estimate this equation as a weighted regression, with the square root of sales volumes as weights, to dampen the impact of highly volatile sales growth rates of small sales levels.

Table 2: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group

Dependent Variable	12-month Log Sales Growth		
	Baseline	No saturated make effects	No saturated fixed effects
	(1)	(2)	(3)
German Manuf. × Post-Scandal	-0.104 (0.035)	-0.110 (0.035)	-0.106 (0.033)
German Manuf.		0.020 (0.011)	0.017 (0.010)
Post-Scandal			-0.038 (0.011)
Time Fixed Effects	Yes	Yes	No
Make Fixed Effects	Yes	No	No
R ²	0.292	0.161	0.015
N	2150	2150	2150

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant and are weighted by the square root of sales volumes. Column (1) is based on a regression with make and time fixed effects. Column (2) is based on a regression with time fixed effects, and an indicator for non-VW German makes. Column (3) is based on a regression with an indicator for non-VW German makes and an indicator for the post-scandal period (September 2015 through August 2016). Data come from Ward’s Automotive.

We estimate that the scandal reduced the sales growth rates of the non-VW German automakers by 10.4 percentage points, as shown in our baseline specification in table 2, column (1). Columns (2) and (3) present specifications with a coarser treatment of the time and make fixed effects. Specifically, in column (2) we replace the saturated make fixed effects with an indicator variable for non-VW German makes. Column (3) presents an even simpler difference-in-differences specification in which we additionally replace the saturated time fixed effects with an indicator for the post-scandal period. The estimated treatment effect δ is negative and stable across these specifications.¹¹

Our estimates suggest that the scandal resulted in 76,070 fewer unit sales for the non-Volkswagen German auto manufacturers between September 2015 and August 2016. We

¹¹Appendices B.2 and B.3 show that the results are also robust to variations in the control group and to several alternative econometric specifications.

calculate this decline by multiplying the manufacturers' total sales of 731,444 units during the twelve month period prior to the scandal by negative 10.4 percent, our estimate of the scandal's effect on their sales growth rate (column (1) of table 2). Actual sales for these manufacturers declined by 29,484 units in the twelve months after the scandal, suggesting that sales would have risen by about 45,000 units in the absence of the scandal.

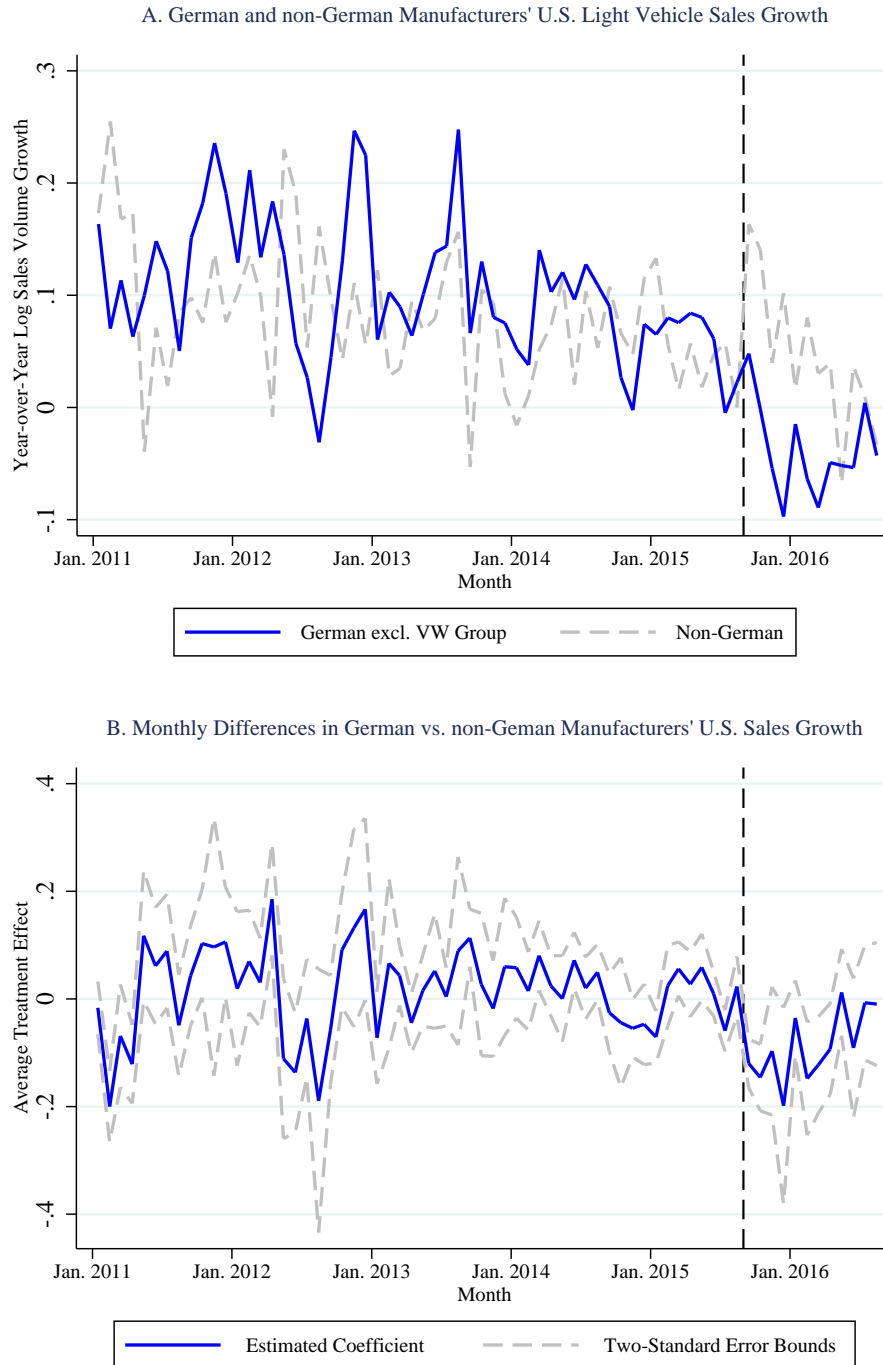
We quantify the joint revenue loss to BMW, Mercedes-Benz, and Smart as \$3.70 billion dollars by multiplying the unit sales decline by the manufacturers' suggested retail prices (MSRPs) for calendar year 2015, also obtained from Ward's. Because actual transaction prices may have included post-scandal discounts not reflected in MSRPs, we view our estimated decline in revenue as a likely lower bound of the scandal's true revenue effects on the non-VW German car manufacturers.¹²

To allay potential concerns about the key identifying assumption underlying our estimation procedure, we provide suggestive evidence in figure 4 that the parallel trends assumption holds. Panel A plots the sales growth rates of the two groups, and panel B plots the monthly differences in sales growth between non-VW German and non-German manufacturers. Both panels show that the growth rates of the two groups' sales were essentially indistinguishable prior to the scandal, consistent with the parallel trends assumption.

Two additional patterns in figure 4 are worth noting. First, the solid blue line in panel A shows that the sales of the non-VW German automakers declined in the aftermath of the scandal. One might have expected the sales of non-VW German makes to increase as VW sales plummeted. The outright decline observed instead would be difficult to explain without reputational spillovers from VW to the other German car manufacturers. Second, panel B traces out the month-by-month sales differential between non-VW German and non-German automakers after the scandal, providing a more dynamic picture of the effects of the scandal: the sales declines were concentrated in the immediate aftermath in the scandal, as evidenced by an inverted hump-shaped response that faded out to zero by August 2016.

¹²More precisely, we calculate the revenue loss in the following manner: we first calculate model-level revenue by multiplying the quantity sold of a model in the year prior to the scandal by its median MSRP across its available trim levels for 2015. We use the median MSRP across trims for each model because the Ward's data does not break out sales volumes by trim. Second, we aggregate model-level revenues to compute the total revenue for the non-VW German auto manufacturers. Third, we divide total revenue by the total quantity sold to construct an average unit sales price for the non-VW German auto manufacturers. Finally, we multiply the estimated unit decline in sales by this average unit sales price. The estimated decline in revenue that we report here hardly changes when estimated using a difference-in-differences regression with MSRP-based revenues directly as the outcome variable. Transaction prices are not readily available to researchers (see [Berry et al. \(1995\)](#), who use MSRPs as well). By contrast, papers in the literature that use transaction prices typically employ specifically designed and highly confidential surveys; see, for instance, [Berry et al. \(2004\)](#).

Figure 4: Differences in U.S. Light Vehicle Sales Growth



Note: Dashed vertical lines show the date of the Volkswagen emissions scandal, September 2015. Panel B displays estimated regression coefficients of the month-by-month differences of German vs. non-German manufacturers' 12-month log U.S. light vehicle sales growth. These coefficients and the corresponding confidence bands are estimated by a pooled (and sales-weighted) regression of the form: $\ln(\text{Sales})_{it} - \ln(\text{Sales})_{it-12} = \sum_{s=1}^T \gamma_s \text{Month}_s + \sum_{s=1}^T \beta_s \text{non-VW German}_i \times \text{Month}_s + \varepsilon_{it}$, where $\{\text{Month}_s\}_{s=1}^T$ is a complete set of month dummies, ranging from January 2011 to August 2016, and "non-VW German" is a dummy variable that takes a value of one if the make i is BMW, Mercedes-Benz, or Smart. Data come from Ward's Automotive.

3.2 Stock Returns

We next show that the scandal’s effect on sales was mirrored in financial outcomes, as measured by stock returns. To this end, we combine two complementary data sources. We construct daily U.S. stock returns from the Center for Research in Securities Prices (CRSP) database, which covers primary listings on NYSE, NYSE MKT, NASDAQ, and NYSE Arca.¹³ We supplement this data with American Depository Receipts (ADRs) for publicly-listed auto manufacturers from other countries.¹⁴ By incorporating ADRs into our dataset, rather than using the home-country listings, we can compare daily returns coming from the same trading days and better capture the reaction of U.S. investors across a common set of securities. ADRs allow us to calculate the daily returns for foreign car manufacturers even on days when the underlying stocks are not traded in their home markets.¹⁵

We start by assuming that an individual stock’s expected return depends only on the stock’s covariance with the market return, its beta. The difference between the expected return on stock i at time t and its actual return is referred to as the “abnormal return,” AR_{it} . Formally, we measure each stock’s abnormal return by estimating the following regression:

$$R_{it} = \alpha_i + \beta_i R_{market,t} + \varepsilon_{it} \quad (2)$$

where i indexes individual stocks and t represents market trading days. The regression sample covers the trading year, approximately 250 trading days, ending thirty days before the scandal. In equation (2), R_{it} is the daily stock return for stock i from day $t - 1$ to day t , and $R_{market,t}$ is the return on the CRSP value-weighted market portfolio (which does not include the ADRs). The abnormal return is the difference between the stock’s actual return and its return predicted from the regression: $AR_{it} = R_{it} - \hat{R}_{it}$. The cumulative abnormal return, CAR_{it} , is then defined as $\sum_{s=0}^t AR_{is}$. The starting point in our definition of cumulative abnormal returns, $s = 0$, is September 16, 2015, two days before the scandal.

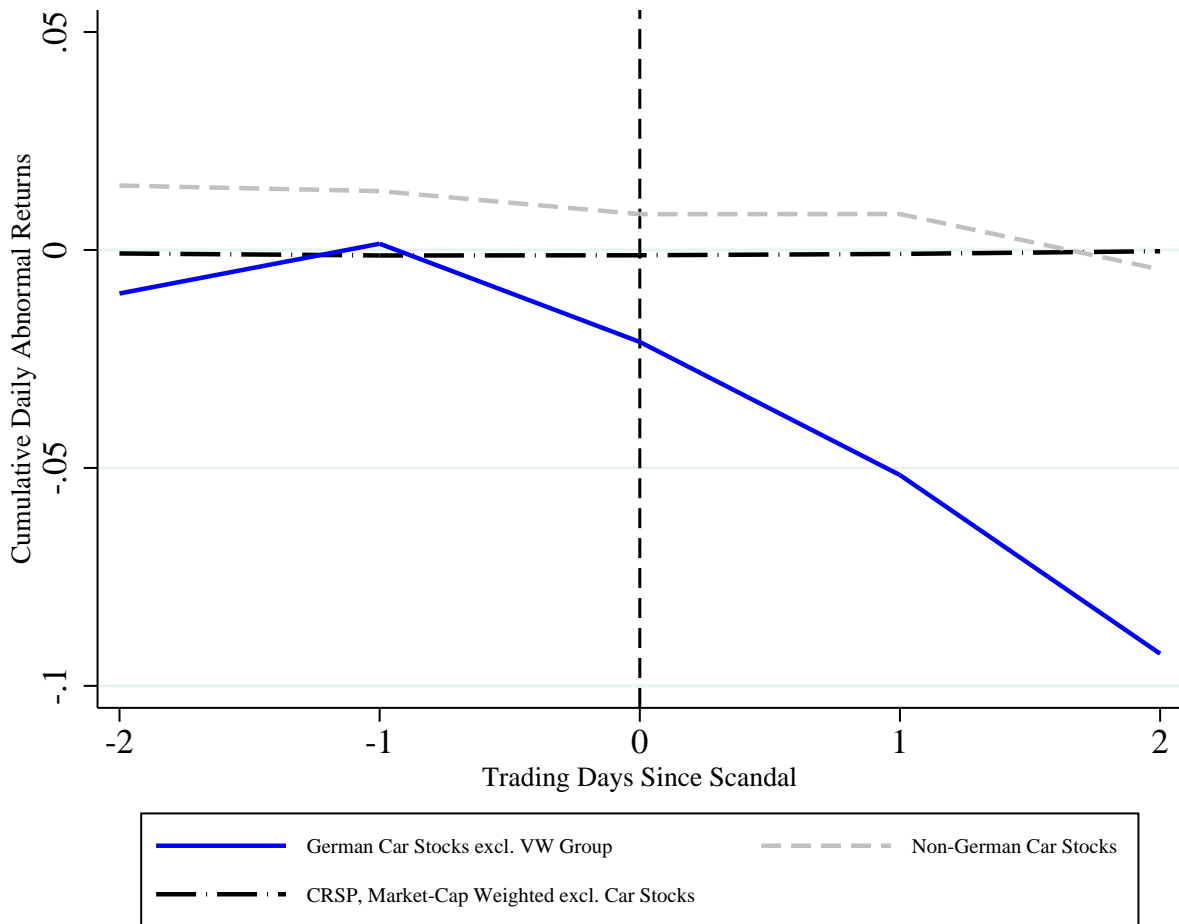
Figure 5 shows that the cumulative abnormal return for German auto manufacturers excluding Volkswagen was negative 10 percent within two trading days of the scandal. This decline contrasts sharply with the near-zero abnormal returns for the non-automotive

¹³NYSE is the New York Stock exchange and the premier market place. NYSE MKT is the marketplace within the NYSE for small market capitalization companies. NASDAQ is the second largest marketplace for stocks in the world after NYSE, with a certain specialization in high-tech companies. Finally, NYSE Arca is another specialized electronic-trading marketplace for U.S. stocks.

¹⁴Appendix table A.2 lists the holding companies of car makes used in our analysis (ADRs for the holding companies of some car makes in the Ward’s sales data were insufficiently frequently traded to be used). Ford, General Motors, and Tesla are listed on U.S. stock exchanges; all remaining prices come from ADRs.

¹⁵For instance, the Tokyo Stock Exchange was closed for holidays September 21-23, 2015; U.S. exchanges were open on those days. If we constructed daily returns of Japanese securities, e.g., Mazda or Nissan, from the Japanese exchange, we would have no observations on those U.S. trading days.

Figure 5: Cumulative Abnormal Stock Returns, Market Model



Note: Dashed line shows the date of the VW emissions scandal, September 18, 2015. Automotive stock data come from the Bloomberg database; CRSP index comes from the Center for Research in Security Prices.

stocks in the CRSP database during the five days around the EPA announcement. Similarly, the non-German auto stocks exhibited only slight abnormal return movements on and around the event date. As the three groups had similar cumulative abnormal returns prior to the scandal date, the divergence of the non-VW German auto manufacturers' returns following the scandal reflects the scandal's causal impact on this group. We formalize this notion through two empirical exercises.

First, we use both the AR_{it} and the CAR_{it} as outcome variables in our difference-in-differences regression. Owing to the high-frequency nature of the data, we use data for September 16 and 17, 2015, as the pre-scandal period, and data for September 18, 21, and 22, 2015, as the post-scandal period.

Table 3 shows the results and quantifies the causal impact of the scandal: relative to non-German car stocks, the non-VW German automakers experienced roughly 2 percent

Table 3: Abnormal Stock Returns – German vs. Non-German Car Firms, Excl. VW Group

Dependent Variable	Abnormal Returns		Cumulative Abnormal Returns	
	(1)	(2)	(3)	(4)
German × Post-Scandal	-0.019 (0.004)	-0.019 (0.005)	-0.064 (0.013)	-0.061 (0.015)
Weighting	None	Sales Volume	None	Sales Volume
Time Fixed Effects	Yes	Yes	Yes	Yes
Company Fixed Effects	Yes	Yes	Yes	Yes
R ²	0.687	0.600	0.882	0.799
N	60	60	24	24

Note: Unit of observation in columns (1) and (2) is the daily abnormal stock return, and in columns (3) and (4) it is the cumulative abnormal returns for the periods before and after the event date. Abnormal returns are calculated using a market model (equation (2)). Automotive stock prices come from Bloomberg and include U.S.-listed stocks (Ford, General Motors, and Tesla) and ADRs (all other care make holding companies). The weighted regressions are sales-weighted, using the Ward’s Automotive sales data, because for ADRs we do not have meaningful market capitalization data. Robust standard errors in parentheses. The pre-scandal period comprises September 16 and 17, 2015, and the post-scandal period comprises September 18, 21, and 22, 2015 (September 18 was a Friday in 2015). All regressions include a constant, company and time fixed effects.

lower daily abnormal returns. The latter two columns of the table compare cumulative abnormal returns at the end of the pre- and post- scandal periods: the non-VW German car stocks experienced roughly 6 percent lower cumulative abnormal return. Both results are statistically significant. This evidence suggests that the Volkswagen emissions scandal materially harmed the financial valuations of automakers linked to the scandal through their collective reputation as German automakers.

Second, we corroborate this analysis through the event-study methodology more commonly used in the finance literature (e.g., [MacKinlay \(1997\)](#)). The market model assumes that the return distributions are the same during the estimation period prior to the scandal and during the event window surrounding it. As a result, the (cumulative) abnormal returns for stocks on the three days of September 18, 21, and 22, 2015 should remain approximately zero if the scandal had no effect on stock returns. We can test this hypothesis

by computing the following test statistic for each stock i :

$$\frac{CAR_{iT}}{\left(T * Var[AR_i]\right)^{\frac{1}{2}}}, \quad (3)$$

where CAR_{iT} is the cumulative abnormal return of stock i between September 16 and September 22, 2015; $T = 5$ (trading) days in the event window; and $Var[AR_i]$ is an estimate of the variance of the abnormal return of stock i . Following MacKinlay (1997), we use the abnormal return variance over the estimation window for equation 2. Assuming that stock returns are normally distributed, this statistic is distributed approximately standard normal. BMW’s cumulative abnormal return of negative 7.2 percent and Daimler’s negative 11.4 percent have respective test statistics of 2.42 and 4.17. We note that both Mercedes-Benz and Smart are subsidiaries of Daimler.

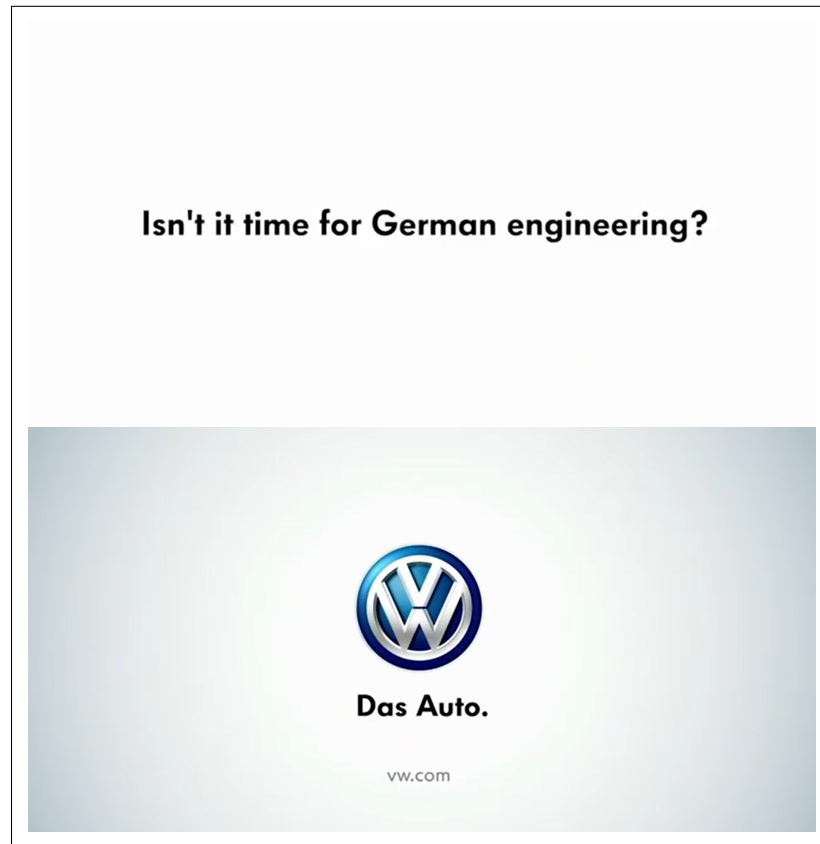
The visual and statistical evidence in this section suggests that the scandal reduced the stock returns of the non-VW German auto manufacturers. Furthermore, the evidence here corroborates the notion that market participants did not anticipate the EPA’s notice of violation.

4 Mechanism: the Scandal and Reputational Spillovers

In this section, we interpret the economic spillovers documented in the previous section as evidence of the scandal’s harm to the group reputation of “German Engineering.” We proceed in five steps. First, we provide suggestive evidence that German automakers constitute a reputationally salient group under the umbrella construct of “German Engineering” in both marketing and the media. Second, we emphasize the scandal’s collective harm by showing that each non-VW German automaker suffered individually as a result of the scandal. Third, we provide direct evidence of a decline in public sentiment toward the non-VW German automakers. After documenting this evidence for the collective reputation mechanism, we consider two alternative mechanisms for the scandal’s spillover effects. We argue that neither can fully account for the scandal’s spillovers without the collective reputation mechanism we document. To that end, we show in the fourth subsection that—despite the scandal’s origins in the diesel market—the non-VW German automakers experienced adverse spillovers in both their diesel and their non-diesel vehicle sales. Lastly, we use differences in internet searches across German automakers to argue that consumers are unlikely to have ascribed malfeasance similar to VW’s directly to the other German automakers.

4.1 “German Engineering” as a Group Identity

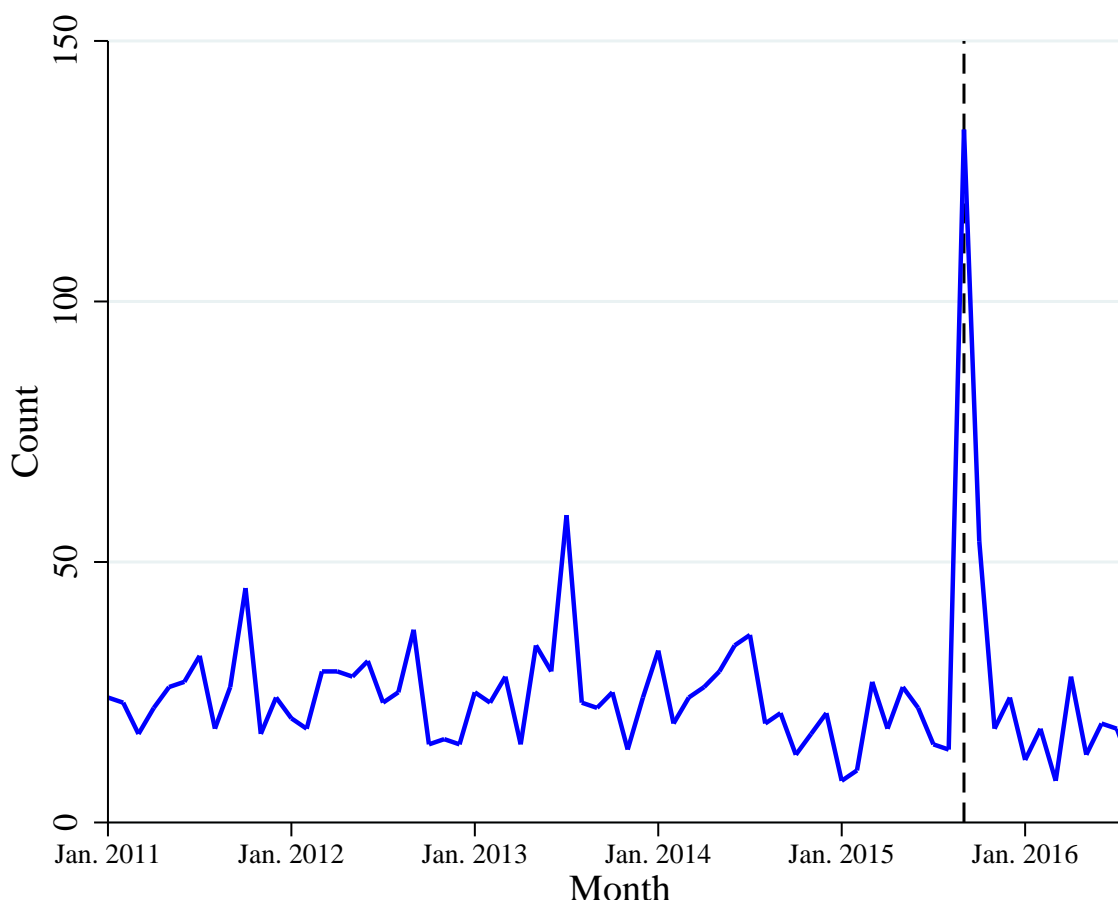
We first note that German manufacturing companies have historically leveraged the broader reputation of “German engineering” in their marketing. For instance, a Volkswagen commercial from 2014 states, “... Everyone knows that the best cars in the world come from Germany.” The ad fades out to the question: “Isn’t it time for German engineering?”



Following the scandal, media attention to “German engineering” spiked, with 130 print articles mentioning the term in September 2015, a five-fold increase over the preceding months. We illustrate this increase with data from the Newsbank aggregator in figure 6. A recurring theme in this coverage was the notion that the scandal might tarnish the broader reputation of German manufacturing firms. As part of this coverage of the scandal, Reuters published an article on September 22, 2015, “VW scandal threatens ‘Made in Germany’ image” (Chambers (2015)). A day later, Reuters doubled down with an article entitled “Volkswagen could pose bigger threat to German economy than Greek crisis” (Nienaber (2015)), which included the claim: “The broader concern for the German government is that other car makers such as Mercedes-Benz and BMW could suffer fallout from the Volkswagen disaster.”¹⁶

¹⁶See also Bruckner (2015), Werz (2016), and Remsky (2017).

Figure 6: Monthly Print Media Mentions of “German Engineering” in the United States



Note: Dashed line shows the date of the Volkswagen emissions scandal, dated September 2015. Data come from the Newsbank news aggregator, which covers roughly 5,000 U.S. newspapers, newswires, journals, and magazines. Time period covered is January 2011 to August 2016.

4.2 Economic Spillovers to Individual German Manufacturers

As evidence of a change in *collective* reputation, we next document that the scandal reduced sales growth for each of the three non-VW German car manufacturers individually. To arrive at this result, in table 4 we estimate parallel difference-in-differences specifications in which the treatment group includes only one non-VW German auto manufacturer at a time; each regression excludes the others. Column (1) reproduces our baseline result that the scandal reduced the non-VW automakers’ sales growth overall by 10.4 percentage points. Looking across the individual automakers, columns (2) through (4) show that the scandal reduced BMW’s sales growth rate by 15.1 percentage points, Mercedes-Benz’s by 6 percentage points, and Smart’s by 30.8 percentage points. These estimates translate into sales losses of 53,000 units for BMW, 23,000 units for Mercedes-Benz, and 2,400

for Smart. We view these pervasive declines as evidence of a change in non-VW German automakers’ collective reputation following the scandal.

Table 4: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group

Dependent Variable	12-month Log Sales Growth			
	Baseline	BMW	Mercedes-Benz	Smart
	(1)	(2)	(3)	(4)
German \times Post-Scandal	-0.104 (0.035)	-0.151 (0.012)	-0.060 (0.011)	-0.308 (0.012)
Time Fixed Effects	Yes	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes	Yes
R ²	0.292	0.296	0.294	0.295
N	2150	2014	2014	2014

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant, make and time fixed effects, and are weighted by the square root of sales volumes. Data come from Ward’s Automotive.

4.3 Direct Reputational Spillovers of the Scandal

Next, we use Twitter sentiment data to show that perceptions of the non-VW German automakers suffered in the aftermath of the VW emissions scandal. To show this result formally and to estimate the causal reputational effects of the scandal, we compare the outcomes of non-VW German and non-German auto manufacturers before and after the scandal, adapting our difference-in-differences regression specification. The unit of observation is now a make-day, and the estimation sample is a window of ± 14 days around September 18, 2015. The outcome variables are, respectively, positive and negative Twitter sentiment towards a particular make, relative to an August 2015 sentiment baseline. Both regressions are weighted by tweet volume.¹⁷

¹⁷Of the 37 auto makes with light vehicle sales in the Ward’s U.S. data (our data source for car sales), Alfa Romeo, Saab, Suzuki and Tesla did not have identifiers in the Networked Insights database; see table A.3 in the appendix for details.

Column (1) of table 5 documents a statistically significant decline of 3.5 percentage points in positive sentiment toward non-VW German manufacturers as a result of the scandal. To put that number in perspective, the share of tweets expressing positive sentiment toward those companies averaged 12.3 percent in August 2015. By contrast, the share of tweets expressing negative sentiment toward the non-VW German automakers did not change meaningfully following the scandal, as seen in column (2).

Table 5: Twitter Sentiment – German vs. Non-German Manufacturers, Excl. VW Group

Dependent Variable	Positive Sentiment	Negative Sentiment
	(1)	(2)
German × Post-Scandal	-0.035 (0.006)	0.002 (0.006)
Time Fixed Effects	Yes	Yes
Make Fixed Effects	Yes	Yes
R ²	0.348	0.268
N	840	840

Note: Unit of observation is vehicle make-day. Sentiment shares are normalized by subtracting the average sentiment share from August 10 to August 31, 2015. The estimation period comprises 14 days before and after scandal date of September 18, 2015. Volkswagen Group is defined as Volkswagen, Audi, and Porsche. All regressions include a constant, make and time fixed effects, and are weighted by tweet volume. Data come from Networked Insights.

We interpret these changes in social-media sentiment as reflecting a decline in the collective reputation of German automakers, but as unlikely to reflect suspicions that the other manufacturers were guilty of the same malfeasance as VW. The sentiment evidence for VW shown in figure 3 suggests that evidence of malfeasance manifests mainly as an increase in negative sentiment toward the wrongdoer. The absence of an increase in negative sentiment toward the other German manufacturers is inconsistent with a suspicion of similar wrongdoing. The decrease in positive sentiment, however, suggests that the scandal did adversely affect their reputations. Whereas the original instigator of a reputational event suffers especially in terms of negative sentiment, the reputational spillover of that event appears to manifest mostly in a decline in positive sentiment.

4.4 The German Effect Is Not a Diesel Effect

A natural concern given the scandal’s origins in the diesel market is that the sales declines we document in section 3.1 were driven by the reputation of or new information

about diesel vehicles, rather than the collective reputation of German automakers. Indeed, table 6 shows that diesel sales declined by 85 percent for the average month and make after the scandal, compared to a 6 percent increase for non-diesel vehicles. This decline was driven primarily by the Volkswagen Group, which was legally prohibited from selling diesel vehicles in the U.S. in the aftermath of the scandal. Nonetheless, even excluding the Volkswagen group, diesel sales declined by 11 percent for the average make-month after the scandal, compared to a 5 percent increase for non-diesels.

Table 6: U.S. Light Vehicle Sales – Diesel vs. Non-Diesel

	Average Vehicle Sales by Make-Month	Average 12-month Log Sales Growth by Make-Month	Number of Make-Months
<i>Non-Diesel</i>			
Pre-Scandal	32,589	0.11	2,378
Post-Scandal	39,548	0.06	420
<i>Diesel</i>			
Pre-Scandal	3,836	0.11	606
Post-Scandal	3,577	-0.85	123
<i>Non-Diesel, excl. VW Group</i>			
Pre-Scandal	34,475	0.11	2,174
Post-Scandal	41,782	0.05	384
<i>Diesel, excl. VW Group</i>			
Pre-Scandal	4,197	0.13	433
Post-Scandal	4,169	-0.11	104

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Volkswagen Group is defined as Volkswagen, Audi, and Porsche. Pre-scandal period is January 2011 to August 2015; post-scandal period is September 2015 to August 2016. Sales are measured in units sold. Data come from Ward's Automotive.

To address the concern that the scandal's spillovers were driven by the diesel market, we document that the reputational consequences of the scandal are evident in both diesel and non-diesel sales. Our difference-in-differences estimates in table 7 show that the scandal reduced German automaker' sales growth of non-diesel vehicles by 9.6 percentage points and that of the diesel vehicles by 23.3 percentage points. We view the scandal's effect on non-VW automakers' non-diesel sales as evidence that a change in the collective reputation of diesel vehicles cannot be the sole driver of our results.

Table 7: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group, By Power Type

Dependent Variable Power Type	12-month Log Sales Growth		
	Baseline	non-Diesel	Diesel
	(1)	(2)	(3)
German \times Post-Scandal	-0.104 (0.035)	-0.096 (0.038)	-0.233 (0.126)
Time Fixed Effects	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes
R ²	0.292	0.289	0.284
N	2150	2150	428

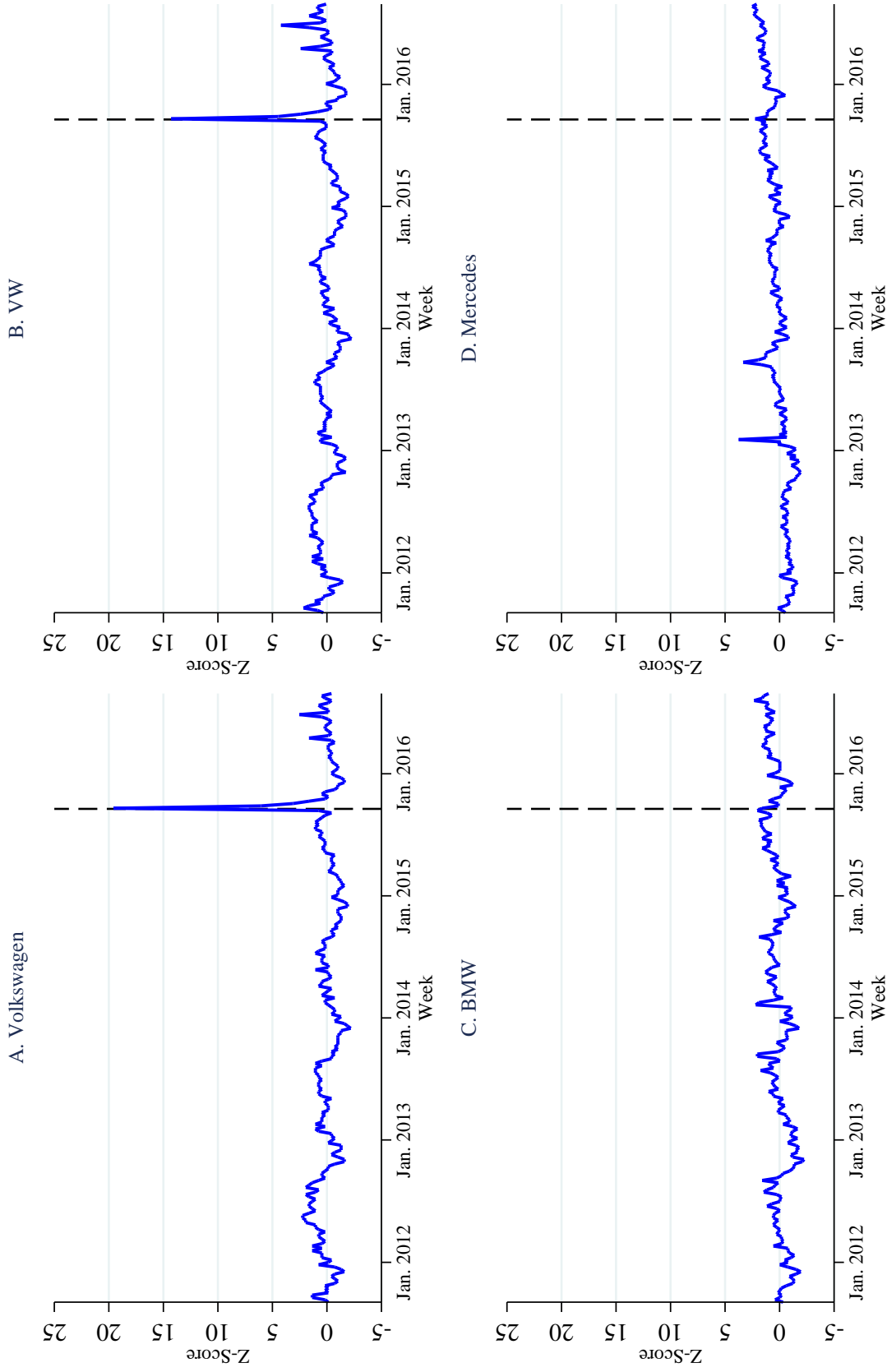
Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant, make and time fixed effects, and are weighted by the square root of sales volumes. Data come from Ward’s Automotive.

4.5 Information Seeking about German Automakers

Finally, we use internet search data to argue that consumers did not engage in increased information-seeking regarding the non-VW German automakers, which is inconsistent with suspicions of malfeasance similar to VW’s. This evidence suggests that the scandal’s effects on non-VW German automakers are unlikely to be driven by informational spillovers. Figure 7 shows that the general public’s information-seeking regarding Volkswagen spiked following the scandal, but did not change noticeably regarding BMW and Mercedes. Each of the four panels plots a time series of a single Google search term (“Volkswagen”, “VW”, “BMW”, and “Mercedes”). The underlying data on Google trends is weekly, and it is scaled so that 100 corresponds to the largest number of searches per week in the search period.¹⁸ We normalize the series and express weekly values as z-scores, deviations from the mean that are scaled by the standard deviation. A z-score equal to 1 indicates a 1-

¹⁸For weekly data, Google trends only allows users to download a few pre-defined search periods. We chose a five-year window from August 2011 to August 2016.

Figure 7: Google Trends of Searches for German Car Manufacturing Firms



Note: Dashed lines show the date of the Volkswagen emissions scandal, dated September 18, 2015. The underlying data on Google trends is weekly and it is scaled so that 100 corresponds to the largest number of searches per week in the search period (August 2011 to August 2016). We construct z-scores as the deviation from the mean of the series, normalized by its standard deviation. The z-scores on the vertical axis are constructed using the mean and standard deviation for each search term over the period prior to September 2015.

standard-deviation increase over the mean. Both the means and the standard deviations are constructed using the period prior to September 2015. Searches for “Volkswagen” and “VW”, in panels A and B, show dramatic increases in information-seeking in the aftermath of the scandal; the week of September 18, the date of the EPA announcement, coincides with z-scores of 22 and 15. By contrast, searches for the two main non-VW German makes, “BMW” in panel C and “Mercedes” in panel D, seem indistinguishable from their regular fluctuations. Together, these panels suggest that rather than precipitating new information-seeking about the individual manufacturers, the scandal changed the collective reputation of German automakers.

5 Conclusion

This paper uses the 2015 Volkswagen emissions scandal as a natural experiment to study the economic consequences of collective reputation. By documenting the changing outcomes of non-VW German car manufacturers relative to non-German car manufacturers, we capture the “German engineering” reputation of BMW, Mercedes-Benz, and Smart. We find that non-VW German car manufacturers suffered in three dimensions from the VW scandal: a loss of 76,000 vehicle sales worth roughly \$3.7 billion of revenue; a sharp decline in their stock returns relative to expected market outcomes; and a deterioration in positive public sentiment toward them. We interpret these outcomes as demonstrating the existence a country-specific collective reputation for German car manufacturing. We thus provide empirical support for the theoretical literature on collective reputation and the existence of group reputation externalities.

Our results also contextualize the economic harm of one of the largest U.S. industrial and public health scandals in recent U.S. history. As a complement to the literature on the public-health costs of the excess emissions, we trace the economic spillovers to companies not directly tainted by the scandal. The economically substantial spillovers we document suggest the need to understand what, if any, policy steps are required to address the centrality of national companies to the reputation of the country as a whole. Our results could thus provide an argument for policy instruments that would incentivize large companies to internalize their potential reputation spillovers.

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Appendix A - Additional Tables

Table A.1: Makes in Sales Volume Data

Acura	Honda	Nissan
Alfa Romeo	Hyundai	Porsche
Audi	Infiniti	Ram
BMW	Jaguar	Saab
Buick	Jeep	Scion
Cadillac	Kia	Smart
Chevrolet	Land Rover	Subaru
Chrysler	Lexus	Suzuki
Dodge	Lincoln	Tesla
Fiat	Mazda	Toyota
Ford	Mercedes-Benz	Volkswagen
GMC	Mini	Volvo
	Mitsubishi	

Note: Data come from Ward's Automotive. We exclude Mercury from the dataset because it was discontinued in January 2011, the first month of our analysis.

Table A.2: Automakers in Stock Price Data

Automaker (Holding Company)	Ticker
BMW	BAMXY:US
Daimler (Mercedes-Benz)	DDAIY:US
Ford	F:US
Fiat-Chrysler	FCAU:US
Fuji-Subaru	FUJHY:US
General Motors	GM:US
Honda	HMC:US
Mazda	MZDAY:US
Nissan	NSANY:US
Toyota	TM:US
Tesla	TSLA:US
Tata Motors (Jaguar and Land Rover)	TTM:US
Volkswagen Group	VLKAY:US

Note: Stock prices for automakers come from Bloomberg. Ford, General Motors, and Tesla are listed on U.S. stock exchanges; all remaining prices come from American Depository Receipts. Sample restricted to companies that sell light vehicles in the United States.

Table A.3: Makes in Twitter Data

Acura	Honda	Mini
Audi	Hyundai	Mitsubishi
BMW	Infiniti	Nissan
Buick	Jaguar	Porsche
Cadillac	Jeep	Ram
Chevrolet	Kia	Scion
Chrysler	Land Rover	Smart
Dodge	Lexus	Subaru
Fiat	Lincoln	Toyota
Ford	Mazda	Volkswagen
GMC	Mercedes-Benz	Volvo

Note: Data come from Networked Insights.

Appendix B - Robustness

In this appendix, we first show that our treatment of Mini as a non-German make in the baseline specification does not drive our results. Next, we document that the results are very similar to the baseline, when we use different control groups, and in a number of alternative econometric specifications.

B.1 Classification of Mini

Table B.1: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group, Robustness – Mini

Dependent Variable Treatment of Mini	12-month Log Sales Growth		
	Baseline (non-German)	Exclude	Include as German
	(1)	(2)	(3)
German \times Post-Scandal	-0.104 (0.035)	-0.105 (0.035)	-0.111 (0.034)
Time Fixed Effects	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes
R ²	0.292	0.294	0.293
N	2150	2082	2150

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant, make and time fixed effects, and are weighted by the square root of sales volumes. Data come from Ward’s Automotive.

In our country classification of car makes, we include Mini—a company with historical roots in Britain that is now owned by BMW—as a non-German make. Our classification is supported by BMW board member Peter Schwarzenbauer, who told Reuters in a 2017 interview that the “brand being perceived as British, that’s important... Most people don’t know where the cars are produced” (Pitas (2017)). This focus on the country of brand association rather than the country of production or ownership drives our baseline classification choice. Nonetheless, we show here that this choice does not impact our results. Column (2) of table B.1 excludes Mini from the analysis altogether; the resulting estimate of a 10.5 percentage point decline in non-VW German car sales growth hardly changes

from the baseline. Classifying Mini as a German make through its ownership by BMW in column (3) of table B.1 leads to an estimated decline of 11.1 percentage points, which is also similar to the baseline result in column (1).

B.2 Alternative Control Groups

Our baseline estimates of the scandal’s spillovers use all non-German makes as the control group. Here, we vary the control group along two dimensions to investigate the stability of our baseline results. First, we partition the control group along one specific country-of-origin dimension, and then along a “more or less expensive”-dimension.

Column (2) of table B.2 shows that using only foreign automakers as the control group (i.e., excluding U.S. makes altogether) leads to a growth decline estimate of 12.0 percentage points for non-VW German car makers. Using only U.S. makes as the control group (i.e., excluding non-U.S. non-German makes altogether), we find a 8.8 percentage point decline in column (3). These estimated effects are both similar to the baseline result of a 10.4 percentage point decline in column (1).

Table B.2: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group
Robustness – Control Group, Country

Dependent Variable	12-month Log Sales Growth		
	Baseline	non-German	U.S.
	(non-German)	non-U.S.	
Control Group Makes	(1)	(2)	(3)
German Manuf. × Post-Scandal	-0.104 (0.035)	-0.120 (0.036)	-0.088 (0.040)
Time Fixed Effects	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes
R ²	0.292	0.313	0.360
N	2150	1402	952

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant, make and time fixed effects, and are weighted by the square root of sales volumes. Data come from Ward’s Automotive.

We next split the control group into more and less expensive non-German makes in table B.3. To construct the two control groups, we first calculate a sales-weighted average of the MSRPs across models for each make in 2015. We then partition the makes by whether their average MSRP is above or below the median non-German average MSRP, approximately \$33,000. The treatment group continues to be defined as the three non-VW German automakers. Smart’s average MSRP is below \$33,000, while BMW’s and Mercedes-Benz’s are above. For comparison, VW’s average MSRP is also below the median. When the control group consists of the more expensive makes, as in column (2), we estimate an 8.2 percentage point decline in the sales growth of non-VW German makes. When the control group consists of the less expensive makes, as in column (3), we estimate an 11.3 percentage point decline. These estimated declines narrowly span our baseline estimate of a 10.4 percentage-point decline that we report in column (1).

Table B.3: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group
Robustness – Control Group, Price

Dependent Variable	12-month Log Sales Growth		
	Baseline (non-German)	More Expensive non-German	Less Expensive non-German
Control Group Makes	(1)	(2)	(3)
German Manuf. × Post-Scandal	-0.104 (0.035)	-0.082 (0.037)	-0.113 (0.036)
Time Fixed Effects	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes
R ²	0.292	0.318	0.311
N	2150	1098	1210

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant, make and time fixed effects, and are weighted by the square root of sales volumes. Data come from Ward’s Automotive.

B.3 Alternative Econometric Specifications

We show here that our difference-in-differences estimates are not sensitive to several alternative econometric specifications. Throughout the paper, we have weighted obser-

vations by the square root of the make’s monthly sales volume. Column (2) of table B.4 shows that our choice to weight the observations leads to a conservative estimate of the spillovers: the unweighted estimate of the sales growth decline is 15 percentage points. Moreover, instead of natural log-differences, in column (3) we consider mid-point growth rates, where the change in sales volume between period t and period $t - 12$ is divided by the average level of sales of the two periods. The estimated effect of the scandal on the German auto manufacturers under this alternative measure is a 10.6 percentage point decline in the sales growth rate, which is similar to the baseline result in column (1). Finally, column (4) shows that including make-specific linear time trends in addition to the make and time fixed effects of the baseline specification again yields a similar result.

Table B.4: U.S. Light Vehicle Sales Growth
German vs. Non-German Manufacturers, Excl. VW Group, Robustness – Econometrics

Dependent Variable Specification	12-month Log Sales Growth			
	Baseline	Unweighted	Mid Point	Make-specific Trends
	(1)	(2)	(3)	(4)
German Manuf. \times Post-Scandal	-0.104 (0.035)	-0.150 (0.057)	-0.106 (0.035)	-0.112 (0.044)
Time Fixed Effects	Yes	Yes	Yes	Yes
Make Fixed Effects	Yes	Yes	Yes	Yes
Make-Specific Linear Time Trends	No	No	No	Yes
R ²	0.292	0.130	0.310	0.397
N	2150	2150	2150	2150

Note: Unit of observation is vehicle make-month. Time period covered is January 2011 to August 2016. Standard errors clustered at vehicle make level in parentheses. Volkswagen Group (Volkswagen, Audi, and Porsche) excluded from all regressions. Volkswagen emissions scandal dated September 18, 2015. Sales are measured in units sold. All regressions include a constant and are weighted by the square root of sales volumes. Regressions in columns (1) through (3) include make and time fixed effects. The regression in column (4) includes, in addition, make-specific linear time trends. Data come from Ward’s Automotive.