Product-Harm Crises and Spillover Effects: A Case Study of the Volkswagen Diesel Emissions Scandal in eBay Used Car Auction Markets*

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Abstract

The Volkswagen emissions scandal began in 2015, when the U.S. Environmental Protection Agency (EPA) announced that diesel cars produced by Volkswagen from 2009 through 2015 were in violation of emissions standards. We analyse the impact of this announcement on transaction prices for Volkswagen cars on the U.S. eBay Motors. The main focus is on Volkswagen cars other than the 2009-2015 diesel models, namely, vehicles that did not violate EPA standards, allowing us to assess whether the negative shock received by the emissions standards violators spilled over to other Volkswagen models that were in compliance. Our difference-in-differences results show that final bid prices declined after the announcement by 14% for non-violating diesel cars and 9% for non-violating gasoline cars. Our analysis also provides little evidence of considerable changes in the numbers of participating bidders, bidding strategies, numbers of listings, and reserve-price strategies, suggesting that the drops in prices likely resulted from lowered willingness to pay from buyers.

Keywords: Volkswagen emissions scandal, eBay auctions, spillover effects

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1 Introduction

A product-harm crisis is a highly publicized event in which products are found to be defective or fail to meet safety and environmental standards (Siomkos and Kurzbard, 1994; Dawar and Pillutla, 2000; Cleeren et al., 2017). Controlling the occurrence of product-harm crises becomes more difficult for firms as products become complex, product-safety laws become more stringent, and consumers become more demanding; accordingly, the risk of product-harm crises increases over time (Chen et al., 2009; Dawar and Pillutla, 2000; Chen and Nguyen, 2013). This trend has motivated plenty of studies examining the consequences of product-harm crises. For an excellent review of the literature, see Cleeren et al. (2017).

One of the negative consequences of product-harm crises is a decline in the demand for the affected product,[1] for which previous studies found evidence in the automobile industry (Crafton et al., 1981; Reilly and Hoffer, 1983), food manufacturing (Van Heerde et al., 2007), and toy manufacturing (Freedman et al., 2012). The demand impact of a product-harm crisis, however, may not be limited to the affected product. In particular, it may spill over to unaffected products under the same brand/company (Crafton et al., 1981), as the company's unaffected products cannot be isolated from information about the affected product. As consumers use information about similar products from the brand/company to update their demand, they may be induced by a product-harm crisis to lower their expectations about the quality of the unaffected products, increasing their disappointment and dissatisfaction and consequently decreasing demand. The current study attempts to empirically investigate the level at which a product-harm crisis impacts on the unaffected products under the same brand.

Although better product-harm crises management requires an understanding of the magnitude of potential risk, the possibility of negative spillover is underexplored in the literature. Only a handful of studies have addressed the possibility, providing equivocal findings. One of the few studies that found a negative spillover was done by Van Heerde et al. (2007), who examined Kraft Food's crisis in Australia, where a peanut butter product was contaminated with salmonella. The baseline sales of a different peanut butter product made by the same company were found to have declined significantly post-crisis, even though it was not affected (although recalled for purely precautionary reasons). Using product recall events data from the

[1] Another negative consequence of product-harm crises is a loss of firm value. A number of previous studies generally found that product-harm crises result in negative and statistically significant abnormal stock returns (Barber and Darrough, 1996; Chen and Nguyen, 2013; Hoffer et al., 1988; Jarrell and Peltzman, 1985; Liu et al., 2017; Pruitt and Peterson, 1986; Thomsen and McKenzie, 2001).

U.S. car market, Liu and Shankar (2015) demonstrated that a product recall on one car nameplate negatively influenced the sales and preferences for all other car nameplates under the same parent brand. Based on lab experiments, Lei et al. (2008) also provided evidence for a negative spillover; a product-harm crisis occurring in a sub-brand lowered the brand evaluation of the parent brand as well as for other sub-brands. On the other hand, Crafton et al. (1981) found that for the U.S. automobile industry, recall announcements did not significantly affect the sales of different models of the same brand. Similar results were obtained by Reilly and Hoffer (1983). Freedman et al. (2012) provided evidence that recalls in the U.S. toy market did not shift consumers away from other types of toys made by the same manufacturers involved in a recall.

The current study explores the impacts of the Volkswagen emission scandal on the transaction prices of unaffected Volkswagen cars, providing insights into the spillover effect of how product-harm crises impact consumers' willingness to pay on the unaffected products. Willingness to pay is defined as the amount of money that a consumer is willing to pay for a product or service. Understanding consumers' willingness to pay is very important for a firm's pricing strategy, that entails calculating how many units of the product or service can be sold for a given price and determining the appropriate price that maximizes profits without alienating consumers. The typical ways to reveal customers' willingness to pay are surveys, experiments, and auctions. Particularly, in a second-price auction format, it is a weakly dominant strategy for potential buyers submit bids equal to their values. Therefore, bids directly reflect consumers' willingness to pay.

A demand curve is, in fact, a willingness to pay curve, in the sense that for any given quantity, price reflects how much the consumer is willing to pay for another unit, and the price falls as the quantity increases. When a product-harm crisis happens, measuring the change in willingness to pay means measuring the price change in demand curve. Our data consist of transactions from eBay Motors, a U.S. online automobile market, where cars are sold through second-price auctions. As one of the most popular car sales platforms in the U.S., eBay Motors is large and active, dealing with almost all car brands. The advantage of using eBay data is that the transaction prices can be observed during auctions (i.e., winning bids that are also the sellers' revenues), which facilitates us to directly measure the change in consumers' willingness to pay and examine changes in market conditions after the scandal announcement.

The scandal under study began on September 18, 2015, when the U.S. Environmental Pro-

tection Agency (EPA) publicly announced that Volkswagen had installed emissions-compliant "defeat device" software in diesel models produced from 2009 to 2015, which allowed those vehicles to pass standard laboratory tests of emissions standards for diesel cars.[2] The announcement surprised the U.S. car market, as there was no prior warning of the scandal. The focus of this study is on the extent to which the announcement influenced transaction prices for Volkswagen cars *other than* the 2009-2015 diesel models. Those vehicles are the unaffected products in our context, as they did not violate EPA emission standards. The cars are classified into three broad categories in our analysis, to account for possible differences in the spillover effect across model year and engine type: 2009-2015 diesel cars, 2000-2008 gasoline cars, and 2009-2015 gasoline cars. For each category, we use a difference-in-differences (DID) approach, where the treatment (control) group consists of corresponding Volkswagen cars (other manufacturers' cars). This allows us to assess whether and how the negative shock to the emission-standard violators (i.e., Volkswagen 2009-2015 diesel models) spilled over to the non-violators (i.e., other Volkswagen models).

The DID results show that Volkswagen non-violators experienced a significant decline in final bid prices as a result of the scandal. Specifically, the final prices of diesel models from 2000-2008 dropped by around 14 percent on average, while a 9 percent decrease was found for gasoline models from both 2000-2008 and 2009-2015. At the same time, there was little evidence of considerable changes in the numbers of participating bidders, bidding strategies, numbers of listings (i.e., the supply) of Volkswagen non-violating cars, and reserve-price strategies before or after the scandal announcement. Hence, the observed drops in prices are likely attributable to lower demand, i.e., willingness to pay, suggesting that a negative demand shock spilled over to the non-violators, namely, unaffected products under the same brand.

To the best of our knowledge, three studies on the Volkswagen emissions scandal are closely related to ours. Bachmann et al. (2017) found that as a result of the scandal, there were significant declines in new car sales in the U.S. as well as in the stock returns of other major German car manufacturers, including BMW, Mercedes-Benz, and Smart. Unlike Bachmann et al. (2017), we find little evidence that the scandal significantly influenced the transaction prices of other manufacturers in the U.S. used car market. Combined with those of Bachmann et al. (2017), our results suggest that the new and used car markets reacted to the scandal in different ways. The other two studies examined used car markets. Ater and Yosef (2018) found that the scandal had

[2]The Tier 2 standards were fully adopted in the U.S. car market, with all car manufacturers required to meet the emission limits. Tier 2 standards were phased out and replaced by Tier 3 standards from 2017 to 2025.

a significant adverse effect on the number of transactions involving used diesel cars made by Volkswagen and on the final asking prices in Israel. Examining the German market, Strittmatter and Lechner (2020) found that the supply of used Volkswagen diesel cars increased after the scandal was revealed and that the positive supply effects increased with the probability of manipulation. The current study differs in that it focuses on Volkswagen models that did not violate emissions standards and addresses changes in consumers' willingness to pay.

The remainder of this paper proceeds as follows: Sections 2 and 3 describe the background of the Volkswagen diesel emissions scandal and the eBay car auction data; Section 4 presents the main empirical analysis; and Section 5 concludes the study.

2 Background

The Volkswagen diesel emissions scandal. The 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 a 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).[3]

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. 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.

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-world operating emissions from European-based diesel cars sold in the United States in 2013. Three tested diesel vehicles, a Volkswagen Passat, a Volkswagen Jetta, and a BMW X5, certified to the Tier 2 standard in the

[3] www.statista.com/statistics/249375/us-market-share-of-selected-automobile-manufacturers.

laboratory tests, were found to have exceeded the standard in real-world driving conditions: NO_x 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, although 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. The affected vehicles included 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.[4] On 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 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 allows us to estimate the causal effects of the scandal announcement on the transaction prices for their unaffected products for two reasons. First, the EPA's announcement was likely to be an exogenous shock to consumers. As the entire investigation procedure and results were not publicly announced until September 18, 2015, it is very unlikely that individual buyers and sellers knew about the emissions scandal and adjusted their behavior accordingly before the announcement day. The announcement being an exogenous shock is also consistent with the results of our placebo tests in Section 4.2. Second, the EPA announcement made it clear that only certain models of Volkswagen cars had violated the emission standards. Due to this clarity, consumers were unlikely to view other Volkswagen cars as emission violators; put differently, it is likely that other Volkswagen cars were understood

[4] https://www.epa.gov/vw/learn-about-volkswagen-violations.

by consumers as "unaffected."

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 secondhand. The marketplace has experienced rapid development in the last two decades. The 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 that sellers use is a variant of a second-price auction with a specified ending time. The fixed ending time of an auction is a pre-specified duration set by the seller with options of 1, 3, 5, 7, or 10 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 the 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 fee. 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.

The seller is required to provide standardized information in the auction listing, including the make of car, body type, mileage traveled, and production year as well as whether the seller is a professional dealer. The seller may also choose to add more details in the item description using text and photos. eBay charges for posting additional information above a certain limit but the fee is rather cheap. For example, if a seller wants to upload more than 8 photos for the listed car, it costs \$0.15 per each additional photo.

3 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, whether the auction has a Buy-It-Now,[5] and who pays the shipping fees after the transaction). Other listing information is also available for this study, including the seller's username on eBay, feedback score, positive feedback percentage,[6] and geographical location (state level), whether the listing ends with the Buy-It-Now option, 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 exclude observations with unclear settings 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 of 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 the 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 and travelled. 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 $2,389.8$ 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

[5] A Buy-It-Now, also called a temporary buyout option, is a pre-determined buy price. If the seller decides to offer a Buy-It-Now in the auction, a bidder can obtain the object immediately by exercising the pre-determined buy price. However, this option is only active as long as no bid has been placed in the auction. Once a valid bid is received, the option disappears (the pre-determined buy price becomes not observable) and the bidding process starts. If the listing ends with the Buy-It-Now option, the ending price is equal to the pre-determined buy price; otherwise, it equals the second highest bid from the bidders.

[6] eBay provides a feedback system to assess the transaction histories of sellers and buyers; this is designed to mitigate information asymmetry and commitment problems. In each completed transaction, the winning bidder rates the seller in the form of a positive $(+1)$, negative (-1), or neutral (0) response, and the seller can leave a positive $(+1)$ or neutral (0) response to the winning bidder. The feedback system mainly consists of two measures, feedback score and positive feedback percentage. Feedback score is a record of overall responses. The higher the feedback score a seller/buyer obtains, the more trading experience the seller/buyer has on eBay. Positive feedback percentage is the percentage of positive responses out of the overall number of responses.

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. Of the $49,497$ listings, $9,422$ auctions (approximately 19 percent) have a Buy-It-Now option. Among these auctions with the option, $1,808$ listings are ended through the option, denoted by SBIN; in this case, the number of bidders in the auction is shown as 0.

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 the diesel and gasoline car markets.

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 account for most of the transactions in the sample; Volkswagen accounts for 5 percent, BMW 6.8 percent, Ford 15 percent, and Toyota 6.6 percent. Furthermore, Columns (1) - (4) list the numbers of diesel and gasoline cars from each manufacturer in model years 2000-2008 and 2009-2015, respectively. Notably, most manufacturers only produce gasoline cars, and the majority of diesel cars are from Ford and Volkswagen, accounting for approximately 68 percent.

4 Empirical Analyses

4.1 Measuring price declines in Volkswagen non-violating used cars

In this section, we examine whether and to what extent the emissions scandal affects transaction prices of Volkswagen non-violating models. The auction format on eBay allows us to observe the competitive bidding process and the final price of the car. Exploiting this feature of the data, along with the fact that the EPA's scandal announcement was not anticipated by the market, we use the difference-in-differences (DID) method, which compares Volkswagen cars (the treatment group) to other manufacturers' cars (the control group), to estimate the spillover

effect on the Volkswagen non-violating cars:

$$\begin{aligned}\ln(P_i) = \beta_0 + \beta_1 Scandal_i + \beta_2 Volkswagen_i + \beta_3 Scandal_i \times Volkswagen_i \\ + Controls_i + \varepsilon_i,\end{aligned} \tag{1}$$

where i indexes a specific auction listing. The dependent variable, $\ln(P_i)$, is the natural logarithm of the final price of the auction listing. $Scandal_i$ 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 $Scandal_i \times Volkswagen_i$ becomes one for Volkswagen cars after the EPA's announcement, and its coefficient β_3 measures how much buyers' willingness to pay (WTP) varies before and after the EPA's announcement (i.e., when the scandal was revealed), reflecting the spillover effect on the Volkswagen non-violating cars.

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, the positive feedback percentage, who pays shipping costs (a dummy variable that equals one if the winner pays for shipping), the natural logarithm of the start price, the secret reserve dummy, the Buy-It-Now dummy, whether the listing ends with the Buy-It-Now dummy (SBIN), 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[7] 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 make-model year level.

Insert Figure 1 about here

Our DID estimation relies on the validity of the control group. 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

[7]For sellers who sell multiple cars, we use their eBay usernames as their identities. For sellers who sell one car only, we use the combination of the seller's geographic location (state level) and feedback score quartile as the seller's identity. This is because seller reputation and geographical location (which may affect shipping cost) are the factors that bidders take into account when submitting their bids.

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 before the scandal. However, the gap in price becomes wider after the start of the scandal (i.e., September 18, 2015), especially for the diesel car market. According to these results, the parallel trend assumption seems to be satisfied in our DID setting. Figure A1 of the Appendix further presents the monthly ratios of auction listings between Volkswagen and non-Volkswagen cars that were sold. Before the emissions scandal announcement, the ratio was around 5.5 percent. The ratio decreased by around 1 percent after the emissions scandal was announced, and then bounced back to almost the same level as before after November 2015.

Insert Figure 2 about here

The seasonal numbers of Volkswagen and non-Volkswagen auction listings, including sold and unsold cars, are further listed in Figure 2 (where the scandal announcement was made in season 3, 2015). The figure demonstrates that except in the violating group, the number of listings was rather stable over the sample period, suggesting that the supply of Volkswagen non-violating cars and non-Volkswagen cars changed little before and after the scandal announcement. Later, we will provide further evidence that the scandal event did not affect the supply of these cars in eBay used car auction markets.

There exists a possibility that buyers, who originally wanted to buy Volkswagen cars, switched to buy other car brands after the scandal announcement. In this case, our DID estimation would violate the stable unit treatment value assumption (SUTVA), which is a threat to the causal interpretation of our results. This assumption is difficult to formally test, as our data do not allow us to directly observe individual buyer behavior. Accordingly, we examine whether buyers, on average, changed their behaviors after the scandal announcement. As will be presented later in this section, we found that entry and bidding by buyers did not significantly change after the announcement. Although not definitive, this evidence lends some support for SUTVA in our DID setting.

Volkswagen non-violating diesel cars in model years 2000-2008. We first examine diesel cars. In the U.S car markets, diesel cars account for a relatively small proportion, i.e., around 5 percent. As mentioned earlier, not all diesel cars made by Volkswagen are emissions standard violators. Only those made in model years 2009-2015 were announced by the U.S. EPA as the

Tier 2 emissions violators. On the other hand, those in model years 2000-2008 are not violators; they conformed to a different emissions standard (Tier 1) by which they were regulated. For this reason, the scandal might have influenced the prices of Volkswagen diesel cars in different manners, depending on whether they were emissions violators. To account for this possibility, we split the sample into two sub-samples based on model year; the first and second sub-samples consist of diesel cars in model years 2000-2008 and 2009-2015, respectively. Our analysis focuses on the first sub-sample (i.e., the non-violating group).[8]

Insert Table 2 about here

The results for the first sub-sample are presented in Column (1) of Table 2, where we control for car and auction characteristics and year/month fixed effects as well as body-type fixed effects. The DID estimate is negative and significant at the five percent level, suggesting that the transaction price of the Volkswagen non-violating diesel group was negatively and significantly affected by the scandal. The point estimate exhibits a decline in the final bid price by 15 percent. These results are robust to controlling for seller-identity fixed effects (Column (2)) and car-make fixed effects (Column (3)) in that the significance remains the same ($p < 0.05$) and the point estimates are similar in magnitude (14-15 percent).

Volkswagen non-violating gasoline cars. We next examine the two sub-samples of gasoline cars. By using the sub-samples, we can make a "vertical" comparison across model years to see whether the effects of the scandal differ across Volkswagen gasoline models. We also make a "horizontal" comparison between Volkswagen diesel and gasoline cars in model years 2000-2008 that are similar in the external and internal designs. These analyses allow us to address whether and the extent to which the scandal surrounding Volkswagen diesel cars affects the prices of Volkswagen gasoline cars in the gasoline car market. The results for model years 2000-2008 are presented in Columns (4) to (6) of Table 2. Regardless of whether we control for seller/make fixed effects, we find that the final bid prices dropped by 9-10 percent after the EPA's announcement. The results for model years 2009-2015, presented in Columns (7) to (9), are similar in significance ($p < 0.05$) and magnitude (9-11 percent).[9]

[8] We also examine the effect of the scandal on the final auction prices of Volkswagen violating diesels and present the estimation results in Tables A5 of the Appendix.

[9] Columns (1) - (9) of Table A3 reports all the estimated coefficients on the control variables. The results are consistent with what would be intuitively expected. For example, car age and mileage, which are the most important characteristics of a used car, are negatively correlated with the final price. The sellers' choices for the auction listing, such as having a secret reserve and including more photos, also significantly influence the final price. These results are consistent with findings in the literature. For example, Hossain (2008) finds that sellers prefer to use a secret

To examine whether the difference in the price drops is significant between the two model-year groups, we pool the two sub-samples and add to equation (1) the triple interaction of the scandal dummy, the Volkswagen dummy, and the model year (2009-2015) dummy. As reported in Column (1) of Table A6 in the Appendix, the estimated coefficient on the triple interaction is not significant at the ten percent level; in other words, the price drops do not significantly differ across the two model-year groups. This suggests that potential buyers downgraded Volkswagen gasoline cars equally, irrespective of model year. Overall, our results reveal that the prices of the Volkswagen cars declined by 9-11 percent in the gasoline car market due to the diesel emissions scandal.[10]

4.2 Robustness checks

Overall, our DID results show that the scandal negatively influenced the final prices of the Volkswagen non-violating cars in both diesel and gasoline car markets. In what follows, we perform several checks to examine the validity of the DID assumptions and then demonstrate the robustness of our main results by considering other checks.

Composition of the control group. In this subsection, we further examine whether our main results are robust to the composition of the control group, thereby addressing the possibility that some car listings in our control group may not be comparable to the Volkswagen car listings. First, we exclude from the control group listings of cars produced by other sub-brands of the Volkswagen group[11] or other German car manufacturers. By doing so, we address the possibility that the final prices for those cars were influenced by the scandal, as those cars have some commonalities with Volkswagen cars (e.g., belonging to the same group or originating from the same country). This exclusion does not affect our main results, however, as presented in Panel A of Table 3.

reserve and that it significantly increases the final price; Lewis (2011) and Che et al. (2019) observe that voluntarily information disclosure from sellers, i.e., more photos, warranty information, helps mitigate adverse selection and increase buyers' willingness to pay.

[10]We compare between Volkswagen diesel and gasoline cars in model years 2000-2008. The "horizontal" comparison in model years 2000-2008 suggests that the price drop was damaged to a greater extent in the diesel car market (14-15 percent) than in the gasoline car market (9-11 percent). To examine whether the price drops are significantly different between the non-violating diesel and gasoline car groups, we pool the two sub-samples in model years 2000-2008 and add to equation (1) the triple interaction term of the scandal dummy, the Volkswagen dummy, and the diesel dummy. As reported in Column (2) of Table A6, the estimated coefficient on the triple interaction is not significant at the ten percent level, implying that the price drops do not significantly differ between the two car groups. We obtain similar results when instead pooling the sub-sample of non-violating diesels and the whole sample of gasoline cars, as presented in Column (3). These results suggest that the negative impacts of a product-harm crisis take the same proportion of the price for differentiated products under the same brand name.

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

Insert Table 3 about here

Second, we exclude from the control group listings of cars produced by manufacturers for which there are a small number of transactions. Those manufacturers take relatively small market shares and may not be comparable to Volkswagen in the U.S. car market. In particular, we exclude listings of cars produced by manufacturers with fewer than 100 transactions in the sample or keep only listings of cars produced by manufacturers that account for no less than one percent of all transactions. As presented in Panel B of Table 3, the DID estimates are similar in magnitude to those reported in Table 2.

Insert Table 4 about here

Third, we instead include into the control group listings of cars produced by particular car manufacturers. We first include only Toyota cars in the control group. The results are presented in Columns (1) - (3) of Table 4 (where Column (1) is blank due to no observation for Toyota diesel cars in model years 2000 - 2008). We then repeat the estimation by using control groups that consists of Ford cars only (Columns (4) - (6)) and of those made by Toyota, Honda, Ford, GMC, and Mercedes only (Columns (7) - (9)). In all the regressions, the DID estimates are negative and significant at least at the ten percent level, broadly similar in size to those in Table 2.

We also address the concern that our sample contains observations that can be considered "outliers;" specifically, there are listings of cars in the sample that traveled more than 200,000 miles or had final prices greater than 100,000 U.S. dollars. We exclude these "outliers" from the sample and then re-estimate equation (1). As presented in Columns (10) - (12), the results are similar to those in Table 2, suggesting that our main results are not influenced by outliers, such as overused or high-end car listings, in the sample.

According to Figure 1, the average prices in the control groups (approximately 7,000 U.S. dollars in the diesel car market and 5,000 U.S. dollars in the gasoline car market) are a few thousand dollars higher than those of the treatment groups. Although we control for observable factors, one might question whether the control groups are comparable to the treatment groups and whether our main results stem from the heterogeneity of consumers across the groups. To address this issue, we only include into the control group car listings with a final price less than 10,000 U.S dollars. Figure A2 in the Appendix plots the monthly average transaction prices of diesel/gasoline cars for the treatment group (Volkswagen) and the restricted control group (non-Volkswagen). The average prices of the non-Volkswagen diesel and gasoline car listings

were relatively stable before and after the announcement, in contrast to those of the Volkswagen car listings which shifted down after the announcement.

Columns (13) - (15) of Table 4 report the DID results based on the restricted control group. The DID estimate for gasoline cars in model years 2000-2008 is almost the same as that reported in Table 2. The estimate for diesel cars in model years 2000-2008 (for gasoline cars in model years 2009-2015) is the same in sign and significance as those reported in Table 2, although it is smaller (larger) in magnitude. It can therefore be concluded that our main results are at least qualitatively robust to excluding from the control group car listings with relatively high final prices.

Pre-announcement period. An important assumption for our DID estimation is that there was no prior warning of the EPA's announcement. This assumption may be subject to scrutiny because related research on emissions violations actually started in 2013, raising the possibility that consumers anticipated and responded to the scandal even before the EPA publicly announced the test results. To check the validity 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 examining the final bid prices after the artificial announcement but before the announcement was actually made. Had we seen the scandal's effect with this artificial announcement, we would have concluded that the scandal was anticipated by consumers and had an effect even before it was revealed.

Insert Table 5 about here

For this purpose, we set the artificial announcement date to March 18, 2015 and estimate equation (1) using the observations before September 18, 2015 only. Panel A of Table 5 presents the results for diesel cars in model years 2000-2008 (Column (1)) and gasoline cars in model years 2000-2008 (Column (2)) as well as those in model years 2009-2015 (Column (3)). None of the DID estimates is significant at the ten percent level. Similar results are obtained when July 18, 2015 is set as the artificial announcement date (Columns (4)-(6)). These results are robust to the exclusion of the listings of cars produced by German car manufacturers from the sample (Columns (7)-(9)) and to the further exclusion of the listings of cars produced by other sub-brands of the Volkswagen group (Columns (10)-(12)). According to these results, the EPA's scandal announcement on September 18, 2015 seems to be as good as random, generating exogenous variations in consumers' demand for diesel and gasoline cars.

Diesel car manufacturers. According to Table A2, not all the car manufacturers produce diesel cars. Our DID estimates may be biased due to the car manufacturers' heterogeneity, i.e., their production of gasoline cars only or of both gasoline and diesel cars. To deal with this issue, we re-estimate the models in Table 2 by including a dummy variable, called the diesel car manufacturer (DCM), where DCM is equal to one if the manufacturer produces diesel cars; otherwise, zero. As reported in Columns (13)-(15) of Panel C in Table 5, the DID estimates are negative and significant at the five percent level, remaining virtually the same in magnitude as before. Furthermore, we re-do similar estimations by including the interaction term between the scandal dummy and the diesel car manufacturer dummy. The DID estimates remain negative and significant (Columns (16)-(18)). Our main results therefore do not seem to be affected by whether the manufacturers produce gasoline cars only or both gasoline and diesel cars.

The impacts over time. 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. To examine this possibility, we re-estimate 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 6, our main results are not much affected by this exclusion. We obtain similar results when further excluding transactions made within a week and a month before and after the EPA's announcement (Columns (4)-(6) and Columns (7)-(9)). These results suggest that the scandal has a relatively long-term impact on eBay used car auction markets. This is in contrast to the relatively short-term impact on the stock price of Volkswagen in the financial market, as mentioned in Section 2.

Insert Table 6 about here

Synthetic control estimates. One may have a concern that our estimation results are driven by violation of parallel trends between the treatment and control groups. To address this concern, we use the synthetic control method (Abadie and Gardeazabal, 2003; Abadie et al., 2010). The method creates from the non-treated units (also called the donor units) a hypothetical counterfactual unit that simulates what the outcome path of the treated unit would be in the absence of a particular event. The counterfactual unit, particularly called the "synthetic control" (SC) unit, is a weighted sum of selected donor units, where the weights are chosen by matching predictors in the pretreatment period of the donor units to those in the pretreatment period of the treated unit. The estimated effect of the event for the treated unit at a given time period

is computed as the difference between the treated unit's actual outcome and the SC's outcome (that is, the treated unit's potential outcome without the event).

For this analysis, we divide the whole sample period into seven two-month periods ($t = 1, 2, ..., 7$). Specifically, the first period ($t = 1$) and the last period ($t = 7$) correspond to the period from January to February 2015 and the period from January to February 2016, respectively, and the scandal announcement occurred during the fifth period ($t = 5$) from September to October 2015. We limit the analyses to gasoline cars in model years 2000-2008 and 2009-2015, as diesel cars of some car makes were not regularly traded during the sample period.

The outcome variable is the natural logarithm of two-month average final prices of gasoline cars in model years 2000-2008 or 2009-2015. The predictors are traveled mileage (in log) and car age, for which we compute sample average values in the pre-scandal periods. We also use as additional predictors the natural logarithm of two-month average final prices before the scandal announcement ($t = 1, 2, 3$). The synthetic Volkswagen is constructed as a weighted average of unaffected car makes. We chose the weights so that they minimize the difference in a set of predictors between the Volkswagen and the synthetic Volkswagen in the pre-scandal periods.

The estimation results are presented in Figure 3 where the upper and lower panels correspond to gasoline cars in model years 2000-2008 and 2009-2015, respectively. The figures illustrate that two-month average final prices of the synthetic Volkswagen closely follow those of the actual Volkswagen in the pre-scandal periods. Moreover, the synthetic Volkswagen is similar in values of the predictors to the Volkswagen in the pre-scandal period, as presented in Table A8. According to these results, the synthetic Volkswagen is expected to work well as a control counterpart for the Volkswagen after the scandal announcement.[12]

As is evident in Figure 3, the curves diverge after the scandal announcement, in that the average final prices of the Volkswagen become smaller than those of the synthetic Volkswagen. The gaps in the last period exhibit approximately 10% and 5% for model years 2000-2008 and 2009-2015, respectively, which are in line with the corresponding DID estimates presented earlier.

Other major manufacturers. We conduct another placebo test to further examine the validity of our identification strategy. Here, we estimate equation (1) by pretending that the treatment group consists of listings of cars produced by a manufacturer other than Volkswagen and

[12]Table A7 presents the contributions of each of the car makes in the donor pool to the synthetic Volkswagen. For the gasoline cars in model years 2000-2008, Volvo (0.675) carries the largest weight, with Lexus (0.192) and Isuzu (0.133) also contributing to the synthetic Volkswagen. For model years 2009-2015, Kia (0.544) contributes the most to the synthetic Volkswagen, followed by Subaru (0.255) and Mazda (0.201).

also by removing Volkswagen listings from the sample. If our identification strategy is sound, the scandal's 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 A9 in the Appendix, the DID estimates are not significant at the ten percent level, regardless of the fuel type or model year that we examine. We also estimate the same models for the auction listings with Mercedes-Benz (Columns (4)-(6)), Honda (Columns (7)-(9)), Toyota (Columns (10)-(12)), and Ford cars (Columns (13)-(15)). For each model, the final prices are not significantly associated with the interaction of the scandal dummy and the brand dummy.[13] Our identification strategy therefore seems to be sound in the sense that it does not falsely detect the scandal's effect for manufacturers other than Volkswagen.[14]

4.3 Further analyses

The observed price drops in Volkswagen non-violating cars after the scandal announcement may be attributed to not only declines in willingness to pay for the Volkswagen non-violators but also changes in the numbers of participating bidders and bidding strategies. Changes in supply (i.e., numbers of listings) and sellers' reserve-price strategies may also be the sources of the observed price drops. In what follows, we explore these possible channels through which the scandal influenced transaction prices for Volkswagen non-violators.

Entry and bidding by bidders. We here examine whether the number of bidders as well as the number of bids for Volkswagen listings change as a result of the scandal. In particular, we estimate a variant of equation (1), where the dependent variable is replaced by the natural logarithm of the number of bidders or the number of bids for each listing. Columns (1)-(3) of Table 7 present the results for the number of bidders. The estimated coefficients on the interaction term are not significant at the ten percent level; in other words, there is little evidence that the scandal influenced bidders' entries for the listings of Volkswagen non-violators. We obtain similar results for the number of bids (Columns (4)-(6)); the scandal does not seem to have influenced the number of bids for Volkswagen diesel cars in model years 2000-2008 or Volkswagen gasoline cars in model years 2009-2015. For gasoline cars in model years 2000-2008, the coefficient on the interaction term is positive (not negative) and significant only at the

[13] In our sample, we do not observe any diesel cars in model years 2000-2008 produced by Honda and Toyota.

[14] To show the robustness of our findings, we consider the impacts of the scandal across different car body types and quantiles of final prices, see Table A10 of the Appendix. Furthermore, our findings are also robust when considering the impacts from the new car markets and Buy-It-Now options, see Tables A11 and A12 of the Appendix.

ten percent level. These results rule out the possibility that our DID estimates are driven by changes in the buyers' entry and bidding behavior after the announcement.

Insert Table 7 about here

It could be argued that drops in realized auction prices may have been driven by an increase in the level of bid shading after the scandal announcement. This possibility, however, is not a major concern. Suppose that when a scandal happens, all bidders employ a new bid shading strategy that further lowers their bids. Then, it would be profitable for a bidder to deviate and use the previous bid shading strategy, as it would give a higher winning probability and a lower second-highest bid as the final price (condition on winning). As a result, all bidders would deviate from the new strategy. Therefore, price drops in auctions after the scandal announcement are unlikely to be the result of an increased bid shading strategy from bidders.

Supply of cars. It is possible that the price drops for non-violating models were attributable to a change in supply after the scandal announcement. To address this possibility, we examine whether a change in supply occurred after the announcement, by regressing the natural logarithm of the numbers of auction listings on the scandal dummy. As reported in Panel A of Table 8, the coefficient on the scandal dummy is not statistically significant for each of the Volkswagen non-violating and non-Volkswagen car groups; in other words, the supply of these cars did not significantly increase or decrease after the announcement. These results, along with Figure 2 as explained earlier, seem to exclude the possibility that a change in supply occurred after the scandal announcement and thereby lowered the prices of non-violating models.

Insert Table 8 about here

These results contrast with the evidence by Strittmatter and Lechner (2020) that the supply of used Volkswagen diesel cars increased after the scandal in a German used-car online advertisement platform. The contrasting results for the two markets may be explained by the trade-off faced by potential sellers. On the one hand, an owner of a Volkswagen non-violating model may want to sell it quickly due to the scandal, which is more likely to be the case for those with higher preferences for quality, as argued by Strittmatter and Lechner (2020). On the other hand, the owner may have an incentive not to sell the car immediately after the scandal announcement, due to the possibility that other owners of Volkswagen non-violating models may also list their cars, driving more competition among sellers and lowering the final price.

Depending on the magnitudes of these two opposing effects as well as on the distribution of preferences, the supply may or may not increase during the sample period.

Reserve prices in the auctions. As mentioned above, a seller in an eBay auction has both "secret reserve" and "start price" as optional reserve-price choices. To address the possibility of the differences in the reserve prices, we first present monthly average start prices in Figure A4 of the Appendix. The figure demonstrates that the average start prices in the Volkswagen and the non-Volkswagen car listings and the gaps between them did not change significantly after the start of the scandal, especially for the diesel car market. We next re-run equation (1) by adding an interaction term of the scandal dummy with secret reserve or with start price. Across all the regressions, the final bid prices are negatively and significantly associated with the interaction of the scandal dummy with the Volkswagen dummy, even after the interaction terms between the scandal dummy and the auction's optional reserve-price choices are controlled for (Panel B of Table 8). According to these results, the effect from the scandal announcement still holds after controlling for reserve prices.

Our additional analyses demonstrate that there were no significant changes in the numbers of participating bidders, bidding strategies, numbers of listings, or reserve-price strategies. Therefore, these results seem to suggest that the observed drops in the auction final prices are mainly due to lowered willingness to pay from buyers. In other words, the negative shock received by Volkswagen violators was likely to spill over to Volkswagen non-violators as a negative demand shock. This identified spillover effect is attributed to consumers' disappointment and dissatisfaction after the crisis, lowering their expectations about the perceived quality and perceived resale values of Volkswagen cars. As a results, consumers submit lower willingness to pay in the auctions.

5 Concluding Remarks

On September 18, 2015, the EPA accused Volkswagen of installing software known as a "defeat device" to cheat on emissions tests in the United States. Exploiting the Volkswagen emissions scandal as an exogenous shock and using individual transaction data from the eBay car auction market, this study examined how and to what extent a product-harm crisis affects demand (transaction prices) of the unaffected Volkswagen cars in the markets. We found a statistically significant spillover effect; there exist a significant decrease in the final prices of

Volkswagen cars that are not identified by the EPA as emissions violating models. This decrease reflects how much buyers lowered their willingness to pay for the unaffected products under the same brand.

Managerial implications. The research findings in our study provide some important managerial and policy implications. First, the Volkswagen emissions scandal is one of the typical instances in which a firm makes myopic decisions that adversely affects its brand equity and profitability in the long term. Our study provided evidence of the spillover effect that prices for Volkswagen non-violating used cars in the online market dropped after the scandal announcement; the final bid prices declined by approximately 14% for the diesel cars and 9% for the gasoline cars. Such estimates give Volkswagen an additional channel through which the company can evaluate its loss of brand equity and profitability linked to the product-harm crisis. Quantifying the spillover effects of the scandal on products not directly involved can help companies to avoid making myopic decisions and keeping their brands healthy over time.

Second, our study extends our knowledge of product-harm crises by studying the consequences of the Volkswagen emission scandal on the auction prices of the unaffected vehicles, thus providing insights on how consumers adjust their willingness to pay as their responses to a crisis. As mentioned in the introduction, firms have incentives to understand consumers' willingness to pay for their products or services. By estimating the change in willingness to pay and further working backward to determine pricing strategies, firms can confidently minimize the negative impacts of product-harm crises on revenues (in other words, they can maximize profit margin while capturing as much value as possible from consumers).

Third, the results in Table A6 of the Appendix demonstrate that the price drops for the violating models are not statistically different from those for the non-violating models. Consumers' willingness to pay for the violating models did not drop as much, plausibly due to the expectation of compensation provided by Volkswagen. Put differently, despite the fact that the quality of non-violating models was unchanged, their prices dropped significantly as a result of the spillover effect. Therefore, offering (at least partial) compensation to the owners of the non-violating models might have been a sensible policy which in turn could have helped the firm regain consumer trust and accelerated its recovery from the crisis. These managerial implications are valuable not only for Volkswagen but also for other car manufacturers at large.

Limitations and extensions. Due to data limitations, we could not examine whether and

how the sales probability of a Volkswagen non-violating car varies after the scandal announcement. This additional analysis would be possible given the increasing availability of online transaction data, providing further insights into the impact of the announcement on the sales probability. Furthermore, it would also be interesting to examine how advertising after the scandal affects the sales probability.

Second, the study focused on durable goods in online markets. Given the development of online markets in recent years, it is common for consumers to purchase a variety of consumption goods online. Further work is needed to investigate how a product-harm crisis influences consumers when they purchase consumption goods online and whether their purchase behavior would differ from that for durable goods.

Third, due to data availability, this study considered online markets exclusively. However, our results may not be generalized to offline markets partly due to differences in search and transaction costs. A useful extension would be to develop a data scale that makes it possible to compare consumer responses to products by the same brand in online and offline markets in the event of a product-harm crisis. Such an extension would provide a more holistic understanding of the impacts of product-harm crises.

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
Positive Feedback Percentage	49,497	95.18	19.67	0	100
Buy-It-Now	49,497	0.19	0.39	0	1
SBIN	49,497	0.04	0.19	0	1
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	4.20	2	17
Mileage	49,497	108829.70	122331.90	1	9999999

Note: "Buy-It-Now" is a dummy variable to indicate whether the auction has a Buy-It-Now option; "SBIN" is a dummy variable that indicates whether the listing is sold through the Buy-It-Now option; "Secret Reserve" is a dummy variable to indicate whether the auction has a secret reserve price; "Buyer Shipping" is a dummy variable to indicate whether the winning buyer needs to pay the shipping fee.

Figure 1: Monthly Average Transaction Prices

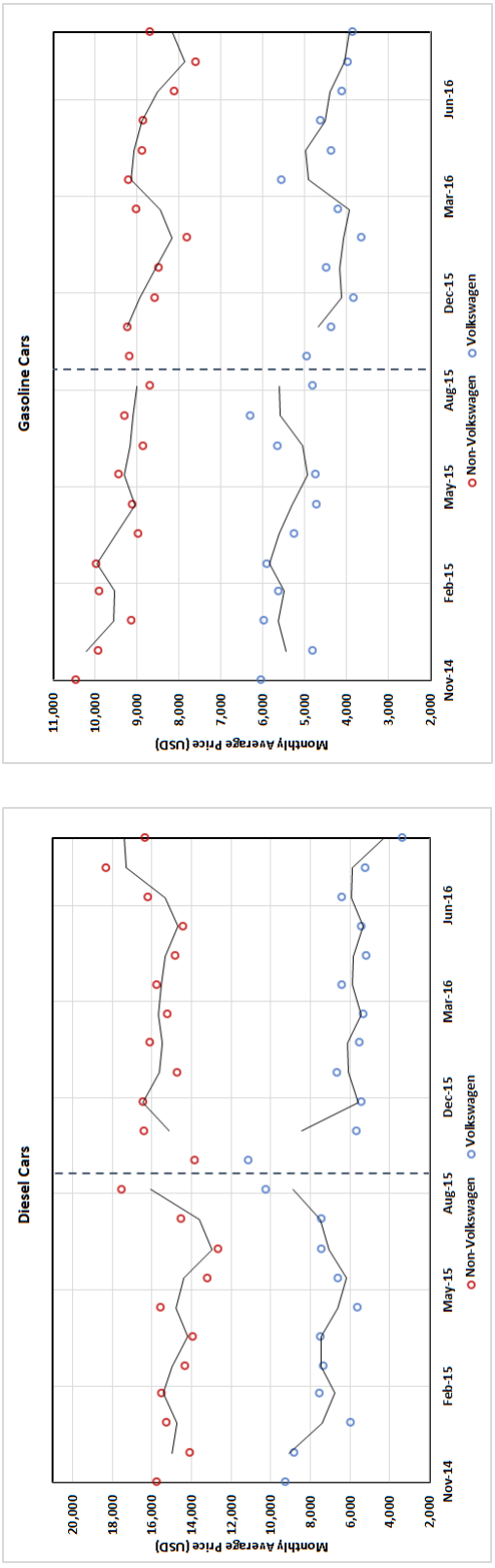
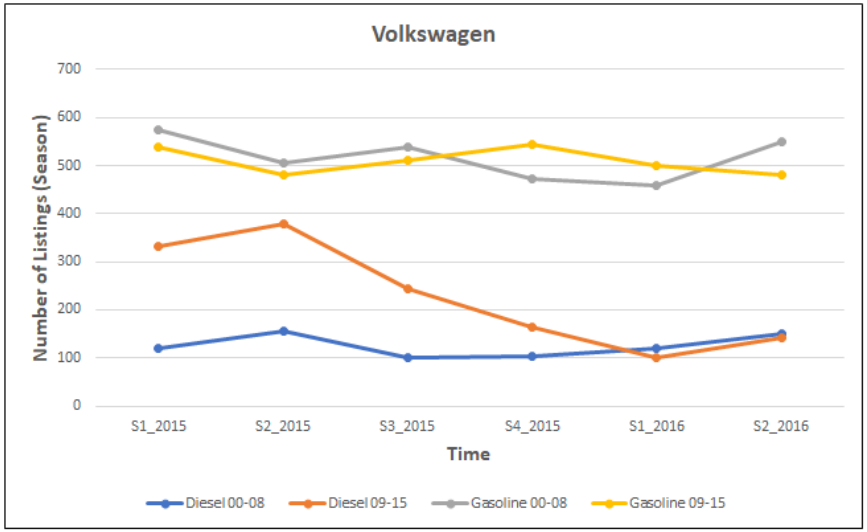


Figure 2: Seasonal Numbers of Volkswagen and Non-Volkswagen Car Listings

	Volkswagen				**Non-Volkswagen**			
	Diesel 00-08	Diesel 09-15	Gasoline 00-08	Gasoline 09-15	Diesel 00-08	Diesel 09-15	Gasoline 00-08	Gasoline 09-15
S1_2015	121	333	575	538	1626	2264	16012	22237
S2_2015	155	379	506	481	1312	1952	14301	21688
S3_2015	101	244	538	510	1158	1181	13882	19366
S4_2015	103	163	472	545	1334	1594	13773	19703
S1_2016	120	100	458	501	1456	1674	12658	16806
S2_2016	149	143	549	482	1560	1622	14631	19992



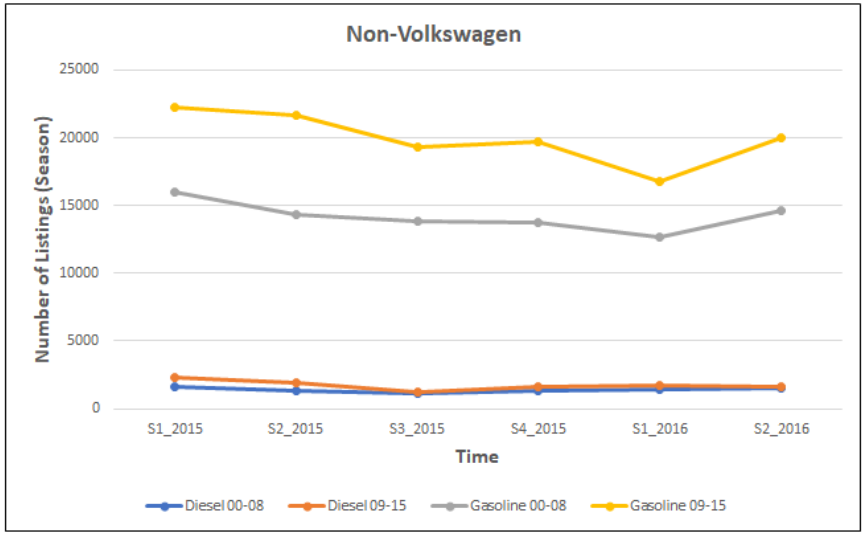


Table 2: Volkswagen Emissions Non-Violating Cars

ln(Final Price)	Diesel 00-08			Gasoline 00-08			Gasoline 09-15		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Scandal x Volkswagen	-0.152**	-0.152**	-0.144**	-0.097***	-0.097**	-0.093**	-0.110**	-0.110**	-0.092**
	(0.06)	(0.07)	(0.06)	(0.03)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)
Scandal	0.202	0.202	0.232*	-0.015	-0.015	-0.006	0.020	0.020	0.012
	(0.18)	(0.13)	(0.12)	(0.04)	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)
Volkswagen	-0.741***	-0.741***	-0.954***	-0.208***	-0.208***	-0.324***	-0.215***	-0.215***	-0.333***
	(0.06)	(0.07)	(0.11)	(0.02)	(0.04)	(0.04)	(0.04)	(0.05)	(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)-(3) are diesel cars, and Columns (4)-(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, positive feedback percentage, Buy-It-Now dummy, SBIN, buyer shipping dummy, the natural log of start price, secret reserve dummy, listing duration, number of entering bidders; see Table A3. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 3: The Validity of Control Group - I

Panel A						
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	-0.152**	-0.095**	-0.106**	-0.161**	-0.094**	-0.103**
	(0.07)	(0.04)	(0.04)	(0.06)	(0.05)	(0.04)
Scandal	0.201	-0.008	0.008	0.143	-0.023	0.027
	(0.13)	(0.04)	(0.03)	(0.15)	(0.04)	(0.04)
Volkswagen	-0.736***	-0.192***	-0.190***	-0.762***	-0.150***	-0.162***
	(0.07)	(0.04)	(0.04)	(0.09)	(0.04)	(0.05)
R^2 (within)	0.43	0.45	0.35	0.44	0.45	0.38
Obs.	2,841	31,706	12,056	2,704	28,345	11,029

Panel B						
ln(Final Price)	Diesel 00-08 (7)	Gasoline 00-08 (8)	Gasoline 09-15 (9)	Diesel 00-08 (10)	Gasoline 00-08 (11)	Gasoline 09-15 (12)
Scandal x Volkswagen	-0.145**	-0.091**	-0.093**	-0.144**	-0.092**	-0.093**
	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	0.236*	-0.013	0.018	0.232*	-0.012	0.019
	(0.12)	(0.04)	(0.03)	(0.12)	(0.04)	(0.03)
Volkswagen	-0.950***	-0.325***	-0.331***	-0.954***	-0.325***	-0.332***
	(0.11)	(0.04)	(0.04)	(0.11)	(0.04)	(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. In Panel A, Columns (1) - (3) are the estimated results without Volkswagen sub-brands; Columns (4) - (6) are the estimated results without other German car manufacturers. In Panel B, Columns (7) - (9) are the results in which a car brand with less than 100 observations is excluded; Columns (10) - (12) are the results in which a car brand with less than 1% market share is excluded. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 4: The Validity of Control Group - II

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)	Diesel 00-08 (7)	Gasoline 00-08 (8)	Gasoline 09-15 (9)
Scandal x Volkswagen		-0.076**	-0.119***	-0.187***	-0.112**	-0.090**	-0.153**	-0.092**	-0.107***
		(0.04)	(0.03)	(0.06)	(0.05)	(0.04)	(0.06)	(0.04)	(0.03)
Scandal		0.059	-0.054	0.295*	0.134*	0.156	0.323**	0.049	0.103*
		(0.13)	(0.14)	(0.15)	(0.08)	(0.09)	(0.13)	(0.05)	(0.06)
Volkswagen		-0.235***	-0.153***	-0.761***	-0.027	-0.014	-0.811***	-0.067	-0.50
		(0.03)	(0.04)	(0.09)	(0.04)	(0.05)	(0.08)	(0.05)	(0.04)
R^2 (within)		0.53	0.57	0.49	0.47	0.50	0.49	0.50	0.52
Obs.		3,891	1,232	1,994	5,046	2,556	2,265	12,408	5,017

	(10)	(11)	(12)	(13)	(14)	(15)
Scandal x Volkswagen	-0.150**	-0.091**	-0.099**	-0.071**	-0.101***	-0.187***
	(0.06)	(0.04)	(0.04)	(0.02)	(0.04)	(0.04)
Scandal	0.236**	0.008	0.014	0.218	-0.017	-0.049
	(0.11)	(0.04)	(0.03)	(0.17)	(0.04)	(0.04)
Volkswagen	-1.049***	-0.377***	-0.333***	-0.514***	-9.255***	0.178***
	(0.11)	(0.03)	(0.04)	(0.13)	(0.04)	(0.04)
R^2 (within)	0.48	0.55	0.55	0.35	0.47	0.26
Obs.	2,034	30,521	12,518	1,526	29,105	4,244

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) - (3) are the results in which only Toyota car listings are in the control group; Columns (4)-(6) are the results in which only Ford car listings are in the control group; Columns (7)-(9) are the results in which car listings are from Toyota, Honda, Ford, GMC, and Mercedes in the control group. Columns (10)-(12) are the results where we exclude transactions that are either travelled more than 200,000 miles or with the final price more than 100,000 U.S dollars; Columns (13)-(15) are the results in which only the non-Volkswagen car listings with the final price less than $10,000$ U.S dollars are included in the control group. Other control variables and fixed effect are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 5: Robustness Checks - I

Panel A						
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	-0.118	-0.080	-0.035	0.017	-0.110	-0.073
	(0.07)	(0.05)	(0.04)	(0.13)	(0.07)	(0.10)
Scandal	0.052	0.024	0.008	0.039	0.014	-0.002
	(0.06)	(0.04)	(0.04)	(0.11)	(0.02)	(0.04)
Volkswagen	-0.922***	-0.299***	-0.310***	-0.992***	-0.326***	-0.320***
	(0.13)	(0.05)	(0.04)	(0.14)	(0.04)	(0.04)
R^2 (within)	0.45	0.58	0.55	0.45	0.58	0.55
Obs.	1,593	16,554	5,959	1,593	16,554	5,959
Panel B						
ln(Final Price)	Diesel 00-08 (7)	Gasoline 00-08 (8)	Gasoline 09-15 (9)	Diesel 00-08 (10)	Gasoline 00-08 (11)	Gasoline 09-15 (12)
Scandal x Volkswagen	-0.002	-0.105	-0.070	-0.002	-0.101	-0.081
	(0.13)	(0.06)	(0.10)	(0.13)	(0.07)	(0.10)
Scandal	0.034	0.013	-0.004	0.034	0.012	0.011
	(0.11)	(0.03)	(0.04)	(0.11)	(0.03)	(0.04)
Volkswagen	-1.000***	-0.322***	-0.323***	-1.000***	-0.324***	-0.319***
	(0.15)	(0.04)	(0.04)	(0.15)	(0.04)	(0.04)
R^2 (within)	0.45	0.56	0.55	0.45	0.54	0.52
Obs.	1,519	14,352	5,260	1,518	13,551	4,988
Panel C						
ln(Final Price)	Diesel 00-08 (13)	Gasoline 00-08 (14)	Gasoline 09-15 (15)	Diesel 00-08 (16)	Gasoline 00-08 (17)	Gasoline 09-15 (18)
Scandal x Volkswagen	-0.144**	-0.093**	-0.092**	-0.148**	-0.087**	-0.086**
	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	0.232*	-0.006	0.012	-0.353	0.003	0.021
	(0.12)	(0.04)	(0.03)	(0.60)	(0.04)	(0.03)
Volkswagen	-0.954***	-0.337***	-0.198***	-0.952***	-0.340***	-0.201***
	(0.11)	(0.04)	(0.04)	(0.11)	(0.04)	(0.05)
DCM	-0.129	0.013	-0.134***	-0.362*	0.020	-0.128***
	(0.27)	(0.03)	(0.04)	(0.20)	(0.03)	(0.05)
DCM x Scandal				0.585	-0.014	-0.016
				(0.57)	(0.01)	(0.01)
R^2 (within)	0.48	0.56	0.56	0.48	0.56	0.56
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. In Panel A, Columns (1) - (3) are the results when the artificial announcement is set to be March 18, 2015, and Columns (4) - (6) are the results when the artificial announcement is set to be July 18, 2015. In Panel B (where the artificial announcement is set to be July 18, 2015), Columns (7) to (9) exclude other German manufacturers, and Columns (10) to (12) exclude other German manufacturers and other sub-brands in Volkswagen group. In Panel C, "DCM" denotes diesel car manufacturer dummy. Columns (13) - (15) are the results when the DCM dummy is included and Columns (16) - (18) are the results when the interaction term between the DCM dummy and the scandal dummy is included as well. Related control variables and fixed effects are also included in all the regressions above. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 6: Robustness Checks - II

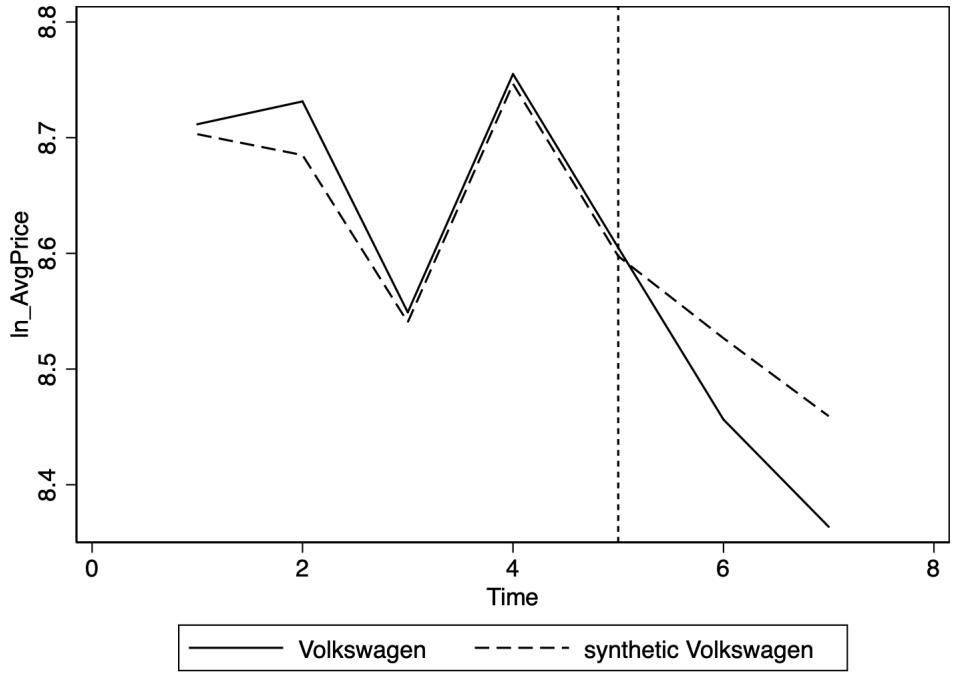
ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)	Diesel 00-08 (4)	Gasoline 00-08 (5)	Gasoline 09-15 (6)
Scandal x Volkswagen	-0.144**	-0.093**	-0.092**	-0.146**	-0.103**	-0.078**
	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	0.231*	-0.008	0.022	0.094	-0.061	0.055
	(0.12)	(0.03)	(0.03)	(0.20)	(0.07)	(0.07)
Volkswagen	-0.954***	-0.323***	-0.333***	-0.945***	-0.312***	-0.337***
	(0.11)	(0.04)	(0.04)	(0.11)	(0.04)	(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

ln(Final Price)	Diesel 00-08 (7)	Gasoline 00-08 (8)	Gasoline 09-15 (9)
Scandal x Volkswagen	-0.149**	-0.109**	-0.085**
	(0.06)	(0.04)	(0.04)
Scandal	0.030	-0.131***	-0.141***
	(0.05)	(0.02)	(0.02)
Volkswagen	-0.937***	-0.310***	-0.337***
	(0.11)	(0.04)	(0.04)
R^2 (within)	0.48	0.56	0.56
Obs.	2,799	32,343	12,238

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1) - (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; Columns (7) - (9) are the results when the listings within one month after the scandal announcement have been dropped. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Figure 3: Synthetic Control Estimates of the Impacts of the Emissions Scandal

Volkswagen Gasoline Cars in Model Years 2000-2008



Volkswagen Gasoline Cars in Model Years 2009-2015

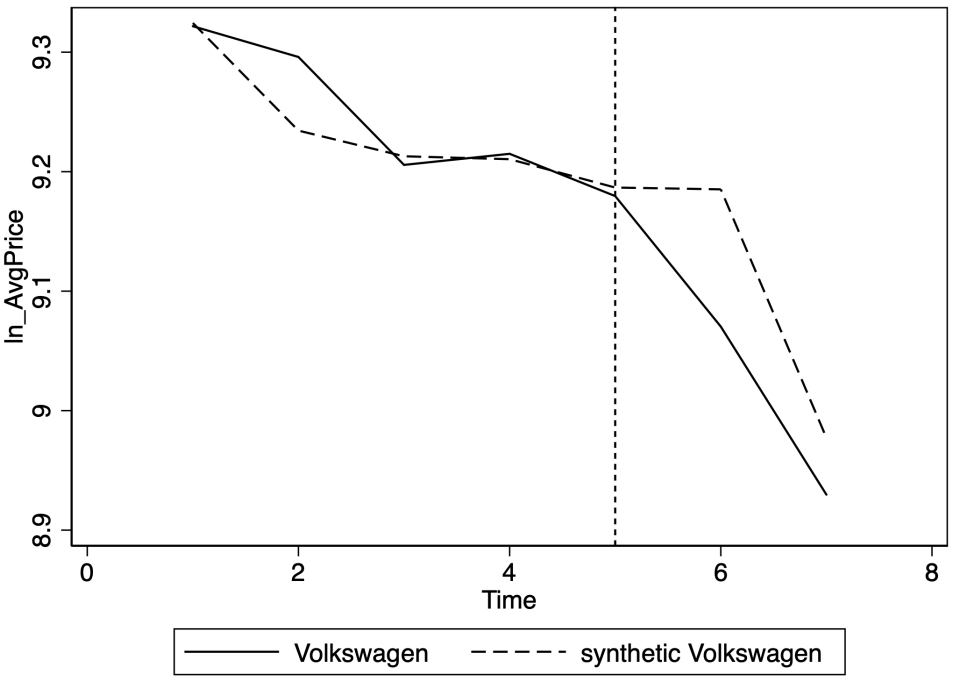


Table 7: Buyer Behavior

	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	-0.041	0.050	0.097	-0.044	0.109*	0.143
	(0.07)	(0.05)	(0.08)	(0.08)	(0.06)	(0.11)
Scandal	0.114	0.002	-0.056	0.238	0.001	-0.023
	(0.14)	(0.04)	(0.06)	(0.21)	(0.05)	(0.08)
Volkswagen	-0.110	-0.062	-0.323***	-0.040	-0.062	-0.393***
	(0.09)	(0.04)	(0.11)	(0.12)	(0.05)	(0.15)
R^2 (within)	0.32	0.30	0.26	0.31	0.30	0.26
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. Columns (1) - (3) are the results when the dependent variable is the natural log of the number of entering bidders, and Columns (4) - (6) are the results when the dependent variable is the natural log of the number of bids. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 8: Numbers of Listings and Seller Behavior

Panel A						
	VW			Non-VW		
ln(listings)	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline
	00-08	00-08	09-15	00-08	00-08	09-15
	(1)	(2)	(3)	(4)	(5)	(6)
Scandal	-0.175	-0.148	0.030	-0.260	-0.238	-0.244
	(0.11)	(0.11)	(0.08)	(0.20)	(0.15)	(0.16)
R^2	0.124	0.094	0.0078	0.085	0.134	0.117
Obs.	21	21	21	21	21	21

Panel B						
ln(Final Price)	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline
	00-08	00-08	09-15	00-08	00-08	09-15
	(1)	(2)	(3)	(4)	(5)	(6)
Scandal x Volkswagen	-0.141**	-0.091**	-0.093**	-0.155**	-0.095**	-0.091**
	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	0.220*	-0.013	0.017	0.290**	0.030	-0.034
	(0.12)	(0.03)	(0.03)	(0.13)	(0.06)	(0.04)
Volkswagen	-0.958***	-0.324***	-0.333***	-0.947***	-0.323***	-0.333***
	(0.10)	(0.04)	(0.04)	(0.11)	(0.04)	(0.04)
Secret reserve x Scandal	0.033	0.031	-0.030			
	(0.05)	(0.03)	(0.03)			
ln(start price) x Scandal				-0.010	-0.006	0.008**
				(0.01)	(0.01)	(0.00)
R^2 (within)	0.48	0.56	0.56	0.48	0.56	0.56
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. In Panel A, "VW" denotes Volkswagen car listings and "Non-VW" denotes non-Volkswagen care listings. In Panel B, other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

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Web Appendix

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
Positive Feedback Percentage	692	96.70	16.09	0	100	1,856	94.40	21.30	0	100
Buy-It-Now	692	0.14	0.35	0	1	1,856	0.16	0.37	0	1
SBIN	692	0.02	0.14	0	1	1,856	0.04	0.18	0	1
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	11.46	3.95	2	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
Positive Feedback Percentage	2,880	94.50	21.21	0	100	44,069	95.23	19.54	0	100
Buy-It-Now	2,880	0.21	0.41	0	1	44,069	0.19	0.39	0	1
SBIN	2,880	0.04	0.19	0	1	44,069	0.04	0.19	0	1
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	3.47	2	17	44,069	10.80	4.26	2	17
Mileage	2,880	155011.90	203309	1	9999999	44,069	105379.10	117056.70	1	9999999

Note: "Buy-It-Now" is a dummy variable to indicate whether the auction has a Buy-It-Now option, "SBIN" is a dummy variable that indicates whether the listing is sold through the Buy-It-Now option, "Secret Reserve" is a dummy variable to indicate whether the auction has a secret reserve price, "Buyer Shipping" is a dummy variable to indicate whether the winning buyer needs to pay the shipping fee.

Table A2: All the Car Makes in the Sample

Make	Diesel		Gasoline		Freq.	Percent	Cum.
	00-08	09-15	00-08	09-15			
Acura	0	0	461	135	596	1.20	1.20
Aston Martin	0	0	19	10	29	0.06	1.26
Audi	0	40	1,239	516	1,795	3.63	4.89
BMW	0	38	2,468	860	3,366	6.80	11.69
Bentley	0	0	40	4	44	0.09	11.78
Buick	0	0	392	261	653	1.32	13.10
Cadillac	0	0	1,240	885	2,125	4.29	17.39
Chevrolet	71	6	538	236	851	1.72	19.11
Chrysler	0	0	1,095	374	1,469	2.97	22.08
Dodge	385	34	847	389	1,655	3.34	25.42
Ferrari	0	0	24	5	29	0.06	25.48
Fiat	0	0	0	72	72	0.15	25.63
Ford	1,568	166	3,626	2,120	7,480	15.11	40.74
GMC	133	27	623	306	1,089	2.20	42.94
Honda	0	0	2,140	789	2,929	5.92	48.86
Hummer	18	0	181	10	209	0.42	49.28
Hyundai	0	0	512	360	872	1.76	51.04
Infiniti	0	0	454	250	704	1.42	52.46
Isuzu	25	0	73	0	98	0.20	52.66
Jaguar	0	0	553	80	633	1.28	53.94
Jeep	40	2	874	290	1,206	2.44	56.38
Kia	0	0	243	212	455	0.92	57.29
Lamborghini	0	0	13	8	21	0.04	57.34
Land Rover	1	2	520	106	629	1.27	58.61
Lexus	0	0	755	197	952	1.92	60.53
Lincoln	0	0	664	303	967	1.95	62.48
Lotus	0	0	20	1	21	0.04	62.53
Maserati	0	0	65	15	80	0.15	62.69
Mazda	1	0	775	190	966	1.95	64.64
Mercedes-Benz	138	109	2,128	570	2,945	5.95	70.59
Mercury	0	0	342	21	363	0.73	71.32
Mini	0	0	342	183	525	1.06	72.38
Mitsubishi	6	0	412	78	496	1.00	73.39
Nissan	2	0	1,625	807	2,434	4.92	78.30
Oldsmobile	0	0	77	0	77	0.15	78.46
Other	19	1	10	14	44	0.09	78.55
Plymouth	0	0	17	0	17	0.03	78.58
Pontiac	0	0	578	30	608	1.23	79.81
Porsche	1	2	285	58	346	0.70	80.51
Ram	3	36	3	65	107	0.22	80.73
Replica/Kit Makes	0	0	12	9	21	0.04	80.77
Saab	0	0	546	39	585	1.18	81.95
Saturn	0	0	367	18	385	0.78	82.73
Scion	0	0	119	54	173	0.35	83.08
Smart	5	0	50	65	120	0.24	83.32
Subaru	0	0	995	295	1,290	2.61	85.93
Suzuki	0	0	143	20	153	0.33	86.26
Toyota	0	1	2,471	796	3,268	6.60	92.86
Volkswagen	426	266	1,420	436	2,548	5.15	98.01
Volvo	0	0	887	100	987	1.99	100.00
Total	2,842	730	33,283	12,642	49,497	100	

Figure A1: Monthly Ratios of Volkswagen and Non-Volkswagen Sold Car Listings

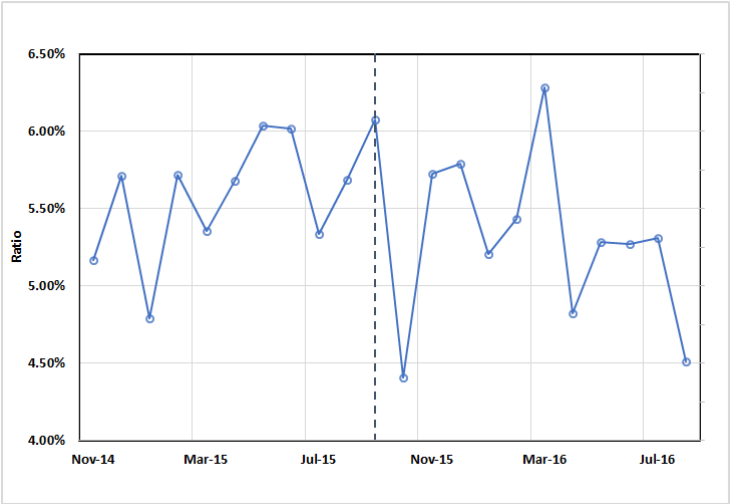


Table A3: Effects of Other Characteristics on Auction Prices

	Diesel 00-08			Gasoline 00-08			Gasoline 09-15		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ln(Car Age)	-0.734***	-0.734***	-0.868***	-1.609***	-1.609***	-1.723***	-0.391***	-0.391***	-0.485***
	(0.06)	(0.08)	(0.08)	(0.02)	(0.07)	(0.06)	(0.01)	(0.04)	(0.03)
ln(Mileage)	-0.068***	-0.068***	-0.063***	-0.102***	-0.102***	-0.101***	-0.062***	-0.062***	-0.054***
	(0.01)	(0.02)	(0.02)	(0.00)	(0.04)	(0.04)	(0.00)	(0.01)	(0.01)
ln(Start Price)	0.052***	0.052***	0.048***	0.086***	0.086***	0.068***	0.050***	0.050***	0.032***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Secret Reserve	0.282***	0.282***	0.277***	0.384***	0.384***	0.344***	0.367***	0.367***	0.320***
	(0.03)	(0.04)	(0.03)	(0.01)	(0.03)	(0.02)	(0.01)	(0.04)	(0.04)
Buy-It-Now	0.685	0.685***	0.701***	-1.256***	-1.256**	-1.151*	0.118	0.118*	0.532***
	(0.56)	(0.15)	(0.14)	(0.31)	(0.59)	(0.60)	(0.36)	(0.07)	(0.17)
SBIN	0.144**	0.144**	0.061	0.254***	0.254***	0.252***	0.092***	0.092***	0.077***
	(0.06)	(0.07)	(0.07)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
ln(Seller Feedback)	0.011	0.011	0.006	-0.037***	-0.037	-0.025	0.015***	0.015	0.010
	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)	(0.00)	(0.02)	(0.01)
Positive Feedback Percentage	-0.001**	-0.001***	-0.001**	0.001***	0.001*	0.001*	-0.002***	-0.002***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Duration	0.037***	0.037***	0.041***	0.097***	0.097***	0.083***	0.045***	0.045***	0.038***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)	(0.00)	(0.01)	(0.01)
Buyer Shipping	0.023	0.023	-0.002	-0.064***	-0.064*	-0.054	0.075***	0.075	0.052
	(0.07)	(0.06)	(0.07)	(0.02)	(0.04)	(0.04)	(0.02)	(0.06)	(0.05)
Photos	0.008***	0.008***	0.008***	0.009***	0.009***	0.007***	0.007***	0.007***	0.005***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of Bidders	0.026***	0.026***	0.026***	0.050***	0.050***	0.039***	0.020***	0.020***	0.010***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: Each column in this table corresponds to that in Table 2, presenting the results for control variables. For convenience, we denote the natural log of car age by ln(Car Age), the natural log of traveled mileage by ln(Mileage), the natural log of start price by ln(Start Price), the natural log of seller feedback by ln(Seller Feedback), "Buy-It-Now" is a dummy variable to indicate whether the auction has a Buy-It-Now option, "SBIN" is a dummy variable that indicates whether the listing is sold through the Buy-It-Now option, "Secret Reserve" is a dummy variable to indicate whether the auction has a secret reserve price, "Buyer Shipping" is a dummy variable to indicate whether the winning buyer needs to pay the shipping fee. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Volkswagen diesel violating group. In this subsection, we examine consumers' responses to the emissions violating group: Volkswagen diesel cars in model years 2009-2015 (the summary statistics are presented in Table A4). In particular, we estimate equation (1), where the treatment group consists of these violating cars. As presented in Columns (1) - (3) of Table A5, the estimated coefficients on the interaction term are negative and significant at the five percent level, suggesting that the auction final price for Volkswagen violating group dropped as a result of the scandal. Somewhat surprising about the results are the point estimates. We would expect a dramatic price drop for Volkswagen emissions violating cars. However, the point estimates exhibit a decline in price by about 11-13 percent, while the magnitude of the decline in price for diesel non-violating group is 14 percent (Column (3) in Table 2). We further find that the declines in price are not significantly different between the two groups; the impact of the scandal announcement on the final price seems to be the same regardless of whether the diesel car is a violator or not.[15]

These results could be explained by the following reasons. First, as shown in Figure 2, the scandal decreases the supply of the Volkswagen violating cars, which would increase the final price of a Volkswagen violating car. Second, after the emissions scandal announcement, rational consumers would have lowered their demand to reflect consumers' disappointment and the potential higher 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 announcement, including recall, buyback, and/or cash payment, and that only violating model owners would be eligible for compensation from Volkswagen, as firms usually do so when recalling their products. 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.[16] Therefore, both effects weaken the overall impacts of the scandal on the price of the Volkswagen violating group.

[15]The estimation result is reported in Column (4) of Table A6. Further, we examine the difference in the price drops between the Volkswagen emissions violating group and non-violating groups. To do so, we drop car listings from other brands but keep Volkswagen car listings only. The price difference is captured by the triple interaction term of the scandal dummy, the diesel dummy, and the group dummy. The estimation result is reported in Column (5) of Table A6, showing that the coefficient of the interaction term is not statistically significant.

[16]As mentioned in Section 2, on October $25, 2016$, Volkswagen 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 U.S. On April $21, 2017$, Volkswagen was issued a 2.8-billion-dollar criminal fine by the U.S. Justice Department for cheating on the emissions tests.

Table A4: Summary Statistics - Volkswagen Emissions Violating Diesel Cars

	Obs.	Mean	S.D	Min	Max
Auction Characteristics					
Start Price	266	1947.47	4074.97	0.99	31000
Final Price	266	11302.14	5187.13	2855	38888
Seller Feedback	266	505.31	1358.10	1	11991
Positive Feedback Percentage	266	97.89	12.35	0	100
Buy-It-Now	266	0.14	0.35	0	1
SBIN	266	0.03	0.16	0	1
Secret Reserve	266	0.17	0.37	0	1
Photos	266	8.10	8.97	1	24
Duration	266	6.95	1.51	3	10
Buyer Shipping	266	0.97	0.17	0	1
Number of Bidders	266	10.29	4.74	0	26
Car Characteristics					
Car Age	266	6.01	1.53	2	8
Mileage	266	84320.74	43863.29	1	252900

Note: "Buy-It-Now" is a dummy variable to indicate whether the auction has a Buy-It-Now option; "SBIN" is a dummy variable that indicates whether the listing is sold through the Buy-It-Now option; "Secret Reserve" is a dummy variable to indicate whether the auction has a secret reserve price; "Buyer Shipping" is a dummy variable to indicate whether the winning buyer needs to pay the shipping fee.

Table A5: Volkswagen Emissions Violating Diesel Cars

	(1)	(2)	(3)
Scandal x Volkswagen	-0.126***	-0.126**	-0.106**
	(0.05)	(0.06)	(0.05)
Scandal	0.002	0.002	-0.020
	(0.14)	(0.06)	(0.06)
Volkswagen	-0.665***	-0.665***	-0.547***
	(0.04)	(0.06)	(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: Columns (1) - (3) are the results when adding different fixed effects in the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table A6: Robustness Checks -
The Impacts of the Emissions Scandal Across Model-Year Categories

ln(Final Price)	(1)	(2)	(3)	(4)	(5)
Scandal	0.030	0.004	0.010	0.185**	0.108
	(0.03)	(0.04)	(0.03)	(0.09)	(0.09)
Volkswagen	-0.316***	-0.318***	-0.341***	-0.576***	
	(0.04)	(0.04)	(0.04)	(0.08)	
Scandal x Volkswagen	-0.091**	-0.097**	-0.065*	-0.148**	
	(0.04)	(0.04)	(0.04)	(0.06)	
Group	0.194**			0.314***	0.098
	(0.09)			(0.06)	(0.08)
Group x Volkswagen	-0.025			0.108	
	(0.05)			(0.07)	
Group x Scandal	-0.096***			-0.114**	-0.092
	(0.01)			(0.05)	(0.06)
Group x Scandal x Volkswagen	0.037			0.023	
	(0.06)			(0.08)	
Diesel		0.688***	0.677***		0.073
		(0.04)	(0.03)		(0.04)
Diesel x Volkswagen		-0.541***	-0.540***		
		(0.07)	(0.08)		
Diesel x Scandal		0.106**	0.112***		0.096*
		(0.04)	(0.04)		(0.06)
Diesel x Scandal x Volkswagen		-0.020	-0.045		
		(0.10)	(0.10)		
Diesel x Group					0.116
					(0.07)
Diesel x Group x Scandal					-0.043
					(0.12)
R^2 (within)	0.61	0.57	0.61	0.59	0.59
Obs.	45,925	36,125	48,767	3,572	2,548

Note: Column (1) is the result for the gasoline cars in model years 2000 - 2015; Column (2) is the result for the gasoline and diesel cars in model year 2000-2008; Column (3) is the result for the gasoline cars in model years 2000 - 2015 and the diesel cars in model year 2000-2008; Column (4) is the result for the diesel cars in model years 2000 - 2015; Column (5) is the result when pooling all the Volkswagen gasoline and diesel cars and dropping car listings from other brands. "Group" is a dummy variable that if a car is in model years 2009-2015, equals 1, and if a car is in model years 2000 - 2008, equals 0. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Figure A2: Monthly Average Final Prices of the Non-Volkswagen Car Listings $\leq$ 10,000 U.S Dollars

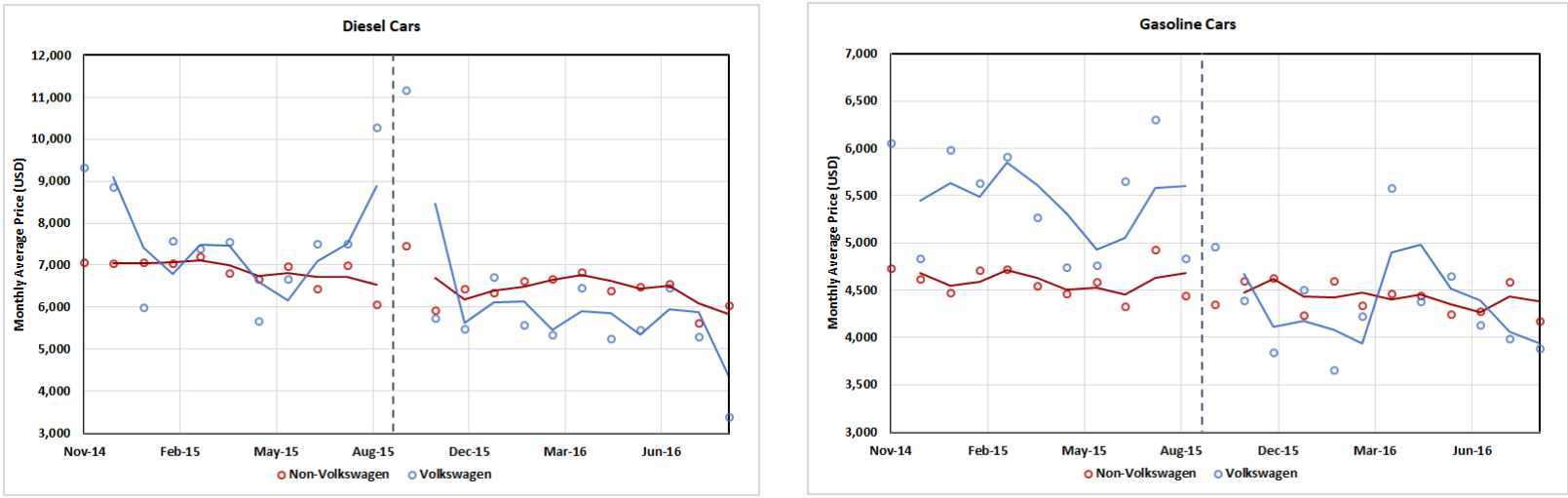


Table A7: Car Make Weights in Synthetic Volkswagen

Gasoline 00-08		Gasoline 09-15	
Brand	Weight	Brand	Weight
Acura	0	Audi	0
Audi	0	BMW	0
BMW	0	Cadillac	0
Buick	0	Chrysler	0
Chrysler	0	Ford	0
Ford	0	GMC	0
GMC	0	Honda	0
Honda	0	Kia	0.544
Hummer	0	Lexus	0
Hyundai	0	Mazda	0.201
Isuzu	0.133	Mercedes-Benz	0
Kia	0	Nissan	0
Lexus	0.192	Subaru	0.255
Mazda	0	Toyota	0
Mercedes-Benz	0	Volvo	0
Mercury	0		
Mini	0		
Mitsubishi	0		
Nissan	0		
Saab	0		
Subaru	0		
Suzuki	0		
Volvo	0.675		

Table A8: Means Before the Emissions Scandal

	Gasoline 00-08		Gasoline 09-15	
	Volkswagen	Synth. Volkswagen	Volkswagen	Synth. Volkswagen
Avg. Age	2.407821	2.405468	1.729305	1.660284
ln_Avg. Mileage	11.65729	11.64571	11.05234	10.84230
ln_Avg.Price 1	8.711617	8.703036	9.321743	9.324451
ln_Avg.Price 3	8.549078	8.540486	9.205694	9.212877
ln_Avg.Price 4	8.754998	8.746580	9.214955	9.210457

Table A9: Robustness Checks -
The Impacts of the Emissions Scandal Announcement on Other Major Car Manufacturers

ln(Final Price)	Diesel 00-08	Gasoline 00-08	Gasoline 09-15	Diesel 00-08	Gasoline 00-08	Gasoline 09-15
	(1)	(2)	(3)	(4)	(5)	(6)
	GMC	GMC	GMC	Mercedes	Mercedes	Mercedes
Scandal x Brand	0.037	0.023	0.090	-0.125	-0.048	-0.074
	(0.08)	(0.04)	(0.08)	(0.08)	(0.03)	(0.06)
Scandal	0.185	-0.039	0.026	0.172	-0.036	0.037
	(0.13)	(0.04)	(0.04)	(0.14)	(0.04)	(0.04)
Brand	0.214***	0.105***	-0.008	-0.070	0.350***	0.561***
	(0.05)	(0.04)	(0.07)	(0.06)	(0.03)	(0.05)
R^2 (within)	0.19	0.46	0.34	0.19	0.46	0.37
Obs.	2,416	31,863	12,206	2,416	31,863	12,206

	(7)	(8)	(9)	(10)	(11)	(12)
	Honda	Honda	Honda	Toyota	Toyota	Toyota
Scandal x Brand		0.005	-0.018		-0.015	0.001
		(0.03)	(0.04)		(0.03)	(0.03)
Scandal		-0.039	0.032		-0.032	0.029
		(0.04)	(0.04)		(0.04)	(0.04)
Brand		-0.062***	-0.136***		0.135***	-0.022
		(0.02)	(0.04)		(0.01)	(0.03)
R^2 (within)		0.46	0.34		0.46	0.34
Obs.		31,863	12,206		31,863	12,206

	(13)	(14)	(15)
	Ford	Ford	Ford
Scandal x Brand	0.081	0.011	0.015
	(0.06)	(0.03)	(0.02)
Scandal	0.105	-0.039	0.035
	(0.13)	(0.04)	(0.04)
Brand	-0.066	-0.122***	-0.220***
	(0.04)	(0.01)	(0.02)
R^2 (within)	0.19	0.46	0.36
Obs.	2,416	31,863	12,206

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Different categories of body types and quantiles of final prices. Here, we examine how the impacts of the scandal vary across different car body type categories. We broadly classify all the auction listings in the sample into four categories according to car body types: (1) Sedan and Hatchback (SH), (2) SUV, (3) Coupe and Convertible (CC), and (4) Van. We then estimate equation (1) for each body type category; the exception is diesels in model years 2000-2008 of the Coupe and Convertible category, where we do not have a sufficient number of observations for estimation (there are only 35 observations in the category).

As reported in Panel A of Table A10, each body type category includes at least one fuel type - model year combination for which the DID estimate is negative and statistically significant. Our main results are therefore not driven by particular body type categories. In most body type - model year categories, the DID estimates are negative and significant at least at the ten percent level. The point estimates show that the prices declined by 28.3, 26.4, and 26 percent for SUV-diesel in model years 2000-2008, CC-gasoline in model years 2009-2015, and Van-diesel in model years 2000-2008, respectively. In contrast, in the categories of SH-gasoline in model years 2000-2008 and Van-gasoline in model years 2000-2008, there was a small and insignificant decline in price.

We further investigate how buyers responded to the scandal across different price levels. For this purpose, we classify all the auction listings by the final price quartiles (the cutoffs are $1,250, $6,400, and $15,100) and then estimate equation (1) for each price quantile. The results are presented in Panel B of Table A10 (where Columns (1) and (3) are blank due to insufficient number of observations for estimation). The estimated coefficients on the interaction term are negative and statistically significant in most of the regressions, demonstrating that our main results hold in a wide range of final prices.

Table A10: Robustness Checks -Different Categories of Body Types and Four Quartiles of Final Prices

Panel A	SH			SUV			CC			Van		
	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline
	00-08	00-08	09-15	00-08	00-08	09-15	00-08	00-08	09-15	00-08	00-08	09-15
ln(Final Price)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scandal x Volkswagen	-0.155**	-0.024	-0.087*	-0.283**	-0.181*	-0.196*		-0.102	-0.264**	-0.260*	-0.043	0.110
	(0.07)	(0.04)	(0.05)	(0.12)	(0.10)	(0.11)		(0.08)	(0.10)	(0.14)	(0.09)	(0.09)
Scandal	0.047	-0.068	0.013	0.098	-0.020	0.074*		0.097	-0.144	0.092	0.053	-0.047
	(0.10)	(0.05)	(0.05)	(0.15)	(0.06)	(0.04)		(0.07)	(0.11)	(0.18)	(0.10)	(0.09)
Volkswagen	-0.586***	-0.326***	-0.265***	-0.272***	-0.136	-0.208		-0.302**	-1.684***	-1.206***	-0.292***	0.005
	(0.09)	(0.05)	(0.06)	(0.09)	(0.09)	(0.14)		(0.13)	(0.10)	(0.15)	(0.09)	(0.13)
R^2 (within)	0.58	0.57	0.55	0.62	0.57	0.52		0.60	0.66	0.31	0.48	0.51
Obs.	339	12,175	6,005	310	7,321	2,812		5,895	1,844	1,762	5,547	1,447

Panel B	Q1			Q2			Q3			Q4		
	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline	Diesel	Gasoline	Gasoline
	00-08	00-08	09-15	00-08	00-08	09-15	00-08	00-08	09-15	00-08	00-08	09-15
ln(Final Price)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scandal x Volkswagen		-0.130**		0.031	-0.072***	-0.053*	-0.281***	-0.041**	-0.078***	-0.391**	0.065	0.017
		(0.06)		(0.05)	(0.02)	(0.03)	(0.09)	(0.02)	(0.03)	(0.16)	(0.22)	(0.11)
Scandal		-0.017		0.258	0.001	0.038	0.097	-0.056	0.033	-0.183	0.160*	0.025
		(0.09)		(0.23)	(0.03)	(0.09)	(0.10)	(0.03)	(0.03)	(0.18)	(0.09)	(0.05)
Volkswagen		0.131		-0.255***	-0.084***	0.059	-0.054	-0.057**	-0.022	-0.239***	0.148	-0.328***
		(0.05)		(0.05)	(0.02)	(0.05)	(0.06)	(0.03)	(0.02)	(0.06)	(0.15)	(0.07)
R^2 (within)		0.24		0.19	0.23	0.10	0.05	0.07	0.10	0.18	0.14	0.18
Obs.		3340		796	20,572	1,629	1,414	7,500	5,222	591	1,871	5,774

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. In Panel A, Columns (1) - (3) are for Sedan and Hatchback, denoted by SH; Columns (4) - (6) for SUV; Columns (7) - (9) for Coupe and Convertible, denoted by CC; Columns (10) - (12) for Van. In Panel B, Q1, Q2, Q3, and Q4 are corresponding to quartiles 1, 2, 3, and 4. Other control variables are also included in all the regressions. In Panel A, year fixed effects, month fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. In Panel B, year fixed effects, month fixed effects, body type fixed effects, seller fixed effects, and make fixed effects are also included in all regressions above. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

New car market. The new car market may influence the market values of used cars. In our context, changes in values and sales of new Volkswagen cars after the EPA's announcement might have influenced consumers' purchasing behavior in the used car markets. To address this issue, we incorporate into our data monthly total new car sales data and new Volkswagen car sales data in the U.S. and examine whether our main results are robust to controlling for sales information in the new car market.[17]

Columns (1) - (3) of Table A11 are the estimation results with the monthly total new car sales data. Despite the fact that the new car sales play some role in WTP for a used car after the scandal announcement, the DID estimates remain almost the same as those in Table 2. We obtain similar results when controlling for the new Volkswagen car sales data (Columns (4)-(6)). Our main results therefore do not depend on the new car market.

Table A11: Robustness Checks - the Impacts of New Car Markets

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	-0.148**	-0.093**	-0.092**	-0.149**	-0.092**	-0.092**
	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)
Scandal	-6.029**	-2.343**	0.615	-4.675**	-1.295*	-0.031
	(2.67)	(0.95)	(1.24)	(2.21)	(0.67)	(0.85)
Volkswagen	-0.940***	-0.324***	-0.332***	-0.939***	-0.323***	-0.332***
	(0.10)	(0.04)	(0.04)	(0.10)	(0.04)	(0.04)
ln(New)	-0.678	0.087	-0.215			
	(0.60)	(0.19)	(0.16)			
Scandal x ln(New)	0.442**	0.165**	-0.042			
	(0.19)	(0.07)	(0.09)			
ln(New Volkswagen)				-0.535	0.153	-0.202
				(0.57)	(0.11)	(0.17)
Scandal x ln(New Volkswagen)				0.483**	0.127*	0.004
				(0.22)	(0.07)	(0.08)
R^2 (within)	0.48	0.56	0.56	0.48	0.56	0.56
Obs.	2,842	33,283	12,642	2,842	33,283	12,642

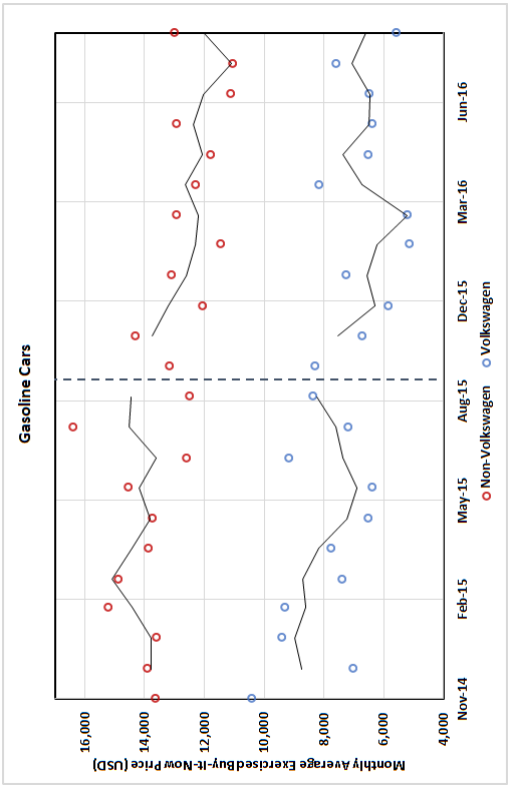
Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. "New" denotes monthly new car sales. "New Volkswagen" denotes monthly Volkswagen new car sales. Columns (1)-(3) are the results in which monthly new car sales data are included; Columns (4)-(6) are the results in which monthly Volkswagen new car sales data are included. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

[17]The monthly total new car sales data are collected from U.S. Bureau of Economic Analysis, and the monthly new Volkswagen car sales data are collected from GoodCarBadCar.net, a car sales data and statistics company.

Buy-It-Now options. In Figure A3, we present monthly average exercised Buy-It-Now prices, showing a similar pattern that the gap between Volkswagen and non-Volkswagen cars becomes wider after the start of the scandal, especially for the diesel car market. This observation may seem to introduce doubt regarding whether our main results are driven by the differences in the Buy-It-Now prices after the emissions scandal announcement. To address these concerns, we show in the following that our main results hold after dropping all the listings that are ended through the Buy-It-Now option.

As mentioned above, the seller can offer a Buy-It-Now option in eBay auctions. In the auction with this option where the seller pre-determines the Buy-It-Now price, the first arriving bidder who is willing to pay the Buy-It-Now price can immediately obtain the object by exercising it; in this case, we may treat the seller as a "bidder" in the auction, and the price of the option is the second highest bid. One might wonder the extent to which our main results are influenced by removing those auctions from the sample, as the buyer's optimal bidding strategy may depend on whether or not the Buy-It-Now price is available (Wang et al., 2008). To address this question, we re-estimate equation (1) by excluding 1,774 auctions that were ended through the Buy-It-Now option (87 diesel car listings in model years 2000-2008, and 1,125 and 562 gasoline car listings in model years 2000-2008 and 2009-2015, respectively). As reported in Columns (7) - (9) of Table A12, the estimated coefficients on the interaction terms are negative and significant at the five percent level; moreover, the point estimates are similar in magnitude to those reported in Table 2. Our DID estimates are therefore robust to the exclusion of the listings ended through the Buy-It-Now option from the sample.

Figure A3: Monthly Average Exercised Buy-It-Now Prices



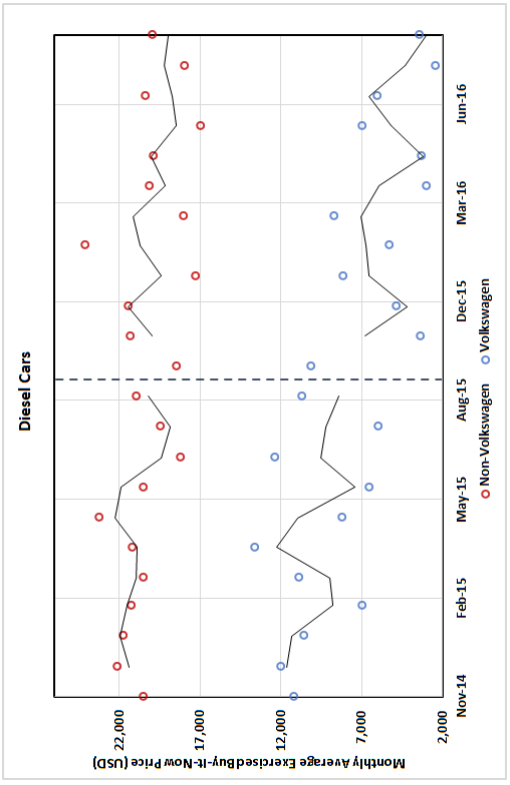


Table A12: Robustness Checks - the Impacts of Buy-It-Now options

ln(Final Price)	Diesel 00-08 (1)	Gasoline 00-08 (2)	Gasoline 09-15 (3)
Scandal x Volkswagen	-0.140**	-0.086**	-0.098**
	(0.06)	(0.04)	(0.04)
Scandal	0.234*	-0.020	0.006
	(0.12)	(0.04)	(0.03)
Volkswagen	-0.954***	-0.329***	-0.315***
	(0.11)	(0.04)	(0.04)
R^2 (within)	0.48	0.56	0.56
Obs.	2,755	32,158	12,080

Note: "00-08" denotes model years 2000 - 2008; "09-15" denotes model years 2009 - 2015. Columns (1)-(2) are the results where we exclude transactions that are ended through the Buy-It-Now option. Other control variables and fixed effects are also included in all the regressions. $***$, $**$, and $*$ denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Figure A4: Monthly Average Start Prices