

Is high-quality production location-specific? Evidence from the automobile industry^{*}

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Abstract

A large literature has documented substantial heterogeneity in the performance of similar firms within industries, but what are the sources of that heterogeneity? In this paper we investigate one potential source of differential performance, the role of location-specific factors, including the quality and attitudes of the local workforce, the type of supplier networks, the education system, the institutional infrastructure, and local “culture.” We focus on the automobile industry and in particular the role that location-specific factors play in determining the quality of automobile production. We exploit the natural experiment provided by the establishment of assembly plants in the U.S. by Japanese auto manufacturers. A number of the most popular Japanese car models are assembled both in Japanese plants and U.S. plants. We use a unique data set of over 400,000 used-car transactions at wholesale auctions to test whether the long-run quality of otherwise identical cars depends on the country of assembly. Japanese-assembled cars sell for a modest \$50 more on average and other measures of quality also show small or no differences. The finding that American plants can produce high quality (Japanese) cars suggests that there is not an inherent limitation to the U.S. manufacturing environment and that the sources of heterogeneity in quality automobile production are likely dominated by *firm-specific* rather than *location-specific* factors.

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1. Introduction

The existence of heterogeneity among firms, even within narrowly defined industries, is now a well-accepted finding in many streams of research in economics and management. Evidence from large-sample as well as case studies has convincingly shown that seemingly similar companies differ in several measures of performance, from productivity to product quality and profitability. Theoretical and empirical contributions highlight the economic relevance of these heterogeneities through their effects on industry structure and evolution, on the patterns of international trade and investments, and ultimately on economic growth.¹

There is less agreement and less empirical evidence, however, on the *sources* of heterogeneity among firms. While the debate has long focused on assessing the relative influence of firm-specific vs. industry-specific factors,² several studies over the past decades have suggested that some of the sources of a firm's competitive advantage or disadvantage might be location-specific factors, including the quality and attitudes of the local workforce, the type of supplier networks, and more broadly, the education system, the institutional infrastructure, and local "culture".³ The debate has revived in recent years, mostly as a consequence of two important phenomena. First, the increasing relevance of multinational companies has led several scholars to investigate the determinants of their location decisions, as well as their ability to transfer their best practices in different establishments, within and between countries.⁴ Second, in response to the perceived crisis of the overall manufacturing sector in several countries and in particular the United States, discussions have emerged on whether corporate and business strategies and other managerial decisions, over time, are responsible for the decline in competitiveness and employment in U.S. manufacturing; or more structural characteristic of the U.S. environment make it "unfit" to the

¹ Studies documenting heterogeneity include: Argote and Epple, 1990; Bloom and Van Reenen, 2010; Chew, Bresnahan and Clark, 1990; Ichniowski, Shaw, and Prennushi, 1997; Syverson, 2004. For theoretical and empirical analyses of the effects of firm heterogeneity, see, among others: Adner and Zemsky, 2006; Aghion and Howitt, 2009; Chaney, 2008; Dunne, Roberts and Samuelson, 1989; Helpman, Melitz and Yeaple, 2004; Henderson and Cockburn, 1994; Jovanovic, 1982; Lippman and Rumelt, 1982; Nelson, 1991; Nelson and Winter, 1982; Redding, 2011; Yeaple, 2009.

² McGahan and Porter 1997, 1999; Rumelt, 1991; Schmalensee, 1985.

³ See for example: Barrell and Pain, 1999; Council of Competitiveness and Deloitte, 2010; Dertouzos, Lester and Solow, 1989; Makin, Isobe and Chan, 2004; McGahan and Victor, 2009; Porter, 1998; Safford, 2009.

⁴ See, among others: Abo, 1994; Beechler and Yang 1994; Bloom, Sadun and Van Reenen, 2010; Doeringer, Lorenz and Terkla, 2003; Gertler, 2001; Liker, Fruin and Adler, 1999; Lowe, Morris and Wilkinson, 2000. Rivkin, 2001 and Szulanski, 1996 have studied in more general terms (not only with reference to multinationals) issues of replications of practices and strategies within and between organizations.

production of high-quality, competitive goods.⁵ It is clearly important to both policymakers and managers to understand if in fact these types of location-specific factors play a central role in the relative performance of firms. Yet it is often a challenge to identify empirically the effect of location-specific factors separately from other aspects of the firm.

In this paper, we investigate this question in the context of the automobile industry. We exploit a natural experiment provided by the presence of assembly plants of Japanese auto-manufacturers in the U.S. In addition to producing in their Japanese plants, Japanese car manufacturers established production plants in the U.S. as a result of the import barriers created by the Voluntary Export Restraints of the early 1980s. Honda and Nissan set up their first American assembly plants in 1982 and their move was soon followed by all other major Japanese car makers (Chung, Mitchell and Yeung, 2003). These Japanese-owned auto assembly plants have, increasingly, employed the local workforce (both on the shop floor and in managerial positions) and relied on U.S.-based parts suppliers (Abo, 1994; Chung et al., 2003; Dertouzos et al, 1989; Hashimoto, 1994; Klier and Rubenstein, 2008). Because a number of Japanese car models, including some very popular, high-volume automobiles (e.g., Honda Accord, Toyota Camry) are produced in both Japanese-based and U.S.-based plants, it is possible to compare whether the short-run and long-run quality of cars is affected by the country of production, holding fixed company-level factors.

We use a unique dataset from the leading provider of wholesale used car auctions in the U.S.; the dataset includes over 400,000 Japanese-make used cars brought to auction between 2002 and 2008. The data contain detailed information on each car and, importantly, we can observe the Vehicle Identification Number (VIN) that lists the country of manufacture for each vehicle. With that information, we can investigate whether there are long-run quality differences along a number of dimensions for identical cars depending on whether they were assembled in the U.S. or Japan. The idea behind this empirical strategy is analogous to that adopted by Bloom, Sadun, and Van Reenen (2010), who analyze differences in the impact of IT adoption on productivity between U.S.-owned and non-U.S.-owned “observationally identical” plants in the U.K. This strategy allowed

⁵ Among the recent contributions to the scholarly and policy debate on this issue, see for example: Engardio, 2009; Helper, 2009; Magnus, 2010; Pisano, 2010; Tassej, 2010.

them to separate location-specific factors from management-level determinants of the effectiveness of IT investments.

Our primary measure of quality is simply the sale price. The bidders at wholesale auctions are used-car dealers who intend to resell cars to final customers. Given the competitive nature of these auctions, any observable quality differences should be incorporated into the sale price of used cars. Thus, for our main analysis, we run regressions of sale price on an indicator for whether the car was produced in Japan or the U.S., controlling for key observable characteristics of the car (e.g., mileage). Because of the large size of our dataset, we are able to include very fine-level fixed effects for the combination of make, model, model year, body style, auction site, and year. We can identify the Japan–U.S. price difference within, for example, the sample of 2002 Honda Accord SE 4-door sedans with 4-cylinder engines sold in 2005 at the auction site in Chicago. Using our full dataset, we find a statistically significant but very modest difference in sale prices, with Japanese cars selling for an estimated \$50 more than their U.S.-produced counterparts. Compared to the average sales price of \$8,899, this estimate implies that Japanese-built cars sell for around 0.6% more. At the 95% confidence level, we can rule out that the difference is any more than \$68. These price differentials are similar in absolute terms across a range of car ages. For example, the estimated difference for cars that are 1 to 3 years old is \$36 and for cars between 7 and 9 years of age is \$49.⁶ For older cars, the estimated differences are on the order of 1% to 2% of the average selling price. Interestingly, the Japanese–U.S. price differential seems to have decreased over time. The estimate of the difference for cars produced before 1999 is \$77 whereas, for those produced after 1999, it is only \$9.

In addition to sale prices, we examine other more direct measures of quality, including whether the car underwent reconditioning prior to sale, whether it was auctioned with announced defects, whether it sold at the auction, and, conditional on selling, whether there was a problem with the car that resulted in after-sale arbitration between the buyer and seller.⁷ All else equal, we find that Japanese-built cars are approximately 1% more likely to sell at auction (off a base rate of 64%). We find no significant differences between Japan-built and U.S.-built Japanese cars along any of the other quality dimensions.

⁶ Of course, for older cars, this differential reflects a higher percentage relative to the average sale price.

⁷ The use of sale prices at auctions together with more direct measures of quality to assess quality differences across durable goods is similar to the methodology adopted in Mas (2008).

Taken together, our estimates reveal that the quality of Japanese-make cars differs little depending on whether they were produced in the U.S. or Japan. This suggests that, at least in the car industry, the sources of high quality and superior performance likely stem from their corporate-level practices (including management characteristics and style, and corporate culture) and design, rather than from anything inherently superior about the specific manufacturing environment. Hence, although the recent massive recall of Toyota automobiles, because of a potential defect in the accelerator pedal produced by a U.S. supplier, revived debates about the difficulties of producing high-quality cars on American soil (Jackson, 2010; Kim and Krolicki, 2010; Welch, 2010), our results provide little support for an argument that there are systematic limitations to quality production in the United States.⁸

These results are particularly relevant in light of the recent crisis in the U.S. automotive industry, which required a massive government intervention along the entire auto-making value chain. In addition to addressing the immediate emergencies of the industry, policymakers have shown a renewed interest in understanding the origins of the performance differential, in particular, between American and Japanese car manufacturers. Japanese cars are generally perceived to be of higher quality and more reliable (Cusumano, [1985, 1988]; Fujimoto, 2000; JD Power and Associates, 2010; Train and Winston, 2007; Womak, Jones, and Roos, 1990). Many scholars have argued that this quality premium is the key to the success of Japanese brands in the North American market (Barber and Darrough, 1996; Cusumano, 1985; Helper, 1991; Shimokawa, 2010). Better design, management practices, and corporate culture in Japanese firms have long been identified as the main determinants of this quality differential (Yates, 1983; Womack et al., 1990). However, a number of studies have also highlighted location-specific characteristics of the American environment itself (e.g., labor relations, supplier networks, workers' attitudes and education) that might affect the ability to produce high-quality cars in the U.S. (Aoki, 1988; Dassbach, 1994; Dore and Sako, 1998; Hashimoto, 1994; Helper, 1991; Hofstede, 1984; Ingrassia and White, 1994; Sako and Helper, 1998). Our results suggest that the sources of the Japanese quality advantage are unlikely to be strongly related to the location-specific manufacturing environment in the U.S.

⁸ During the summer of 2010, a number of papers reported that early testing of this issue by the U.S. Department of Transportation actually found no evidence that faulty accelerators were the cause of unwanted reported problems with sudden acceleration and seemed to suggest that the primary problem might have been driver error.

In addition to contributing to the literature on the origins of performance differences across similar organizations, our paper provides some insights into the transferability of practices and performance within organizations, an issue of particular relevance for multinational companies as they try to transfer their practices to their foreign “transplants.” The studies focused on multinationals mentioned above have, in some cases, documented convergence in organizational practices and productivity levels across plants in different countries but, in other instances, have also found that firms have difficulties replicating the practices of the plants in the home country abroad. Bloom et al. (2010), for example, find that U.S. multinationals have been able to obtain similar levels of productivity increase from investments in IT in their U.S. and U.K.-based establishments. With reference to the automobile industry, particular interest has been given to assessing whether and how the *Japanese* transplants in the U.S. and in other countries differ from the auto assembly plants in Japan in terms of productivity and the adoption of certain management practices (human resource management, just-in-time production, etc.). The findings are, again, mixed; whereas some studies document that the transplants are comparable to the original Japanese factories, other studies identify a series of weaknesses in the performance of Japanese plants abroad.⁹ Our results suggest that the Japanese automakers might have successfully exported their best practices to their transplants in the United States.

Our data and empirical approach also represent a contribution to this literature. At a basic level, the scale and quality of our data are rare in the literature on cross-plant performance differences, which is based on smaller sample and case studies, with the plants being compared potentially producing different products (or model of a product) thus making comparisons harder to interpret. We can compare products at a very granular level (i.e., “otherwise identical” car models), which gives us confidence in our estimates of cross-country differences. Perhaps more fundamentally, whereas most studies in this literature focus on *productivity* as the outcome of interest, our approach allows us to examine whether there are cross-plant differences in longer-run product *quality*. The data also allow us to explore whether quality differences emerge at various points in the products’ life cycle. These are important questions for the automobile industry and, more generally, for high-priced durable goods industries.

⁹ These studies include Fucini and Fucini 1990, Graham 1995, Hashimoto 1994, Kenney and Florida 1995, Pil and MacDuffie 1999, and Shibata 2001.

The remainder of the paper proceeds as follows. Section 2 describes the data in this study, and offers background information on the wholesale used car auction company from which the data have been obtained. In Section 3, we present our findings, first through graphical analysis and then through a regression framework. Section 4 offers a discussion and concluding remarks.

2. Data

The data for this study come from the largest operator of wholesale used-car auctions in the United States. The wholesale auction process starts when a seller brings a used car to one of the company's 89 auction facilities located throughout the U.S. Details of the car are registered into the company's system. The seller can then purchase detailing or reconditioning services from the auction company before a car is auctioned. Examples of reconditioning would include body work or repainting. Auction sites typically hold auctions once or twice a week. On these auction days, licensed used-car dealers come to the auction to purchase cars for resale. Depending on the particular auction site, more than 2,000 transactions can occur in a day. Most auction sites have somewhere between 4 and 7 auction lanes operating simultaneously, through which cars are driven and put onto the auction block. Once on the auction block, the used-car dealers bid for them in a standard English (oral ascending-price) auction that lasts around 2 minutes per car. The highest bidder receives the car and can take it back to his used-car lot himself (by driving it or placing it on a truck), or can arrange delivery through independent delivery agencies that operate at the auctions. After the auction ends, if the buyers discover a significant defect with the car that was not disclosed by the seller at the auction, the auction company provides an arbitration procedure that allows buyers to demand compensation from the seller and, potentially, to return the car for a refund.

Our data contain information about the auction outcome and other details for each car brought to auction from January 2002 through September 2008. The full dataset contains information on just over 27 million cars. We observe information about each car, including its make, model, body style, model year, and odometer mileage as well as an identifier for the buyer and seller who brought the car to the auction. Although all of the buyers at the auctions are used-car dealers, there is more diversity in the sellers. There are two major classes of sellers: car dealers and fleet/lease. A typical dealer sale might involve a new-car dealer bringing a car to auction that she

received via trade-in and does not wish to (or cannot) sell on her own lot. The fleet/lease category includes cars from rental-car companies, university or corporate fleets, and cars returned to leasing companies at the end of the lease period. The important difference between these two types of sellers for our analysis is that the fleet/lease sellers tend to bring cars to the auction in large lots and set very low reservation prices whereas the dealers who sell cars at auction set higher reservation prices and sell a lower fraction of their cars. For the most part, therefore, there are fewer potential selection issues with cars brought to the auction by fleet/lease companies, which we investigate in robustness analyses for our regression results later in the paper.

A number of different variables in the dataset are useful as outcomes in our analysis. The data report whether the car was sold and, if so, the sale price. There is also a range of information in the dataset related to a car's condition. First, many cars are given a condition report by the auction company when they arrive on the lot. Second, there is information on whether a seller purchased reconditioning services from the auction company for a given car prior to the auction. We also have information on whether the car had known defects at the time of the auction. Cars run through the auction using a system of lights (displayed as the car goes through the auction block) that signal the level of known defects with a car. A green light indicates that the car has no known major defects. When a car is assigned a yellow light, some specific defects are listed. A car that is assigned a red light may have some significant defects and is sold "as is." Finally, after the transaction, a buyer has the possibility of using an arbitration procedure offered by the auction company if they find major defects with the car that were not reported by the seller during the auction.

Crucial for our study, the data also report the Vehicle Identification Number (VIN) for each car at the auction. The 17-digit VIN of a car uniquely identifies a vehicle by its make, model, model year, body style, production year, production number on an assembly line, assembly plants, and, as indicated by the first digit of the VIN, the country where a car was assembled. For example, a number 1, 4, or 5 in the first digit of the VIN indicates that the car was assembled in the United States whereas the letter "J" indicates that the car was assembled in Japan.

On the auction day, the VIN of the car is reported on a screen above the auction block along with a range of other information about the car. The used-car dealers bidding at the auctions could determine the country of assembly for a car by looking at the VIN number. For this reason, any differences we find in the average selling price for cars assembled in different countries could

reflect quality differences the dealers observe at the auctions or their perceptions of the difference in value across country of production. Of course, if dealers systematically discount cars based solely on their observation of the country of assembly from the VIN number, and not from observed defects of the car, it must be that they anticipate lower value of those cars in the resale market. We focus on differences in value at the auctions and remain largely agnostic about the degree to which dealers are using direct information about the VIN in their auction purchase decisions. However, our anecdotal observations of the auction process and discussions with managers at the auction company do not give us any reason to suspect that dealers are systematically reacting to this information. We also doubt that many retail used-car buyers look for this information because very few people are familiar with VIN decoding.

In order to perform a meaningful analysis of comparable cars, we isolate all vehicles that were assembled in both the U.S. and Japan as identified by make, model, model year, and body style. We limit the analysis to car types in which at least 5% and no more than 95% of the cars were assembled in Japan. Because our analysis uses fine-grained fixed effects, we also limit our analysis to cars for which we have at least 20 observations of the same car in a given auction location and sold by the same category of seller (fleet/lease vs. dealer). We further focus on cars between 1 year and 15 years of age and with at least 1,000 miles and less than 250,000 miles on the odometer.

Overall, this sample of multi-country models includes 413,984 unique cars. The vast majority of the cars in this sample are Hondas (43%) and Toyotas (53%). The fraction of cars assembled in Japan is approximately 32% and is nearly identical for both Honda and Toyota cars. The cars that appear most frequently in our data are Honda Accords and Toyota Camrys (both with four-cylinder engines), with the two most frequent cars being the 1999 Honda Accord (47,603 cars) and the 1999 Toyota Camry (47,804 cars).

Table 1 provides basic summary statistics for this sample of cars. The average used car at an auction is just under 5 years old with a little less than 73,000 miles on the odometer. Approximately 64% of all cars brought to the auction sell, with an average selling price of roughly \$9,000.

This table also shows how these basic summary statistics vary by whether the car was assembled in the U.S. or Japan. For most variables, there is little difference between the American and Japanese cars. The two large differences that stand out in the raw data are that the Japanese cars

are (not surprisingly) more likely to appear in auctions in western states¹⁰ and that the Japanese cars have much higher average sale prices (\$10,056 vs. \$8,344). The primary goal of the empirical analysis in the next section is to estimate whether that difference actually reflects the effect of country of assembly or if it is instead the result of compositional differences in the cars assembled in the different countries.

3. Results

Our goal is to assess whether the country of assembly of cars affects their long-term value differences. The challenge for this analysis is how to measure long-run quality and value since there is no simple one-dimensional index of quality. Our baseline approach is to assess whether the prices of cars differ depending on whether they were produced in the U.S. or Japan holding all other relevant variables constant. Once we isolate a particular car type and control for key observables, such as mileage, the variation in prices at the auction will reflect noise, local-market fluctuations, and any quality differences in the cars that are observable to the buyers at the auction. It is this last source of variation that we are interested in, because it should reflect aspects of cars that are not captured in any quantitative datasets, such as visual appearance, engine noise, and rust.

We also assess the presence of value differences using five more direct measures of quality as outcome variables, as available in the dataset: whether the car was reconditioned before being auctioned; whether the car was given a positive condition report; whether the car was assigned a “green light” on the auction block, denoting no major defects; whether the car was sold at the auction; and whether an arbitration procedure was requested by the buyer after the car had been sold. The order in which we present these measures corresponds roughly to their relevant timing in the auction process. The condition report by the auction company and any reconditioning that the seller chooses to have performed are conducted prior to the auction. Information about these actions is available to auction buyers who wish to investigate it. The light system, indicating defects, is displayed prominently for all cars that run through the auction blocks and provides probably the cleanest measure of known major defects for a car. The reasons that might cause a car to run under a yellow or red light would include transmission problems, exhaust-system issues, structural

¹⁰ Of the states represented in the auction, we include AZ, CA, CO, HI, NV, NM, OR, UT, and WA as western states.

damage from an accident, and so on. While visible defects to a car should generally be priced into the car, a significant fraction of cars (36%) fail to sell at the auction. This suggests that some problems with cars could lead to a failure to sell rather than simply a reduction in sale price. For this reason, we also use the information on whether or not the car sold as an indicator for quality. Finally, the arbitration procedure exists to aid buyers who, after the car was transacted, find major defects with a car that were not disclosed.

3.1 Main findings

We begin our comparison of cars assembled in Japan with their U.S. counterparts with some simple graphs of average sale prices across a range of ages. Figure 1 shows the average prices of the four car models with the highest number of observations in our data (two Toyota Camry models and two Honda Accord models). These graphs provide our first suggestive evidence that there is very little difference in the prices of used cars depending on where they were assembled. The price-by-age lines for the American and Japanese assembled cars are very close in all four cases across the full range of available ages. Interestingly, whereas, for the two older models (made in 1999), there seem to be a small premium for those assembled in Japan, the opposite is true for the newer models (2002). However, these differences are very small in all cases.

We confirm these descriptive results through regression analyses based on versions of the following model:

$$PRICE_{ij} = \alpha + \beta JAP_i + \gamma(JAP_i * Age_i) + \theta X_i + \delta_j + \varepsilon_i, \quad (1)$$

where j indexes a particular “car type” and i indicates individual observations of that car. The dependent variable in Equation (1) is the sale price conditional on selling. We regress this variable on an indicator for whether the car was assembled in Japan (JAP) so that our primary estimate of interest is $\hat{\beta}$. In some specifications, we include an interaction between JAP and a measure of the car’s age to explore whether country-of-production differences vary with age.¹¹ We control for characteristics of the individual car, such as its mileage, denoted by the matrix X_i . Finally, we include fixed effects for the car type, given by δ_j in the equation. Given the richness and size of our dataset, and to help us perform the best possible “apples-to-apples” comparison, the car type is

¹¹ The direct term for the car’s age cannot be estimated separately because the fixed effects (δ) include both the model year and the year in which the car was sold, thereby capturing age.

defined at a very fine level. For all of our specifications, this car type includes the combination of make, model, body style, and model year of the car. Accounting for these characteristics is important because models within the sample are produced in the U.S. and in Japan at different rates.

Table 2 reports the price-regression results. Each specification in the table includes the fixed effects described above as well as a cubic polynomial in mileage and an interaction between mileage and the age of the car. Column (1) adds only the dummy variable *JAP*. The estimated effect of a car being assembled in Japan rather than the U.S. is \$126. However, the specification in Column (1) is likely biased in the direction of higher Japan-assembled prices. The reason is that this specification does not account for the auction location in which a car was sold. Due to transportation costs, for any particular car model, the units assembled in Japan are more likely to be sold on the west coast than elsewhere in the country. That pattern is clearly reflected in the data; Japanese-assembled cars are much more likely to appear in western states, as shown in Table 1 above. This fact is relevant for our analysis because cars depreciate more quickly in places that have snowy winters (due to increased accidents and the use of road salt); therefore, used cars that are sold in the Midwest (where there is a greater concentration of U.S.-assembled models) will have lower value for reasons not related to the country of assembly of the car. More generally, there may also be different price levels in different local markets, which again could bias the results.

In the remaining columns of the table, we include the auction location within our “car type” fixed effect. Adding that control, Column (2) reduces the Japan-effect by more than half, with the estimates showing that, all else equal, cars assembled in Japan sell for \$49.99 more than their U.S.-built counterparts. This is a modest difference, especially when compared to the average sale price of \$8,899. As Column (3) shows, that estimate does not change if we also add the seller type (dealer vs. fleet lease) to the car type in our fixed effect analysis. Given the size of the dataset, we are able to obtain fairly tight estimates of this difference; the 95% confidence interval around the estimate (using robust standard errors clustered at the fixed-effect level) ranges from \$32 to \$68.

As reported in Column (4), these differences are similar in absolute magnitude for cars of different ages, peaking at an estimated difference of \$82 for cars that are between 4 and 6 years old and hovering in the neighbourhood of \$40 for other ages. In percentage terms, relative to the average sale price, Japanese assembly is associated with a 0.3% increase for cars less than 3 years

old, a 1.1% increase for cars 4-6 and 7-9 years old, and a 1.7% difference for cars between 10 and 15 years old.

In Column (5), we explore whether the differences between U.S. and Japanese assembly have changed over time by interacting the JAP indicator with an indicator for car models built before 1999.¹² This specification reveals that there are only very small average differences for cars produced after 1999 (\$8.84) whereas there are more significant differences (\$77) for car models produced before 1999. Although the differences are very limited in both samples, these results are at least suggestive that country-of-assembly effects might have been falling over time as the Japanese makers established their U.S. transplants.

Although we will explore Japanese vs. American differences in other direct quality measures available in our data below, in Column (6), we also use these quality proxies as right-hand side variables in our price regressions. Including these measures reduces the sample size especially because information on the light codes that are used to signal defects is available in our data only after 2005.¹³ The results on the Japan vs. U.S. assembly coefficients are changed very little by including these direct quality measures. This is the case despite the fact that these variables have a large effect on prices, which reflects the fact that there is little correlation between country of assembly and these quality measures, as we confirm in the next section.

In Table 3, finally, we consider the five variables of a car's quality described above and conduct essentially the same analysis we did for prices. These variables are all dichotomous; therefore we estimate empirical models of this type:

$$Prob(Y_{ij} = 1) = f(\alpha, JAP_i, JAP_i * Age_i, X_i, \delta_j, \varepsilon_i) \quad (2)$$

where Y_{ij} is, in turn, one of the five indicators, and the arguments of the function $f(\cdot)$ are as in model (1) above. Because we control for car types using a large number of fixed effects, we use linear probability estimation rather than a Probit or Logit specification. In each of the columns of Table 3 we report the parameter estimates from a specification equal to the one in Column 5 of Table (2), with each of the five quality indicators as the dependent variable. With the exception of the probability of sale, we find no statistically significant differences in any of these measures as a

¹² We chose 1999 because it is roughly the mid-point of car model years in our sample.

¹³ For the condition-report variable, the omitted category is not having received a report. Receiving a poor condition report is a strongly negative signal, with only 2% of cars getting such a report, and is (not surprisingly) associated with a drop in price of almost \$700.

function of where the car was assembled. Cars assembled in Japan have, all else equal, a statistically significantly higher probability of being sold (0.8%), but the economic magnitude of this effect is very small.

3.2 Selection issues and robustness

The findings reported above indicate that “otherwise identical” cars produced in Japan and in the U.S. do not present any meaningful quality difference. In this section, we investigate whether these “null” results are robust to potential alternative explanations that would, instead, indicate a role for the country of production in ways that our empirical strategy does not capture.

A first concern with regard to the price regressions in particular is that they are based on cars that eventually sold at an auction. Cars that go unsold might be of systematically low quality. If these low-quality cars were disproportionately assembled in one of the two countries, then the estimates in Table 2 might not be reliable. However, the fact that there are very small differences in selling probability between cars assembled in the U.S. and Japan is reassuring that the price regressions described in the previous section are not affected by this type of selection bias. Note also that, in the regressions in Table 3, where we analyze direct quality measures, in all cases except for the probability of arbitration, the models are estimated on the full sample of both sold and unsold cars (the sample is smaller when we use the green light indicator, because this variable began to be recorded only from 2005).¹⁴

Somewhat more fundamentally, our sample is selected in that cars brought to auction are not necessarily representative of all used cars transacted in different markets. Not all used cars go through the wholesale auction process, and it may be that quality (either good or bad) is a driver of whether cars appear at the auction in the first place. This presents a potential challenge to the external validity of our results. For example, suppose that only very low-quality cars are transacted at wholesale auctions. This would tend to lead us to find only small differences in quality by country of production even if there were large differences in the universe of used cars. One way that we can address this concern is to exploit the differences in behavior between our different seller types. Recall that the fleet/lease sellers (e.g., rental-car companies) tend to sell their entire aging fleets in large lots at the auctions. There is plausibly very little or no selection in the cars that these

¹⁴ The estimates on the sample of only sold cars are very similar to those on the full sample, for all of these variables.

sellers bring. On the other hand, the dealer sellers have a fair amount of discretion on which cars they bring to auction rather than selling on their own lots. Columns (7) and (8) of the price regressions in Table 2 break the sample between fleet/lease sellers and dealer only sellers. It is clear that the differences between U.S. and Japanese produced cars are somewhat larger for the fleet/lease sellers, which is consistent with the possibility of a selection bias in the dealer cars that might be biasing down our estimates in the full sample. In fact, a regression of the probability that a car was built in Japan controlling for observables and a car-type fixed effect reveals that dealer-sold cars are approximately 1 percentage point less likely to be Japanese than the fleet/lease cars, again consistent with a selection story. However, when we concentrate only on the fleet/lease sellers, for whom selection is unlikely to be an important issue, the qualitative interpretation of the results is largely unchanged. In particular, the average difference for cars produced after 1999 is still only \$38. For the other measures of quality, we find no meaningful differences in the results if we limit the sample to only fleet/lease sellers.

To further explore whether the selection of which cars come through wholesale auctions is affecting our results, we try to compare the distribution of country of assembly in our auction data to the fraction produced in each country when the cars were sold new. Although the auction locations for this company do not cover the country in a representative fashion, given the large scale of the auction data here we could expect that in the absence of quality selection into the auction the distribution at the auctions would roughly match the production data. However, if only low-quality cars are brought to auction and there are systematic differences in quality by country-of-assembly, then the ratios of Japanese to U.S. cars should be different in the auction data than in the underlying production runs for the cars. There are 45 models (make, model, model year) represented in our regression sample that were produced in the U.S. and Japan.¹⁵ For these models, we collected data from *Ward's Automotive Yearbook*, a leading automobile trade publication, on the fraction of new-car sales in North America that were imports (i.e., assembled in Japan) versus domestically produced. In Figure 2, we graph the fraction of cars for each model that were assembled in Japan in the auction data against the fraction imported from Japan based on the new-sales data from *Ward's Automotive Yearbook*. Our data are closely related to the fraction of imports when cars were new;

¹⁵ The number of distinct car types in our fixed effects is much larger because, for those fixed effects, we combine the make, model, and model year with the specific body style, the year of sale at the auction, the location of the auction, and the seller type.

the correlation coefficient between the two fractions is of 0.7, and a linear regression of the fraction of used cars for each model in the auction data on the fraction of new cars imported from Japan give a statistically significant coefficient estimate of .84.¹⁶ This suggests that substantial differential selection into the auctions by country of production is unlikely to be a problem.

Beyond these selection issues, one might also be concerned that the high *R*-squared values in our price regressions imply that there is little variation in auction prices once the basic observables have been controlled for, and that this is the reason why we find only modest differences between Japanese and U.S. cars. For instance, imagine that, for efficiency reasons, dealers bought used cars based on an explicit formula that used inputs of the car type and mileage and ignored all other observations about the car. In such a setting, even if there were underlying differences in value due to the country of production, the market would not be pricing them in, and the absence of a difference in value related to the country of production would not emerge in such an analysis. We are not concerned, however, that this is the situation with these used-car auctions. First, as Column (6) showed, despite these high *R*-squared values, variables such as a poor condition report or defects listed in the light system have very large estimated impacts on prices. In addition, the residuals from a regression specification such as that in column (1), dropping the Japanese dummy, range by over \$2,000 from the 10th to 90th percentile, suggesting that there is significant variation in auction prices that is not captured by controlling for car characteristics and local-market conditions.

Finally, our analysis above is conducted on means. When considering the formation of perceptions of long-run quality, however, it may also be worth considering the extremes of the value distribution. In particular, it could be that the chance of buying a car of very low value is what most significantly influences perceptions of long-run quality. We investigate these extreme-value differences using, again, a residual analysis. First we regress sale price on car characteristics (e.g., mileage) and the car-type fixed effects, repeating the specification in Column (3) of Table 2 but dropping the Japan dummy. We obtain the residuals from that regression and calculate cut offs for various percentiles of the residual distribution. For example, the 10th percentile of residuals is at -\$1,139. We then calculate the probability that a car will have a price residual below this cut-off as a function of the country of production. The results of these analyses are reported in Table 4.

¹⁶ The correlation coefficient rises to 0.83 and the coefficient estimate from the regression to .9, if we drop the one extreme outlier from the sample.

Consistent with the earlier regression results, there is a very modest difference in favor of the Japanese-built cars. Compared to their American-built counterparts, Japanese cars are approximately a half percentage point (0.5%) less likely to be at or below the 5th percentile cut-off and 0.8 percentage points less likely to be below the 10th percentile. At the same time, Japanese cars are about 1 percentage point more likely to be of very high value at or above the 90th or 95th percentiles, which correspond to residuals of \$1,064 and \$1,393 respectively.

4. Conclusion

Based on over 400,000 used automobiles brought to wholesale auctions, we document that “otherwise identical” cars (i.e., cars of the same make, model, model year, and body style that were transacted in the same year at the same auction site where they were brought by the same type of seller) sell for nearly identical prices and are indistinguishable in terms of quality at any age, regardless of whether they were produced in the U.S. or in Japan. The similarity in values is particularly strong for models assembled over the past decade whereas some differences (although small) exist for older models.

Our findings are consistent with U.S. plants being able to produce cars of a comparable quality to other countries and, in particular, Japan. They also suggest that Japanese car makers might have been successful in exporting their best practices to their “transplants” in the U.S. Thus, the evidence in this paper points to the fact that, if U.S. car makers struggle to produce cars of comparable quality to their foreign competitors, that competitive disadvantage is unlikely to be primarily a result of *location-specific factors*, such as labor relations, available supplier networks, and general American “work culture.” Any disadvantage is more likely to stem, instead, from *company-specific factors*, such as design and management practices defined at the corporate level.

These results also contribute to the debate on the challenges in transferring practices and achieving similar performance levels between companies as well as within units of the same firm. At least for the case of automobile production, our findings are consistent with *replication within* plants of the same company (in different countries) having been achieved, and with replication being different from *imitation between* competitors (Gibbons and Henderson, 2010; Rivkin, 2001; Szulanski, 1996). Our findings also resonates with recent work in international trade theory, such as

Helpman, Melitz, and Yeaple (2004), who show that the companies making direct investments in in foreign countries are those with better management skills, and this is consistent with their ability to transfer their best practices abroad.

The analysis and methodology of this paper are a contribution to the relevant literature because of the size and detail of the data that allow for comparison across the same car models and because of the availability of multiple measures of product quality in the short as well as long term. They can also represent a starting point or “laboratory” for additional studies of how otherwise identical products (not only cars) differ in quality according to their location of production. A first extension would be to compare multiple countries of assembly instead of only the U.S. and Japan. This would be particularly interesting as firms from large emerging economies, such as China and India, are gaining presence in international markets (and, vice versa, Western multinationals increasingly producing in plants in these and other emerging countries). The approach in this paper could also be used to study differences across identical products manufactured in multiple plants *within* a country to assess questions such as plant-specific quality as well as the effect of events such as labor disputes and unrest (see, for example, Mas, 2008).

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Figure 1: Average Sale Price by Country of Assembly for Popular Models

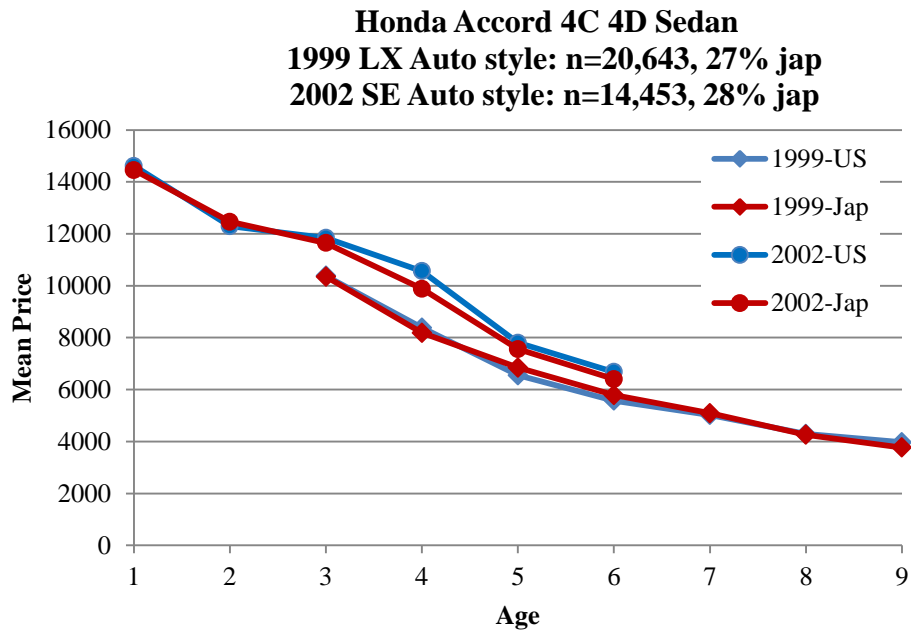
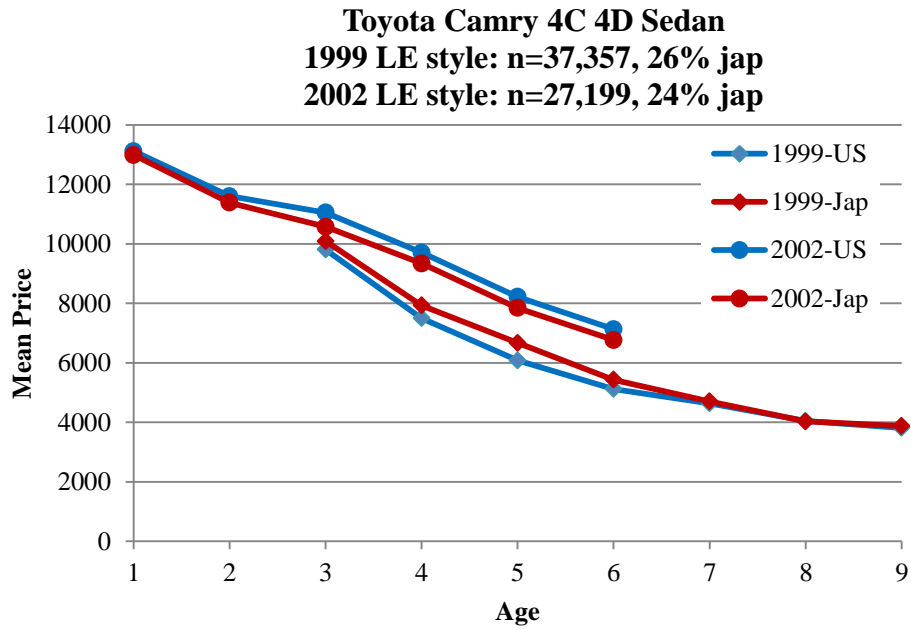


Figure 2: Comparison of Fraction of Cars Assembled in Japan in Auction Data vs. Production Data

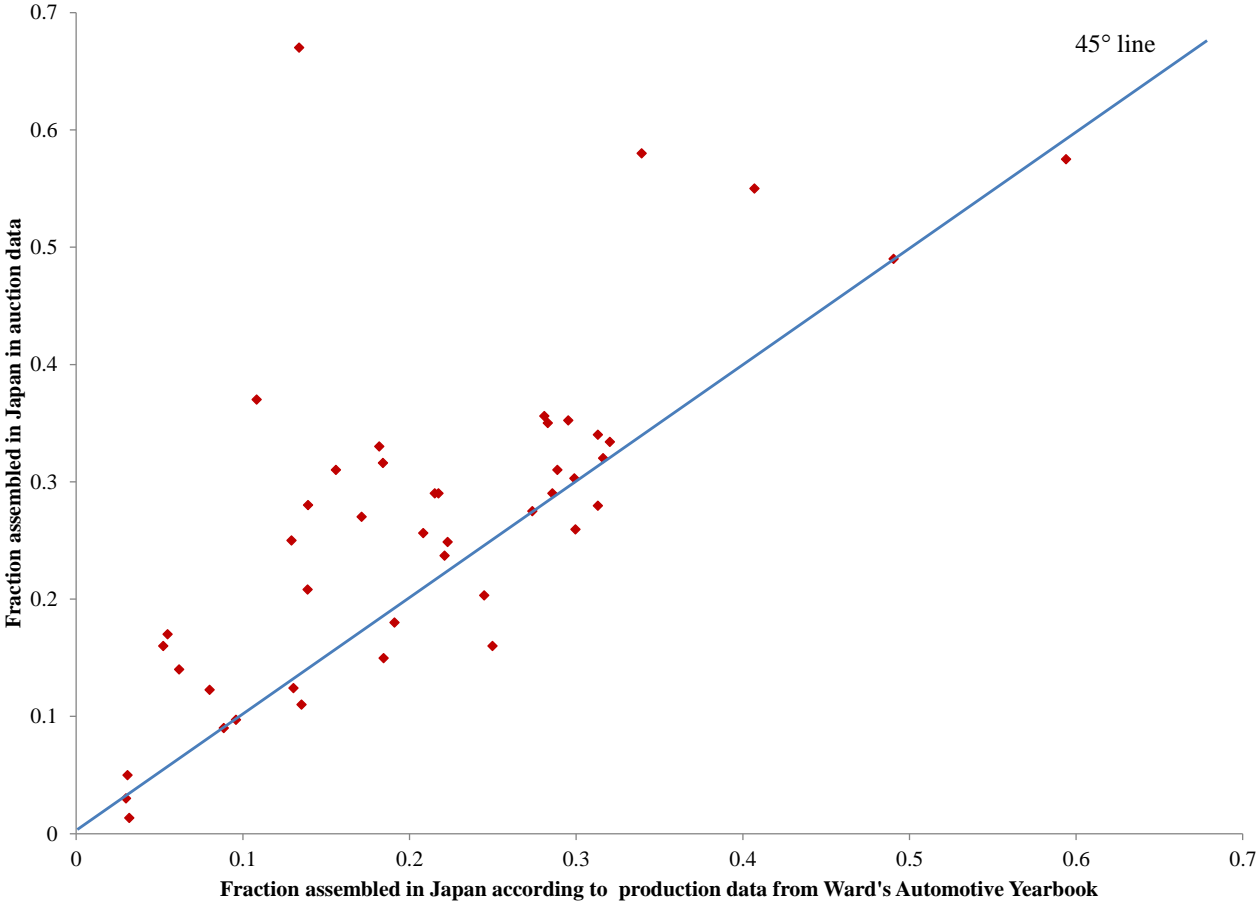


Table 1: Summary Statistics

Variable	All	US	Japan
Model year	1999.5 (3.63)	1999.4 (3.60)	1999.7 (3.70)
Age at time of auction	4.8 (3.24)	4.9 (3.26)	4.7 (3.19)
Miles on odometer	72,844 (47,336)	73,025 (47,564)	72,458 (46,845)
Seller paid for reconditioning	0.29 (0.45)	0.30 (0.46)	0.28 (0.45)
Given a good condition report	0.06 (0.24)	0.06 (0.24)	0.07 (0.26)
Given a poor condition report	0.02 (0.13)	0.02 (0.13)	0.02 (0.14)
Green light (no significant defects reported)	0.75 (0.43)	0.74 (0.44)	0.78 (0.41)
Sold at auction	0.64 (0.48)	0.64 (0.48)	0.65 (0.48)
Price (conditional on sale)	8,899 (4,926)	8,344 (3,959)	10,056 (6,342)
Went through arbitration	0.02 (0.15)	0.02 (0.15)	0.02 (0.15)
Sold by fleet/lease seller	0.63 (0.48)	0.64 (0.48)	0.62 (0.49)
Auction in western state	0.20 (0.40)	0.13 (0.34)	0.35 (0.48)
Observations	413,984	281,429	132,555

Note: Standard deviations in parentheses

Table 2: Regression Results for Sale Price by Japanese vs. U.S. Assembly

	Full Sample						Fleet/Lease Only	Dealer Only
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	Sale price	Sale price	Sale price	Sale price	Sale price	Sale price	Sale price	Sale price
Mean of dependent variable:	\$8,899	\$8,899	\$8,899	\$8,899	\$8,899	\$9,396	\$10,912	\$7,127
Japan	126.00*** (10.37)	49.99*** (9.125)	49.90*** (9.175)		8.84 (10.58)	-25.19** (12.75)	37.55** (14.76)	-30.10** (13.49)
Japan x pre-1999 model					77.00*** (17.35)	85.27*** (16.40)	103.60*** (35.02)	81.84*** (15.20)
Japan x age 1-3				36.19** (17.48)				
Japan x age 4-6				82.20*** (13.25)				
Japan x age 7-9				49.47*** (11.29)				
Japan x age 10-15				37.65*** (9.059)				
good condition report						178.90*** (48.29)		
bad condition report						-672.10*** (51.40)		
ran under "yellow light"						-549.00*** (23.34)		
ran under "red light"						-849.10*** (21.46)		
reconditioned prior to sale						-7.10 (40.45)		
cubic polynomial in mileage	X	X	X	X	X	X	X	X
mileage x age interaction	X	X	X	X	X	X	X	X
fixed effect includes: <i>make, model, body style, model year, year at auction</i>	X	X	X	X	X	X	X	X
fixed effect also includes:		auction location	auction location, seller type	auction location, seller type	auction location, seller type	auction location, seller type	auction location	auction location
Observations	265,918	265,918	265,918	265,918	265,918	114,728	124,499	141,419
Number of clusters	6,766	6,766	6,766	6,766	6,766	3,397	1,494	5,272
Adjusted R-squared	0.955	0.959	0.960	0.960	0.960	0.975	0.908	0.973

Notes: Robust standard errors adjusted for clustering at the fixed-effect level (make, model, body style, model year, year at auction, auction location, seller type) are in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1. The omitted category for the dummies on the condition report is cars with no condition report. Cars that run under a yellow light have some stated defects and can only be challenged in arbitration for unannounced defects. Cars running under red lights are sold "as is." The omitted category for the light variables are cars that run under green lights, announcing no major defects. Data on the lights is available from 2005 and thereafter only, which is why the number of observations drops in Column (6) when the light dummies are included.

Table 3: Regression Results for Alternative Quality Measures

	(1)	(2)	(3)	(4)	(5)
Dependent Variable (all indicators)	Did not get reconditioning	Given a good condition report	Ran with green light (no defects)	Sold at auction	Sale did not lead to arbitration
Mean of Dep Var:	0.708	0.063	0.752	0.642	0.968
Japan	0.00001 (0.0024)	0.0016 (0.0013)	0.0019 (0.0031)	0.0082** (0.0036)	0.0003 (0.0013)
Japan x pre-1999 model	0.0001 (0.0031)	-0.0013 (0.0013)	0.0001 (0.0067)	0.0017 (0.0050)	0.0011 (0.0018)
cubic polynomial in mileage	X	X	X	X	X
mileage x age interaction	X	X	X	X	X
fixed effect combination of: <i>make, model, body, model year, year, auction location, seller type</i>	X	X	X	X	X
Observations	413,984	413,984	181,567	413,984	265,918
Number of clusters	6,768	6,768	3,398	6,768	6,766
Adjusted R-squared	0.801	0.708	0.326	0.157	0.055

Notes: Robust standard errors adjusted for clustering at the fixed-effect level are in parentheses. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables in this table are indicator variables, taking on values of 1 or 0. In columns (1) - (4), both cars that sold and went unsold at the auctions are included. In column (2), the dependent variable is 1 if the car received a good condition report and 0 if the car either received a poor report or was not given a report. For column (3), cars that ran under a green light were advertised with no major defects, which contrasts with yellow lights (some stated defects) and red lights (sold "as is"). Data on the lights is available from 2005 and thereafter only, which is why the number of observations drops in column (3). Once sold, cars may enter arbitration if the buyer feels the car was misrepresented by the seller during the auction. Only sold cars can be arbitrated, which is why there are fewer observations in column (5).

Table 4: Probabilities of Extreme Price Values by Japanese vs. U.S. Assembly

	Full Sample					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	1st pct. & below	5th pct & below	10th pct & below	90th pct & above	95th pct & above	99th pct & above
Percintile cutoff value:	-\$2,831	-\$1,623	-\$1,139	\$1,064	\$1,393	\$2,134
Japan	-0.0004 (0.0005)	-0.005*** (0.001)	-0.008*** (0.002)	0.012*** (0.003)	0.009*** (0.002)	0.003*** (0.001)
cubic polynomial in mileage	X	X	X	X	X	X
mileage x age interaction	X	X	X	X	X	X
fixed effect includes: <i>make, model, body style, model year, year at auction, auction location, seller type</i>	X	X	X	X	X	X
Observations	265,918	265,918	265,918	265,918	265,918	265,918
Number of clusters	6,766	6,766	6,766	6,766	6,766	6,766
Adjusted R-squared	0.014	0.021	0.022	0.041	0.043	0.042

Notes: Robust standard errors adjusted for clustering at the fixed-effect level (make, model, body style, model year, year at auction, auction location, seller type) are in parentheses. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variables for these regressions are indicators for whether or not the car's sales price put it at or below the given percentile of prices based on the residual analysis described in the text at the end of Section 3.