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**Department of Economics**

Willingness to Pay for Brand Reputation:  
Lessons from the Volkswagen Diesel  
Emissions Scandal

Xiaogang Che<sup>1</sup>  
City, University of London

Hajime Katayama  
Waseda University

Peter Lee  
J.P. Morgan (New York)

**Department of Economics**  
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<sup>1</sup> Corresponding author: Xiaogang Che, Department of Economics, City, University of London, Northampton Square, London EC1V 0HB, UK.  
Email: [xiaogang.che@city.ac.uk](mailto:xiaogang.che@city.ac.uk)

# Willingness to Pay for Brand Reputation: Lessons from the Volkswagen Diesel Emissions Scandal\*

Xiaogang Che<sup>†</sup>      Hajime Katayama<sup>‡</sup>      Peter Lee<sup>§</sup>

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## Abstract

In this study, we use the announcement of the Volkswagen emissions scandal on September 18, 2015, as an exogenous shock to measure consumers' willingness to pay (WTP) for brand reputation. Only Volkswagen diesel cars produced in 2009-2015 were announced as emissions violators. Using eBay car auction data, we estimate the impacts of the scandal on the prices of Volkswagen emissions *non-violating* cars. Our difference-in-differences estimates show that final bid prices decreased by 14% and 9% in diesel and gasoline car markets, respectively, which purely reflected a decline in consumers' WTP for Volkswagen's brand reputation. Additionally, the difference in price-drops between the violating and non-violating diesel cars is statistically insignificant. This may be due to the fact that consumers rationally adjust their WTP by expecting compensation which will almost surely be provided by Volkswagen for violating models.

**Keywords:** Volkswagen emissions scandal, willingness to pay, brand reputation.

**JEL codes:** D12, L62.

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<sup>†</sup>City, University of London, UK. E-mail: chexiaogang0925@gmail.com.

<sup>‡</sup>Waseda University, Japan. E-mail: hajime.katayama@waseda.jp.

<sup>§</sup>J.P. Morgan (New York), USA. E-mail: Peter.Lee@jpmchase.com.

# 1 Introduction

Brand reputation, which reflects consumers' view of a firm and affects how much they are willing to pay for its products, is a valuable intangible asset for the firm, especially when information asymmetry exists in markets. Briefly, a positive brand reputation helps the firm establish trust with consumers, which is likely to result in increasing the firm's sales and revenue. A negative brand reputation of the firm, on the other hand, is likely to cause consumers to be hesitant about purchasing the firm's goods and services. In the last two decades, a large body of research in marketing literature has offered discussion on brand reputation and its relevant management, see Keller and Lehmann (2006).

Despite this important recognition, it is difficult, if not impossible, to measure the value of brand reputation – in particular, whether and how much a consumer is willing to pay for a firm's reputation – as reputation is not tangible like the quality or design of a good (Ailawadi et al., 2003; Goldfarb et al., 2009; Luo et al., 2013). This study serves as one of the few attempts to address consumers' willingness to pay (WTP) for a firm's brand reputation by using data on eBay second-hand car auctions. eBay provides a centralized marketplace for buyers and sellers to trade their items. The advantage of using eBay auction data is that the auction mechanism is second-price (ascending English), where it is a weakly dominant strategy for buyers to bid their true values. Hence, transaction prices in the auctions give us a direct measure for consumers' WTP.

In particular, this study examines whether and to what extent the Volkswagen diesel emissions scandal in September 2015 influenced consumers' WTP for Volkswagen cars that are identified as emission standard non-violating models by the United States Environmental Protection Agency (EPA), which purely reflects changes in valuation of Volkswagen's brand reputation. In 2009, a new emissions standard for diesel cars, called Tier 2, was fully adopted in the U.S. car market, requiring that all car manufacturers meet the emissions limits. On September 18, 2015, the EPA publicly announced that Volkswagen had installed emissions-compliance "defeat device" software in their diesel models produced from 2009 to 2015 to help them pass the standard laboratory tests. As there was no prior warning for the scandal, the EPA's announcement was a surprise to the U.S. car market. Exploiting this exogenous shock as a natural experiment, our study focuses on estimating the impact of the scandal on consumers' bidding

behavior (and the final price) for non-violating Volkswagen cars at the individual transaction level and thereby sheds light on a causal relationship between consumers' WTP and the firm's reputation.

Another important feature of this study is that we measure differentials in consumers' WTP for the brand reputation of Volkswagen in accordance with vehicle types and model years. When a seller lists a car in an eBay auction, detailed information about the car is provided, including the make, model year, and mileage. This allows us to examine how consumers adjust their WTP for Volkswagen cars in different conditions, that is, those equipped with and without emissions-compliance defeat device software, and those with different fuel types (either diesel or gasoline) and different model years. These differences will help us further understand how and to what extent consumers tailor WTP as their responses to the same market information across differentiated products and different markets.

For analysis, we split cars into four broad categories: Diesel cars in model years 2000-2008 and model years 2009-2015, and gasoline cars in model years 2000-2008 and model years 2009-2015. Following the EPA's announcement, the Volkswagen diesel cars in model years 2009-2015 were announced as the emissions violators. So we call the diesel cars in model years 2009-2015 the violating category, and others the non-violating categories. Our estimation analysis focus on the non-violating categories. We use a difference-in-differences (DID) approach for each category of the non-violating models, where the treatment group consists of Volkswagen cars and the control group consists of other manufacturers' cars.

Our DID results show that Volkswagen non-violators also experienced a significant decline in final bid prices. Specifically, the final prices of Volkswagen diesel cars in model years 2000-2008 dropped by around 14 percent on average, while a 9 percent decrease was found for their gasoline cars in model years 2000-2008 and 2009-2015. For these non-violating categories, Volkswagen diesel cars experienced a larger drop in price than the equivalent gasoline cars, suggesting that diesel and gasoline models are different markets and have different reputations. These changes in price purely reflect a lowered WTP for the brand reputation of those cars, to the extent that the quality of non-violating cars remains unaffected by the scandal. These results stress the importance of taking consumers' responses into account in the development and

management of brand reputation for firms.

We further conduct several robustness checks to show that our empirical findings are not driven by bidders' entry and bidding times and sellers' listing strategies before and after the emissions scandal. Finally, we discuss the violating category, that is, the diesel cars in model years 2009-2015. As expected, the emissions scandal was also found to have negatively influenced the final bid prices of Volkswagen violating diesel cars. One would further expect a large drop in price for the violating category. However, surprisingly, the point estimate exhibits a 10.8 percent decline; this is smaller than that for Volkswagen non-violating diesel cars, although the difference between the two categories is not significant. This may be because consumers rationally adjusted their WTP for the violating models in anticipation of compensation provided by Volkswagen in the future.

The remainder of this paper proceeds as follows. Section 2 gives a related literature review. Sections 3 and 4 describe the background of the Volkswagen diesel scandal event and the eBay car auction data. In Section 5, we conduct the main empirical analysis. Section 6 concludes the study.

## 2 Literature Review

In this section, we briefly review related studies on the measurement of brand reputation as an intangible asset and how brand reputation would affect revenues of sellers (firms). Thereafter, we provide discussion of the impacts of manufacturer recalls.

**Brand reputation.** After the seminal studies by Klein and Leffler (1981) and Shapiro (1983), many theoretical studies have analyzed the relationship between a seller's brand reputation and transaction prices. The central finding is that a seller with a better reputation obtains a price premium.<sup>1</sup> However, in general, because of a lack of data, such an analysis is a challenging task that speaks directly to the role of brand reputation in supporting market transactions.

In recognition of brand reputations as intangible assets for firms, increased attention has been placed on understanding how to measure the valuation of the brand

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<sup>1</sup>For further theoretical analyses, see the studies by Shapiro (1982), Allen (1984), and Tadelis (1999), for example.

reputation and what are the impacts on consumers' WTP and seller revenues (Keller, 2001; Keller and Lehmann, 2006). Keller (1993) provides a conceptual model of how to build, measure, and manage the valuation of brand equity from the perspective of the individual consumer. Ailawadi et al. (2003) propose that the revenue premium a brand generates (in contrast to that of a private label product) is a simple, objective, and managerially useful product-market measure of brand equity. Goldfarb et al. (2009) consider an approach which takes into account three sources of brand equity – brand awareness, attribute perception biases, and non-attribute preference – and reveals how much each of the three sources contributes to brand equity. Amir and Lev (1996) and Barth et al. (1998) suggest using financial market performance to measure the valuation of brand reputation.<sup>2</sup>

Some empirical studies have shed light on the importance of corporate brand reputation in relation to price premium. For example, Landon and Smith (1997) provided evidence that reputation has a significant impact on consumers' WTP in that long-term reputation is more important than short-term quality movements. Using California vehicle emissions inspection data, Hubbard (2002) studied how reputational incentives work, finding that sellers (firms) have an incentive to shade their reports of the buyer's condition to increase the short-run demand for their services. Jin and Leslie (2009) examined the restaurant inspection program in Los Angeles and demonstrated that reputational incentives are effective at encouraging restaurants to maintain good hygiene. McDevitt (2011) found evidence that poor performance leads a firm to conceal its reputation.

At the same time, with the development of online markets in the last three decades, a great deal of empirical research has addressed reputation and seller revenue using data from online reputation systems. For example, Cabral and Hortaçsu (2010) examined the importance of eBay's reputation mechanism using seller histories (measured by feedback scores). Their results show that when a seller initially receives negative feedback, his or her weekly sales rate drops from a positive 5 percent to a negative 8 percent. Livingston (2005) found that sellers are strongly rewarded for the first few reports that they have behaved honestly, but marginal returns from additional reports decrease

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<sup>2</sup>The valuation of brand reputation is related to other aspects, like environmental impact, corporate social responsibility; see studies, for example, by Bhattacharya and Sen (2003), Gürhan-Canli and Batra (2004), and Luo et al. (2013).

severely. Using panel data from Taobao.com, a Chinese online shopping platform, Fan et al. (2016) found that sellers enjoy substantial returns from positive reputations.<sup>3</sup>

**Manufacturer recalls.** This study links to previous studies about the impacts of car manufacturer recalls.<sup>4</sup> Using automobile manufacturer recall data, Barber and Darrough (1996) and Rupp (2004) found significant and negative market reactions to automobile recall announcements followed by shareholder losses in stock markets. Hammond (2013) tested consumer responsiveness to large-scale product recalls caused by safety problems and found that a recall episode had negative effects in the automobile resale market that were quantitatively small, statistically indistinguishable from zero, and short lived.<sup>5</sup>

To the best of our knowledge, there are three studies on the Volkswagen emissions scandal that are closely related to ours. Bachmann et al. (2017) focused on whether collective reputation matters for firms. In particular, they found significant declines in U.S. new car sales and stock returns of other German major car manufacturers, including BMW, Mercedes-Benz, and Smart, as a result of the scandal. Ater and Yosef (2018) found that the Volkswagen emissions scandal had a statistically significant negative effect on the number of transactions involving used diesel vehicles made by Volkswagen and on their final asking prices in Israel. Strittmatter and Lechner (2018) exploited the decline in the observed quality of Volkswagen diesel cars after the disclosure of the scandal in Germany, finding that the supply of used Volkswagen diesel vehicles increased after the scandal was revealed and, further, that positive supply effects increased with the probability of manipulation.

This study differs from prior studies in several aspects. First, we address consumers' WTP at the individual transaction level by examining data from a second-price auction market. Our data cover transactions in a U.S. popular automobile market, allowing us to measure consumers' responses in the U.S., where the scandal initially happened. Second, we examine individual brand reputation, that is, the reputation of Volkswagen exclusively. We also consider collective reputation by estimating the scan-

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<sup>3</sup>Other empirical studies include those by Melnik and Alm (2002), Brown and Morgan (2006), Cai et al. (2014), Li and Xiao (2014), Jolivet et al. (2016), and Tadelis (2016).

<sup>4</sup>Some other studies have also examined the impacts of recalls of other products. See Freedman et al. (2012) for recalls of toys and children's products; Salin and Hooker (2001) for recalls of food.

<sup>5</sup>See further studies on the impacts of car manufacturer recalls by Jarrell and Peltzman (1985), Hoffer et al. (1988), Rupp and Taylor (2002), and Rhee and Haunschild (2006).



dal's impacts on other major car manufacturers. Unlike Bachmann et al. (2017), who found evidence that the scandal negatively affected the sales growth rate for German car manufacturers, we will show that the scandal did not significantly affect buyers' WTP for other major manufacturers' cars. Third, our analyses across diesel and gasoline car markets and model year groups not only capture how consumers adjust their WTP for the reputation of different cars from the same brand, but also shed light on how consumers rationally respond to a recall event, almost surely anticipating compensation by the firm afterward.

### 3 Background

**Volkswagen diesel emissions scandal.** Volkswagen Group is a German car manufacturer and one of the largest automobile makers in the world, encompassing European car brands that include Audi, Bentley, Bugatti, Lamborghini, Porsche, SEAT, Skoda, Volkswagen, etc. In 2015, the group produced 10.41 million cars with total revenue of 217.267 billion Euros and ranked second behind Toyota in terms of revenue. Their market share in the U.S. is relatively small, about 3.4 percent, compared to other major manufacturers, such as GM (17.3 percent), Ford (14.8 percent), Toyota (14 percent), and Honda (9.3 percent).<sup>6</sup>

The United States EPA announced in 1999 that Tier 2 emissions standards would be gradually implemented from 2004 to 2008 and fully in effect from 2009 on to enforce tighter emissions limits.<sup>7</sup> In 2007, Volkswagen suspended sales of their diesel cars in the U.S. while developing technologies to meet the Tier 2 requirements. In the following year, the group announced new clean diesel car models that satisfy Tier 2 as well as European emissions standard Euro 5. Thereafter, Volkswagen diesel car sales in the U.S. market rebounded, and the group won the Green Car of the Year Award for the 2009 Jetta TDI and 2010 Audi A3 TDI.

In 2013, researchers at the Center for Alternative Fuels Engines and Emissions (CAFEE) at West Virginia University were appointed by the International Council on Clean Transportation (ICCT) to conduct emissions testing for the purpose of investigating real-

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<sup>6</sup>[www.statista.com/statistics/249375/us-market-share-of-selected-automobile-manufacturers](http://www.statista.com/statistics/249375/us-market-share-of-selected-automobile-manufacturers).

<sup>7</sup>Tier 2 emissions standards were phased out and replaced by Tier 3 emissions standards over the period from 2017-2025.

world operating emissions from European-based diesel cars sold in the United States. Three tested diesel vehicles, a VW Passat, a VW Jetta, and a BMW X5, certified to the Tier 2 standard in the laboratory tests, were found to have exceeded the standard in real-world driving conditions: NO<sub>x</sub> emissions were exceeded by a factor of 15 to 35 for the Jetta and by a factor of 5 to 20 for the Passat, and BMW had emissions at levels up to 10 times the standard in rural uphill driving conditions though the vehicle was generally at or below the standard (CAFEE, 2014; ICCT, 2015).

The results were presented to the EPA, which conducted further testing to formally investigate Volkswagen diesel car emissions. After a year-long investigation, the EPA concluded that Volkswagen had installed on some of their diesel cars emissions-compliance “defeat device” software, which is designed to activate only when the cars are undergoing emissions testing. For this conduct, Volkswagen was issued a Notice of Violation of the Clean Air Act on September 18, 2015. Affected vehicles were approximately 590,000 model year 2009 to 2015 diesel cars which were sold in the U.S., mainly under the sub-brands of Volkswagen and Audi as well as some Porsche Cayenne models.<sup>8</sup> In the first business day after the announcement (September 21, 2015), the stock price of Volkswagen Group declined by around 20 percent, and it declined by another 17 percent on the following day. On April 21 and October 25, 2016, the group announced a compensation and buyback plan for the owners of those cars, with the owners to get from 5,000 to 10,000 dollars as individual compensation in the United States. In January 2017, Volkswagen agreed to plead guilty to criminal charges and to an Agreed Statement of Facts stating that because their diesel cars failed to pass federal emissions tests, they developed the device and deliberately sought to conceal its use. On April 21, 2017, the group was issued a 2.8-billion-dollar criminal fine by the U.S. Justice Department for cheating on the emissions tests.

The Volkswagen diesel emissions scandal provides a great opportunity to explore the research questions – whether and to what extent consumers are willing to pay for a firm’s reputation – that we attempt to answer in this study. First, although the EPA’s investigation took a whole year, the whole investigation procedure and results were not announced publicly until September 18, 2015. Therefore, it is very unlikely that individual buyers and sellers knew about the emissions scandal and adjusted their behavior accordingly before the announcement day. This is also consistent with our

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<sup>8</sup><https://www.epa.gov/vw/learn-about-volkswagen-violations>.

placebo tests in Section 5.2. Second, following the announcement by the EPA, only certain models of Volkswagen cars, i.e., diesel cars in model years 2009-2015, were identified as emissions violators. This clear-cut announcement gives an advantage when we explore the impacts of the emissions scandal on Volkswagen non-violating models, as it excludes other factors which may also potentially affect consumers' WTP after the scandal event, such as the possibilities of higher running costs and potential compensation from Volkswagen. Thus, if any price drop exists in the non-violating models, it should be purely driven by reduction in consumers' WTP for Volkswagen's reputation. Third, Volkswagen produces both diesel and gasoline cars across different model years. This feature enables us to examine the differences of changes in consumers' WTP for the same brand with differentiated productions when the emissions scandal happened.

**eBay car auction market.** As one of the world's largest online marketplaces, eBay provides a centralized platform for sellers and buyers. The eBay car auction market, also called eBay Motors, is a web-based marketplace launched in 2000 for dealers and car owners to sell cars, mainly second-hand. The marketplace has experienced a rapid development in the last two decades. Their total gross merchandise volume in 2009 was over 14 billion U.S. dollars, and the market is considered the biggest force in online automobile sales in the United States.

The standard eBay auction format is a variant of a second-price auction with a specified ending time. The fixed ending time is pre-specified by sellers, with the option of a certain number of days. eBay also provides other options that enable sellers to customize their listings. An optional starting price, for example, plays the same role as a public reserve. A secret reserve can also be set, and bidders are informed about whether it has been met during the period of bidding competition. If the final auction price is less than the secret reserve, the seller does not need to commit to the transaction. Sellers can also choose delivery methods for the auction listing, mainly regarding who should pay for the delivery fees. After the auction listing becomes active, bidders submit their bids. When the auction ends, the bidder with the highest bid wins the object, but only pays the maximum between the second highest bid and the starting price. If the auction has a secret reserve price, the second highest bid should be greater than the secret reserve price; otherwise, the seller does not need to commit to the sale.

Further, the seller is required to provide some standardized information in the listing, including the make of car, body type, mileage traveled, and production year as well as whether the seller is a professional dealership. The seller may choose to add more details in the item description by using text, photos, and graphs. eBay may charge fees for posting additional information above a certain limit. For example, if a seller wants to upload more than a certain number of photos, it costs \$0.15 per each additional photo.

eBay's online auction markets are particularly suitable to estimate the impact of the scandal on consumers' WTP for Volkswagen's brand reputation, because transaction prices as well as the bidding records of all bidders are observable. In most existing studies, the prices being compared are typically fixed prices rather than transaction prices, which makes it difficult (and sometimes impossible) to identify the impacts of an event on the variability of transaction prices. In addition, the eBay motor market is sufficiently large and active; it includes almost all car brands and is one of the most popular car sales platforms in the United States. Furthermore, each listing is required to provide detailed information, which allows us to use extensive controls in our regressions. For example, sellers' eBay IDs and geographical locations can be observed. Those advantages help us eliminate the possibility of the main findings arising from idiosyncratic characteristics of particular car brands, potential buyers, and sellers, which may induce systematic differences among auction listings.

## **4 Data and Summary Statistics**

Our data comprise information on successfully sold car auction listings on the U.S. eBay Motors website between November 2014 and August 2016. Each listing contains characteristics of the car (make, body type, age, mileage, and production year) and characteristics of the auction listing (start price, listing duration, number of photos, whether the auction has a secret reserve price, and who pays the shipping fees after the transaction). Other listing information was also available for this study, including the seller's username on eBay, feedback score, and geographical location (state level), the number of bidders, the number of bids, and the start/end time of the listing.

We make several sample restrictions before conducting our analysis. We first ex-

clude observations with an unclear setting or missing data for the listing characteristics, i.e., no information on make, mileage, and/or model year, and we only use listings of either diesel or gasoline fueled cars. We also eliminate listings for cars produced before 2000, thereby focusing on cars with reasonable values and avoiding antique cars intended for collections. In addition, we drop observations where the car is broken but some parts are available for sale. Also eliminated are listings in which vehicles are not comparable to Volkswagen's products in the U.S. car market (e.g., heavy trucks).

Insert Table 1 about here

Summary statistics of the whole sample utilized for our analyses are presented in Table 1. In total, we have 49,497 successfully sold car auction listings. The average car age and mileage are 10.8 years and 108,829.7 miles, respectively, implying that the cars in the sample tend to be well used. On average, a car is listed on the site with 12.6 photos for around 6.4 days, attracting 8.8 bidders in the bidding competition. About 96.6 percent of the auction listings require the winners to pay the shipping costs. The average start price and final price are 2,389.7 dollars and 9,235.1 dollars, respectively. Around 24.3 percent of listings set secret reserves; since the value of a secret reserve is not observable, we set the secret reserve dummy equal to one if the auction listing has a secret reserve; otherwise, zero. The average seller feedback score is 1,119, indicating that most sellers are well experienced and familiar with the rules in the marketplace. Overall, compared to gasoline cars, diesel cars occupy a smaller proportion, around 7 percent; there are 3,572 and 45,925 listings for diesel and gasoline cars, respectively.

Table A1 in the Appendix presents summary statistics for Volkswagen and non-Volkswagen cars with different fuel types (diesel and gasoline). On average, the start and final prices for Volkswagen cars are lower than those of non-Volkswagen cars; in the diesel (gasoline) car market, the average final prices for Volkswagen and non-Volkswagen cars are 6,728 and 15,207 (4,852 and 9,068) dollars, respectively. For most variables related to the characteristics of the auction listings, the means for Volkswagen cars are similar to those of non-Volkswagen cars in both diesel and gasoline car markets.

Insert Figure 1 about here

The left (right) panel of Figure 1 presents monthly average transaction prices of diesel (gasoline) cars separately for Volkswagen and non-Volkswagen. In each of the used diesel and gasoline car markets, the average transaction price of Volkswagen cars is found to be lower than that of non-Volkswagen cars throughout the sample period. Importantly, the prices of Volkswagen and non-Volkswagen cars seem to move in a relatively parallel manner; however, the gap in price becomes wider after the start of the scandal (i.e., September 18, 2015), especially for the diesel car market.

In Table A2 of the Appendix, we report percentage shares of all car makes in the sample. Consistent with market shares in the U.S. car market, major car manufacturers take most of the transactions in the sample; Volkswagen takes 5 percent, BMW 6.8 percent, Ford 15 percent, Toyota 6.6 percent. Figure 2 in the Appendix presents the monthly ratios of auction listings between Volkswagen and non-Volkswagen cars. Before the emissions scandal announcement, the ratio is around 5.5 percent. Although the ratio decreases by around 1 percent after the announcement, it bounces back to almost the same level as before after November 2015.

Overall, these data descriptions indicate that our following estimation results are unlikely to be biased by heterogeneity in the auction characteristics and selection in the car manufacturers. In Section 5.2, we show that our main findings still hold when including different composition of car manufacturers in the control group and considering different optional choices that a seller can choose in the auction listing.

## 5 Empirical Analyses

### 5.1 Measuring WTP for brand reputation

To estimate the impacts of the Volkswagen emissions scandal in the determination of WTP, we use the following difference-in-differences specification.

$$\ln(P_{it}) = \beta_0 + \beta_1 Scandal_t + \beta_2 Volkswagen_i + \beta_3 Scandal_t \times Volkswagen_i + Controls_{it} + \varepsilon_{it}, \quad (1)$$

where  $i$  indexes a specific auction listing and  $t$  indexes the ending time of the auction. The dependent variable,  $\ln(P_{it})$ , is the natural logarithm of the final price for the auc-

tion listing.  $Scandal_t$  is a dummy variable that equals one if the ending time is after the EPA's announcement for Volkswagen violations, capturing aggregate factors that would cause a change in the price even in the absence of the scandal.  $Volkswagen_i$  is also a dummy variable that equals one if the car brand is Volkswagen, accounting for possible differences between the treatment group (Volkswagen cars) and control group (other manufacturers' cars). The interaction term  $Scandal_t \times Volkswagen_i$  becomes one for Volkswagen cars after the EPA's announcement, and its coefficient  $\beta_3$  measures by how much buyers' WTP varied before and after the EPA's announcement (i.e., when the scandal was revealed).

In equation (1), *Controls* include observable variables of the characteristics of the car and of the auction listing, specifically, the natural logarithm of car age, the natural logarithm of mileage, the number of photos, the natural logarithm of the seller feedback score, who pays shipping costs (a dummy variable that equals one if the winner pays for shipping), the natural logarithm of start price, the secret reserve dummy, the listing duration, the number of entering bidders, the year fixed effects, the month fixed effects, and the body-type fixed effects. We also include the seller-identity fixed effects and the car-make fixed effects to control for unobserved heterogeneity in sellers as well as in car manufacturers. For statistical inference, we use robust standard errors clustered at the seller identity level.

We first examine diesel cars. As mentioned earlier, not all diesel cars made by Volkswagen are emissions violators; those in model years 2009-2015 were announced by the U.S. EPA as emissions violators, while those in model years 2000-2008 were not. This raises the possibility that the scandal influenced the prices of Volkswagen diesel cars in different manners, depending on whether or not they are emissions violators.

To account for this possibility, we split the sample into two sub-samples based on model year; the first sub-sample consists of diesel cars in model years 2000-2008, while the second consists of diesel cars in model years 2009-2015. This sample split allows us to provide insights into how the emissions scandal influenced the final prices of Volkswagen diesel cars. In particular, using the first sub-sample, where the treatment group consists of Volkswagen non-violating diesel cars, we can avoid potential costs associated with the uncertainty surrounding the usefulness of the violating models and buyers' expectations of compensation by Volkswagen, and precisely identify the

effect of the scandal on WTP for Volkswagen's brand reputation. If consumers were fully aware of emissions violators due to the EPA's announcement, a fall in the price of a Volkswagen non-violating diesel car after the announcement reflects a decrease in WTP for its brand reputation, to the extent that the quality of the car remained unchanged by the scandal.

Insert Table 2 about here

The DID results for the first sub-sample are presented in Columns (1) to (3) of Table 2. As presented in Column (1), the coefficient of the interaction term is found to be negative and significant at the ten percent level, indicating that WTP for Volkswagen diesel cars was negatively affected by the emissions scandal. When we further include the seller-identity fixed effect and the car-make fixed effect, the significance of the coefficient is not affected. In Column (3), the point estimate exhibits a decline in price by about 14 percent, suggesting that the impact of the emissions scandal is economically significant on consumers' WTP for Volkswagen's brand reputation.

We next examine gasoline cars in the sample. This analysis allows us to address whether and how the scandal surrounding diesel cars affected Volkswagen's brand reputation in the gasoline car market. To provide further insights into impacts of the scandal, we split the sample of gasoline cars into two sub-samples in the same manner as before; the first (second) sub-sample consists of those in model years 2000-2008 (2009-2015). By doing so, we can make a "vertical" comparison across model years to see whether the diesel scandal had different impacts on WTP within Volkswagen gasoline models, as well as making a "horizontal" comparison across Volkswagen diesel and gasoline model years 2000-2008 (keeping model years fixed). Of note is that in the same model period, the external and internal designs are very similar between Volkswagen diesel and gasoline models, except for the engines.

As reported in Columns (4) and (6) of Table 2, our DID estimations show that the prices of Volkswagen gasoline cars dropped by 9 percent for model years 2000-2008. We then re-do the same estimation for the second sub-sample and present the results in Columns (7) and (9), showing that Volkswagen gasoline cars from model years 2009-2015 experienced a significant price drop by 9 percent after the diesel emissions scandal. These findings suggest that potential buyers downgraded Volkswagen gasoline



cars equally, irrespective of model year. The estimates reflect the extent to which the level of Volkswagen’s reputation declined in the gasoline car market. The “horizontal” comparison for model years 2000-2008 also suggests that Volkswagen’s reputation was damaged to a greater extent in the diesel car market than in the gasoline car market. This is in line with the idea that diesel and gasoline cars are in different markets and thus have different reputations even for the same brand, while reputation in one market affects that in another.

Overall, our results suggest that the scandal negatively influenced Volkswagen’s reputation for both diesel and gasoline cars. This is possibly because consumers simply do not like cars made by a manufacturer caught cheating on environmental standards or because they have established the belief that Volkswagen cars generally perform worse in terms of environmental pollution than other manufacturers’ cars.

## 5.2 Robustness checks

In this section, we perform several checks to examine the validity of our identification strategy. Thereafter, we show the robustness of our main findings after considering buyers’ and sellers’ behavior.

**Placebo tests.** Our identification strategy is based on the key assumption that there was no prior warning of the emissions scandal. One might question the validity of this assumption, because related research on emissions violations actually started in 2013, as mentioned in Section 3, raising the possibility that consumers anticipated and responded to the scandal even before the EPA publicly announced the test results. To check the credibility of the assumption, we conduct a placebo test by pretending that the EPA’s announcement was made earlier than the actual date (i.e., September 18, 2015) and then measuring the final bid prices after the artificial announcement but before the announcement was actually made. If we obtain evidence for the scandal effect with this artificial announcement, it would suggest that the scandal was anticipated by consumers and had an effect even before it was revealed.

Insert Table 3 about here

For this purpose, we set the artificial announcement date to be July 18, 2015 and then estimate equation (1) using only observations before September 18, 2015. The

result for diesel cars in model years 2000-2008 is presented in Column (1) of Table 3; the DID estimate is found to be statistically insignificant at the ten percent level. We further examine the gasoline models, and similar results - neither of the DID estimators is statistically significant - are obtained for gasoline cars in model years 2000-2008 and 2009-2015, as presented in Columns (2) and (3), respectively. These results suggest that the announcement of the emissions scandal on September 18, 2015 is as good as random and generates exogenous variations in consumers' WTP. One could argue that the results are driven by the fact that we include other German car manufacturers and other Volkswagen sub-brands in the control group. In Columns (4)-(6), we show that these results are robust to the exclusion of cars made by other German car manufacturers from the sample and to the further exclusion of cars made by other sub-brands of the Volkswagen group (Columns (7)-(9)).

We conduct another placebo test to further examine the relevance of our identification strategy. Here, we estimate equation (1) by pretending that the treatment group consists of cars made by a manufacturer other than Volkswagen; if our identification strategy is sound, the scandal effect should not be detected for this artificial treatment group. For this test, we first select General Motors Corporations (GMC) for an artificial treatment group. As reported in Columns (1)-(3) of Table A3, the DID estimates are not statistically significant at the ten percent level, regardless of the fuel type or model year that we examine. The same tests repeated for Mercedes-Benz provide similar results (Columns (4)-(6)).<sup>9</sup> Overall, our identification strategy seems to be sound in that it does not falsely detect the scandal effect for manufacturers other than Volkswagen.

Since the pioneer work by Tirole (1996), collective reputation, which can be interpreted as a reputational externality affecting individual group members' incentives (payoffs), has been studied broadly.<sup>10</sup> The results we obtained can also be interpreted as indicating that buyers did not adjust their WTP for collective reputation in the car market as a consequence of the emissions scandal. Our results are in contrast to those obtained by Bachmann et al. (2017), who found significant declines in the U.S. sales and stock returns of other German car manufacturers as a result of the scandal.

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<sup>9</sup>We also estimate the same models for the auction listings with Toyota and Honda cars. The results show that the final prices are not significantly associated with the interactions of the emissions scandal dummy with brand dummies.

<sup>10</sup>See related empirical studies by Landon and Smith (1997) and Castriota and Delmastro (2015), for example.

**The composition of the control group.** Here we examine whether our main findings are robust to the composition of the control group. We first address the concern that other sub-brands of the Volkswagen group or other German car manufacturers may not be relevant members of the control group, because they might have been influenced by the scandal due to some similarity to Volkswagen (i.e., belonging to the same group or originating from the same country). For this purpose, we exclude from the control group other sub-brands of the Volkswagen group<sup>11</sup> and other German car manufacturers. This exclusion does not affect our main findings, however, as presented in Table 4.

Insert Table 4 about here

We also test whether our main findings are driven by including in the control group manufacturers for which there are a small number of transactions, as one would argue that the impacts of the emissions scandal on prices are amplified after including those car manufacturers which take relatively small market shares and are not comparable to Volkswagen in the U.S. car market. To do so, we re-estimate equation (1) by excluding those manufacturers with fewer than 100 transactions in the sample or by keeping only those manufacturers that occupy no less than one percent of all transactions. The results are virtually the same as those main findings in Table 2 (we present the estimation results in Table A4 of the Appendix), further demonstrating the robustness of our main findings.

**Buyer behavior.** It is possible that the scandal effects were not stable over time. In particular, they might have been large for a short period of time and then become smaller or even disappeared; if this is the case, our DID estimates of the scandal effects may be misleading. To examine this possibility, we reestimate equation (1) by excluding from the sample all transactions made on September 18, 2015 (i.e., when the EPA made the announcement). As reported in Columns (1)-(3) of Table 5, the results show that our main findings are not significantly affected by this exclusion. Similar results emerge even when we further exclude transactions made within a week before and after the EPA's announcement (Columns (4)-(6)). These results suggest that the scandal

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<sup>11</sup>For our analysis, sub-brands of the Volkswagen group only include Audi, Bentley, and Porsche, because there are no observations in our sample for the other sub-brands such as SEAT, Skoda, and Bugatti.

provided a relatively long-term impact on buyers' preference and WTP for Volkswagen's brand. This is in contrast with the relatively short-term impact on Volkswagen's stock price in the financial market, mentioned in Section 3.

Insert Table 5 about here

We have thus far interpreted our DID estimates as indicating changes in consumers' WTP for Volkswagen's brand reputation before and after the scandal was revealed. One might be concerned about this interpretation, however, because changes in equilibrium final prices can result from changes in bidders' bidding behavior, such as more entries by bidders and/or more bids submitted by each bidder. To address this issue, we set the natural logarithm of the number of bidders for each listing to be the dependent variable in equation (1) and thereby examine whether the number of bidders changed before and after the scandal was revealed.

Insert Table 6 about here

As presented in Columns (1)-(3) of Table 6, the coefficients of the interaction term are not significant even at the ten percent level; in other words, there is no strong evidence that the scandal influenced bidders' entries. We repeat the same exercise for the natural logarithm of the number of bids for each listing (Columns (4)-(6)). According to the results, the scandal does not seem to have significantly influenced the number of bids; the coefficient of the interaction term is significant at the ten percent level only for gasoline cars in model years 2000-2008, while it is not significant for all other categories. These results rule out the possibility that buyers changed their bidding behavior after the scandal was revealed, supporting that our DID estimates of the scandal effects reflect changes in buyers' WTP for Volkswagen's reputation.

**Seller behavior.** As presented above, after the announcement of the scandal, the prices of Volkswagen emissions non-violating cars dropped significantly, suggesting that the scandal damaged Volkswagen's reputation. However, if the emissions scandal affects an auction's attributes chosen by the seller (e.g., number of photos and start price), then the drops in consumers' WTP that we have identified may be an artifact of omitting the interaction terms of the scandal dummy with the auction's attributes. To address this possibility, we estimate equation (1) by adding an interaction term of

the scandal dummy with each optional choice in the auction, namely, start price, secret reserve, number of photos, listing duration, and buyer shipping.

Insert Table 7 about here

Table 7 presents the estimation results, showing that our main empirical findings still hold at least qualitatively; in all the regressions, the final price is still negatively and significantly correlated with the interaction term of the scandal dummy with the Volkswagen brand dummy. Overall, our main results appear to be robust to including an additional interaction term of the emissions scandal dummy and an optimal choice, suggesting that the price drop in consumers' WTP for brand reputation is not driven by seller behavior.

### **5.3 Volkswagen violating diesel models**

In this subsection, we examine consumers' response to the emissions violating group - Volkswagen diesel cars in model years 2009-2015 - after the scandal announcement. As presented in Columns (1)-(3) of Table 8, the coefficient of the interaction term is found to be negative and significant at the one percent level, indicating that consumers' WTP for Volkswagen emissions violating cars was negatively affected by the emissions scandal.

Insert Table 8 about here

Somewhat surprising about the results are the point estimates. We would expect a dramatic price drop for Volkswagen emissions violating cars. However, the point estimate exhibits a decline in price by about 11 percent, while the magnitude of the decline in price for diesel non-violating models is 14 percent (Column (3) in Table 2). We further examine the difference between the two price drops; it is not statistically significant, suggesting that the impact of the emissions scandal on the diesel violating and non-violating cars is the same.

These results can be explained by the following reason. After the emissions scandal, rational consumers would have lowered their WTP to reflect Volkswagen's reputation damage and the potential costs and uncertainty surrounding the usefulness of the

emissions violating cars. But at the same time, buyers could have expected that Volkswagen would have a compensation plan after the scandal, including recall, buyback, and/or cash payment, and that only violating model owners would be eligible for compensation from Volkswagen. Therefore, although the compensation plan had not yet been announced by Volkswagen at that time, potential buyers might have anticipated it and rationally adjusted their WTP for violating models.

## 6 Concluding Remarks

On September 18, 2015, the Volkswagen emissions scandal began; the EPA accused Volkswagen of installing software known as a “defeat device” to cheat on emissions tests in the United States. Exploiting this exogenous shock and using individual transaction data from the eBay car auction market, we examined whether and to what extent the scandal influenced the final prices of Volkswagen cars.

We found a statistically significant decrease in the final prices of diesel cars that were not identified by the EPA as emissions violating models. This decrease reflects how much buyers lowered their WTP for Volkswagen’s brand reputation, to the extent that the scandal did not change the quality of non-violating cars. Our empirical findings evidently identify that brand reputation plays a non-negligible component in determining consumers’ WTP (demand) for a product. In addition, there exist price-drop differentials for Volkswagen non-violating cars; consumers’ WTP for diesel models decreased to a larger extent than for gasoline models. This suggests that consumers respond differently to adjust their WTP even for the same brand.

We also examined the group of Volkswagen’s violating diesel models, showing that it also experienced a significant decrease in final prices. However, interestingly, this price drop is not significantly different from the drop in the group of Volkswagen’s non-violating diesel models. This may be due to consumers’ expectation of compensation from Volkswagen.

Table 1: Summary Statistics - I

	Obs.	Mean	S.D	Min	Max
Auction Characteristics					
Start Price	49,497	2389.87	7049.68	0.01	439000
Final Price	49,497	9235.15	11094.35	1	599984
Seller Feedback	49,497	1119.02	3158.88	1	171320
Secret Reserve	49,497	0.24	0.43	0	1
Photos	49,497	12.56	8.46	0	24
Duration	49,497	6.44	1.67	3	10
Buyer Shipping	49,497	0.97	0.18	0	1
Number of Bidders	49,497	8.82	5.53	0	34
Car Characteristics					
Diesel	49,497	0.07	0.26	0	1
Car Age	49,497	10.85	4.21	1	17
Mileage	49,497	108829.70	122331.90	1	9999999

Figure 1: Monthly Average Transaction Prices

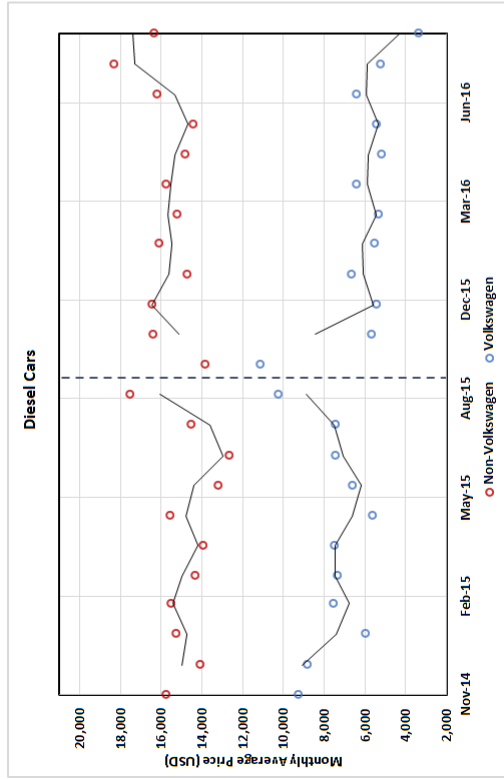
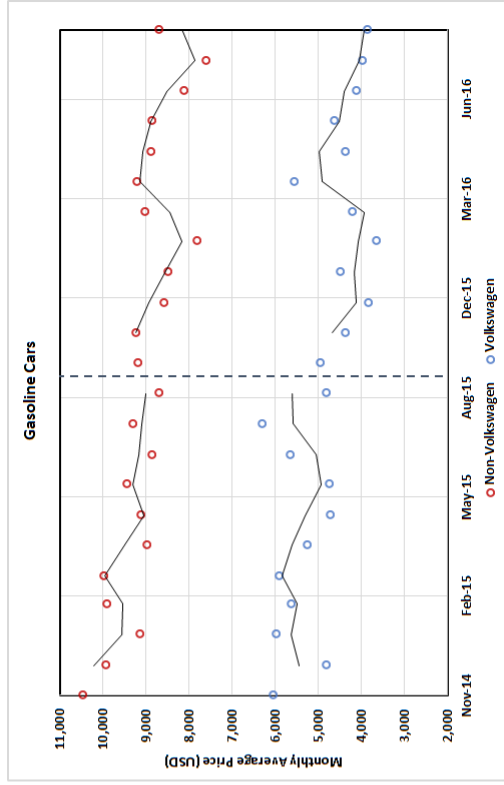




Table 2: Main results

Ln(Final Price)	Diesel 00-08		Gasoline 00-08			Gasoline 09-15			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Scandal x Volkswagen	-0.148** (0.06)	-0.148** (0.07)	-0.141** (0.06)	-0.097*** (0.03)	-0.097** (0.05)	-0.093** (0.04)	-0.109** (0.05)	-0.109** (0.04)	-0.092** (0.04)
Scandal	0.200 (0.18)	0.200 (0.13)	0.231* (0.12)	-0.016 (0.04)	-0.016 (0.04)	-0.007 (0.04)	0.016 (0.05)	0.016 (0.03)	0.009 (0.03)
Volkswagen	-0.744*** (0.06)	-0.744*** (0.07)	-0.960*** (0.11)	-0.209*** (0.02)	-0.209*** (0.04)	-0.325*** (0.04)	-0.215*** (0.04)	-0.215*** (0.04)	-0.336*** (0.04)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Body Type FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Seller FE	N	Y	Y	N	Y	Y	N	Y	Y
Make FE	N	N	Y	N	N	Y	N	N	Y
$R^2$ (within)	0.42	0.43	0.48	0.46	0.46	0.56	0.34	0.35	0.56
Obs.	2,842	2,842	2,842	33,283	33,283	33,283	12,642	12,642	12,642

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) to (3) are diesel cars, and Columns (4) to (9) are gasoline cars. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 3: Robustness Check - Placebo Test on the Identification Strategy

Ln(Final Price)	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Gasoline
	00-08 (1)	00-08 (2)	09-15 (3)	00-08 (4)	00-08 (5)	09-15 (6)	00-08 (7)	00-08 (8)	09-15 (9)	
Scandal x Volkswagen	0.148 (0.11)	0.022 (0.07)	-0.064 (0.06)	0.141 (0.11)	0.014 (0.07)	-0.058 (0.06)	0.141 (0.11)	0.012 (0.07)	-0.062 (0.06)	
Scandal	-0.2 (0.13)	-0.169 (0.11)	0.15 (0.12)	-0.126 (0.15)	-0.170* (0.10)	0.125 (0.12)	-0.126 (0.15)	-0.180* (0.10)	-0.053 (0.05)	
Volkswagen	-1.202*** (0.34)	-0.359*** (0.05)	-0.396*** (0.08)	-1.065*** (0.34)	-0.346*** (0.05)	-0.398*** (0.08)	-1.065*** (0.34)	-0.344*** (0.05)	-0.389*** (0.08)	
$R^2$ (within)	0.58	0.57	0.55	0.58	0.55	0.54	0.58	0.54	0.53	
Obs.	407	5,201	1,908	386	4,488	1,676	386	4,232	1,582	

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (4) to (6) exclude other German manufacturers, and Columns (7) to (9) exclude other German manufacturers and other sub-brands in Volkswagen group. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 4: Robustness Checks - Excluding Volkswagen Sub-brands and Other German Car Manufacturers

Ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
Scandal	-0.148**	-0.095**	-0.106**	-0.154**	-0.098**	-0.096**
x Volkswagen	(0.07)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	0.20	-0.009	0.004	0.163	-0.012	0.013
	(0.13)	(0.04)	(0.03)	(0.14)	(0.04)	(0.03)
Volkswagen	-0.740***	-0.193***	-0.189***	-0.926***	-0.319***	-0.342***
	(0.07)	(0.04)	(0.04)	(0.11)	(0.04)	(0.04)
$R^2$ (within)	0.43	0.45	0.35	0.49	0.55	0.56
Obs.	2,841	31,706	12,056	2,704	28,345	11,029

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) to (3) are the estimated results without Volkswagen sub-brands, Columns (4) to (6) are the estimated results without other German car manufacturers. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 5: Buyer Behavior - Excluding Transactions on the Scandal Day and One Week

Ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
Scandal x Volkswagen	-0.141** (0.06)	-0.093** (0.04)	-0.092** (0.04)	-0.143** (0.06)	-0.103** (0.04)	-0.078** (0.04)
Scandal	0.230* (0.12)	-0.01 (0.03)	0.019 (0.03)	0.099 (0.20)	-0.063 (0.07)	0.054 (0.07)
Volkswagen	-0.960*** (0.11)	-0.324*** (0.04)	-0.337*** (0.04)	-0.950*** (0.11)	-0.314*** (0.04)	-0.341*** (0.04)
$R^2$ (within)	0.48	0.56	0.56	0.48	0.56	0.56
Obs.	2,840	33,233	12,620	2,822	32,730	12,415

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) to (3) are the results in which transactions on 18 September 2015 are excluded; Columns (4)-(6) are the results where we further exclude transactions made within a week before and after the EPA's announcement. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 6: Buyer Behavior - Bidder Entry and Bidding Times

	ln(Bidders)			ln(Bids)		
	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
Scandal x Volkswagen	-0.043 (0.07)	0.05 (0.05)	0.097 (0.09)	-0.047 (0.08)	0.109* (0.06)	0.144 (0.11)
Scandal	0.115 (0.14)	0.002 (0.04)	-0.052 (0.05)	0.239 (0.21)	-0.001 (0.05)	-0.015 (0.08)
Volkswagen	-0.106 (0.09)	-0.062 (0.04)	-0.319*** (0.11)	-0.035 (0.12)	-0.064 (0.05)	-0.385** (0.15)
$R^2$ (within)	0.31	0.30	0.25	0.31	0.30	0.25
Obs.	2,842	33,283	12,642	2,842	33,283	12,642

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 7: Seller Behavior - Interactions of the Scandal and Other Optimal Choices

Ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-16 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-16 (6)	Diesel 00-08 (7)	Gasoline 00-08 (8)	Gasoline 09-16 (9)
Scandal x Volkswagen	-0.150** (0.06)	-0.094** (0.04)	-0.085** (0.04)	-0.130** (0.06)	-0.091** (0.04)	-0.088** (0.04)	-0.145** (0.06)	-0.086** (0.04)	-0.083* (0.04)
Scandal	0.261* (0.14)	0.012 (0.05)	-0.037 (0.04)	0.166 (0.12)	-0.046 (0.03)	0.015 (0.04)	0.137 (0.18)	-0.204*** (0.06)	-0.082 (0.09)
Volkswagen	-0.979*** (0.10)	-0.343*** (0.04)	-0.356*** (0.04)	-0.980*** (0.10)	-0.345*** (0.04)	-0.355*** (0.04)	-0.980*** (0.10)	-0.351*** (0.04)	-0.356*** (0.04)
ln(start price) x Scandal	-0.003 (0.01)	-0.003 (0.01)	0.007** (0.00)						
Photos x Scandal				0.005 (0.00)	0.004 (0.00)	-0.001 (0.00)			
Duration x Scandal							0.014 (0.02)	0.031*** (0.01)	0.013 (0.01)
$R^2$ (within)	0.46	0.52	0.55	0.46	0.52	0.55	0.46	0.52	0.55
Obs.	2,842	33,283	12,642	2,842	33,283	12,642	2,842	33,283	12,642

Ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-16 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-16 (6)
Scandal x Volkswagen	-0.142** (0.06)	-0.091** (0.04)	-0.086** (0.04)	-0.147** (0.06)	-0.093** (0.04)	-0.085** (0.04)
Scandal	0.226* (0.12)	-0.013 (0.03)	0.01 (0.03)	0.208 (0.18)	0.051 (0.04)	0.043 (0.07)
Volkswagen	-0.986*** (0.10)	-0.344*** (0.04)	-0.356*** (0.04)	-0.982*** (0.10)	-0.343*** (0.04)	-0.355*** (0.04)
Secret reserve x Scandal	0.045 (0.05)	0.041 (0.03)	-0.025 (0.03)			
Buyer shipping x Scandal				0.034 (0.12)	-0.057 (0.04)	-0.040 (0.06)
$R^2$ (within)	0.46	0.52	0.55	0.46	0.52	0.55
Obs.	2,842	33,283	12,642	2,842	33,283	12,642

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 8: Volkswagen Violating Diesel Cars

Ln(Final Price)	Diesel 09-15		
	(1)	(2)	(3)
Scandal x Volkswagen	-0.127*** (0.05)	-0.127** (0.06)	-0.108** (0.05)
Scandal	0.004 (0.14)	0.004 (0.06)	-0.018 (0.06)
Volkswagen	-0.665*** (0.04)	-0.665*** (0.05)	-0.545*** (0.06)
Year FE	Y	Y	Y
Month FE	Y	Y	Y
Body Type FE	Y	Y	Y
Seller FE	N	Y	Y
Make FE	N	N	Y
$R^2$ (within)	0.72	0.74	0.76
Obs.	730	730	730

Note: "09-15" denotes model years 2009 - 2015. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

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## Appendix (For Online Publication)

Table A1: Summary Statistics - II

Volkswagen	Diesel					Gasoline				
	Obs.	Mean	S.D	Min	Max	Obs.	Mean	S.D	Min	Max
Auction Characteristics										
Start Price	692	1288.00	2858.74	0.01	31000	1,856	1316.61	2753.21	0.01	29000
Final Price	692	6728.99	5170.13	405	38888	1,856	4852.17	4208.61	1.25	33500
Seller Feedback	692	528.34	1500.84	1	13022	1,856	1621.79	5326.35	1	134377
Secret Reserve	692	0.19	0.40	0	1	1,856	0.20	0.40	0	1
Photos	692	9.27	8.62	0	24	1,856	11.13	7.95	0	24
Duration	692	6.82	1.56	3	10	1,856	6.18	1.77	3	10
Buyer Shipping	692	0.97	0.17	0	1	1,856	0.98	0.15	0	1
Number of Bidders	692	9.63	5.08	0	26	1,856	8.39	5.13	0	28
Car Characteristics										
Car Age	692	10.44	3.92	2	17	1,856	11.50	3.96	1	17
Mileage	692	139492.60	70436.99	1	380101	1,856	107665.30	61995.25	1	999999
Non-Volkswagen	Diesel					Gasoline				
	Obs.	Mean	S.D	Min	Max	Obs.	Mean	S.D	Min	Max
Auction Characteristics										
Start Price	2,880	4154.75	7875.01	0.01	75000	44,069	2337.04	7144.70	0.01	439000
Final Price	2,880	15207.25	11440.99	1	208980	44,069	9068.81	11192.08	1.25	599984
Seller Feedback	2,880	501.77	1471.53	1	32599	44,069	1147.46	3129.66	1	171320
Secret Reserve	2,880	0.32	0.47	0	1	44,069	0.24	0.43	0	1
Photos	2,880	12.59	8.78	1	24	44,069	12.68	8.45	0	24
Duration	2,880	6.87	1.45	3	10	44,069	6.42	1.67	3	10
Buyer Shipping	2,880	0.96	0.18	0	1	44,069	0.97	0.18	0	1
Number of Bidders	2,880	8.60	5.31	0	32	44,069	8.84	5.57	0	34
Car Characteristics										
Car Age	2,880	11.36	3.48	1	17	44,069	10.79	4.26	1	17
Mileage	2,880	155011.90	203309	1	9999999	44,069	105379.10	117056.70	1	9999999

Table A2: All Car Manufacturers in the Sample

Make	Freq.	Percent	Cum.
Acura	596	1.2	1.2
Aston Martin	29	0.06	1.26
Audi	1,795	3.63	4.89
BMW	3,366	6.8	11.69
Bentley	44	0.09	11.78
Buick	653	1.32	13.1
Cadillac	2,125	4.29	17.39
Chevrolet	851	1.72	19.11
Chrysler	1,469	2.97	22.08
Dodge	1,655	3.34	25.42
Ferrari	29	0.06	25.48
Fiat	72	0.15	25.63
Ford	7,480	15.11	40.74
GMC	1,089	2.2	42.94
Honda	2,929	5.92	48.86
Hummer	209	0.42	49.28
Hyundai	872	1.76	51.04
Infiniti	704	1.42	52.46
Isuzu	98	0.2	52.66
Jaguar	633	1.28	53.94
Jeep	1,206	2.44	56.38
Kia	455	0.92	57.29
Lamborghini	21	0.04	57.34
Land Rover	629	1.27	58.61
Lexus	952	1.92	60.53
Lincoln	967	1.95	62.48
Lotus	21	0.04	62.53
Maserati	80	0.15	62.69
Mazda	966	1.95	64.64
Mercedes-Benz	2,945	5.95	70.59
Mercury	363	0.73	71.32
Mini	525	1.06	72.38
Mitsubishi	496	1	73.39
Nissan	2,434	4.92	78.3
Oldsmobile	77	0.15	78.46
Other	44	0.09	78.55
Plymouth	17	0.03	78.58
Pontiac	608	1.23	79.81
Porsche	346	0.7	80.51
Ram	107	0.22	80.73
Replica/Kit Makes	21	0.04	80.77
Saab	585	1.18	81.95
Saturn	385	0.78	82.73
Scion	173	0.35	83.08
Smart	120	0.24	83.32
Subaru	1,290	2.61	85.93
Suzuki	153	0.33	86.26
Toyota	3,268	6.6	92.86
Volkswagen	2,548	5.15	98.01
Volvo	987	1.99	100.00
Total	49,497	100	

Figure 2: Monthly Ratios of Volkswagen and Non-Volkswagen Listings

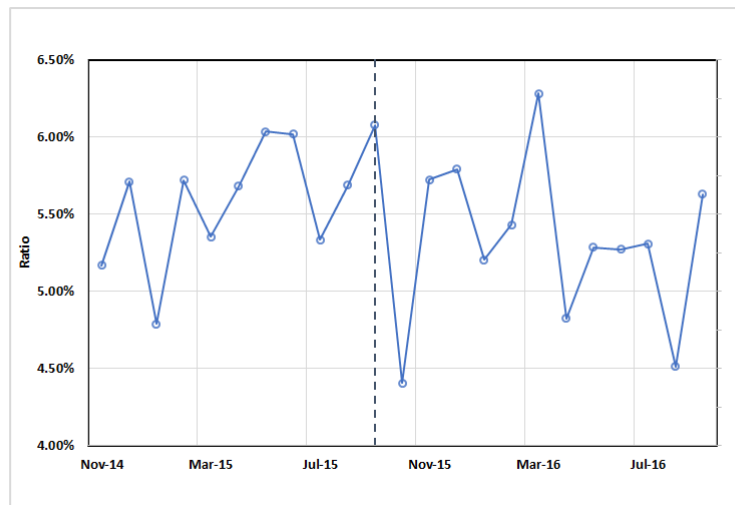


Table A3: Robustness Checks - The Impacts of the Emissions Scandal on Other Major Car Manufacturers

ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
	GMC	GMC	GMC	Mercedes	Mercedes	Mercedes
Scandal x Brand	0.083 (0.08)	0.026 (0.04)	0.095 (0.08)	-0.148 (0.11)	-0.046 (0.03)	-0.076 (0.06)
Scandal	0.287** (0.13)	-0.018 (0.04)	0.01 (0.03)	0.281* (0.14)	-0.015 (0.04)	0.021 (0.03)
Brand	0.218*** (0.06)	0.104*** (0.04)	-0.01 (0.07)	0.301*** (0.07)	0.365*** (0.03)	0.574*** (0.05)
$R^2$ (within)	0.38	0.45	0.34	0.37	0.46	0.37
Obs.	2,842	33,283	12,642	2,842	33,283	12,642

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. Year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table A4: Robustness Checks on Manufactures with Small Number of Transactions

In(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
Scandal x Volkswagen	-0.142** (0.06)	-0.091** (0.04)	-0.093** (0.04)	-0.141** (0.06)	-0.091** (0.04)	-0.093** (0.04)
Scandal	0.235* (0.12)	-0.014 (0.04)	0.015 (0.03)	0.231* (0.12)	-0.013 (0.04)	0.015 (0.03)
Volkswagen	-0.956*** (0.11)	-0.326*** (0.04)	-0.335*** (0.04)	-0.960*** (0.11)	-0.326*** (0.04)	-0.335*** (0.04)
$R^2$ (within)	0.49	0.55	0.55	0.48	0.55	0.55
Obs.	2,823	33,128	12,591	2,842	33,178	12,609

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) - (3) are the results in which a car brand with less than 100 observations is excluded; columns (4) - (6) are the results in which a car brand with less than 1% market share is excluded. Control variables are the natural log of car age, the natural log of mileage, the number of photos, the natural log of the seller feedback score, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders. The robust standard errors are clustered at the seller identity level. \*\*\*, \*\*, and \* denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.