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Estimating the Effect of Salience in Wholesale and Retail Car Markets[†]

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Modern economic life requires individuals to evaluate many pieces of decision-relevant information every day. A growing body of evidence shows that not all information is equally salient to consumers.[1] This is the case even for large-scale purchases made in well-functioning markets such as the market for automobiles, as shown by Lacetera, Pope, and Sydnor (2012). In this paper, we study how the effects of information salience propagate through markets, specifically between retail and wholesale markets, by examining the effect of "left-digit bias" on the valuation of automobile mileage.

Lacetera, Pope, and Sydnor—henceforth, LPS—found that *wholesale* prices of used vehicles with mileage just over a 10,000-mile threshold were $150 to $200 lower than the prices of vehicles with mileage just under the same threshold. These results are intriguing because they suggest that left-digit bias exists in a wholesale auction market in which the buyers and sellers—car dealers, vehicle lessors, and fleet owners—are all parties that participate in these transactions frequently and in large volumes. LPS speculate that the wholesale price discontinuities arise because dealers who participate in the *wholesale* market anticipate that final customers in the *retail* market will find the first digit of the odometer more salient than trailing digits.

In this paper, we look specifically at retail data on used vehicle transactions and find that retail price effects around 10,000-mile thresholds follow a very similar pattern to the price effects in the wholesale market. This suggests that the wholesale price discontinuities are driven by the limited attention of retail customers. We combine our data on retail price discontinuities with a simple model of left-digit bias to estimate the inattention parameter implied by the retail price discontinuities. We also investigate whether this parameter varies by the income of used vehicle buyers.

I. Data

Our data come from two sources. Data on wholesale transactions come from one of the largest operators of wholesale used car auctions in the United States. In these auctions, vehicles are sold by dealers and by fleet and lease companies in an English-style auction to licensed car dealers. We have detailed information on more than 22 million transactions occurring between 2002 and 2008.

Information on retail used vehicle transactions comes from a major market research firm that collects detailed data on every transaction that occurs at a sample of about 20 percent of the new car dealerships in the United States. We use data on used vehicle transactions between 2001 and 2008, a total of about 16 million transactions. For every transaction, the data include information about the vehicle transacted (including make, model, model year, and trim level),

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[1] See discussions in DellaVigna (2009) and Lacetera, Pope, and Sydnor (2012).

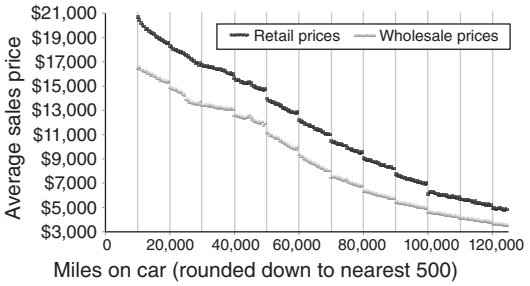

Figure 1. Average Price by Mileage

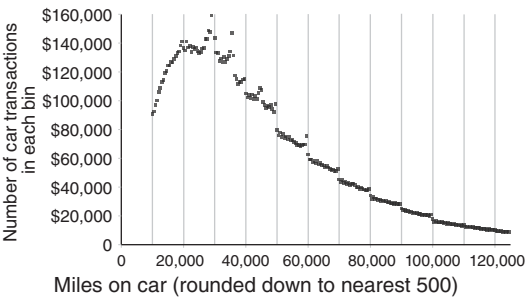

Figure 2. Retail Sales Volume by Mileage

the price negotiated between the customer and the dealer,[2] and the average demographic characteristics (from the 2000 census) associated with the buyer's census block group.[3]

II. Inattention and Retail Prices

We begin our investigation of the effect of left-digit bias on retail prices with a descriptive analysis. Figure 1 plots by 500-mile bins the average *retail* price of the used vehicles in our data (in black) and the average *wholesale* price (in gray). The two plots echo each other strikingly, with both showing pronounced discontinuities in prices at 10,000-mile odometer thresholds. Over the entire range of mileage depicted in the figure, the prices of vehicles in the retail market fall by about $50 on average between most 500-mile odometer bins (excluding the differences between bins just above and just below a 10,000-mile threshold). In contrast, the average price decrease at a 10,000-mile threshold is $448. Since vehicles do not undergo any sudden change in functionality or performance when they cross an odometer threshold, these changes in prices appear to be driven by changes in consumer perception of vehicle value.[4]

The volume of retail transactions is also distinctly higher for vehicles with mileage just under rather than just over 10,000-mile thresholds, as shown in Figure 2.[5] This pattern raises an interesting puzzle. Used vehicles sold by new car dealers come from two sources: the vehicles that a dealer accepts as trade-ins, and vehicles it purchases at auction. Vehicles at auction come from other dealers' trade-ins and from the sales of fleet owners (such as car rental companies) and lease returns. LPS found that there is no effect of 10,000-mile increments on the auction sales of vehicles by fleet and lease sellers,[6] but that there is an effect for the auction sales by dealers. These results—that dealers sell a higher volume of vehicles with mileage just under a 10,000-mile threshold than just over it at both wholesale and retail—suggests that there is a greater supply of vehicles coming into dealers from trade-ins that have mileage just under a 10,000-mile threshold that just over it. In other words, the implication is that customers are trading in a disproportionate share of vehicles just before they cross a 10,000-mile threshold.

In Figure 3, we show the total volume of trade-ins taken in by the dealers in our sample

[2] For transactions involving a trade-in, our measure of price subtracts off the difference between what the dealer paid the customer for the trade-in vehicle and the actual cash value of the trade-in as booked by the dealer (a figure we observe separately). In other words, if the customer lost money on the trade-in, we add that to the purchase price. If the customer made money on the trade-in, we subtract that from the purchase price.

[3] Further information on the data and institutional setting for the wholesale data can be found in LPS, and for the retail data in Busse, Silva-Risso, and Zettelmeyer (2006).

[4] As LPS discuss, these effects are unlikely to be driven by warranties or other factors that might affect the fundamental value of a vehicle.

[5] Figure 2 also shows two areas of bunching not at 10,000-mile increments. These are most likely created by the sale of formerly leased vehicles returned just before hitting 36,000- and 48,000-mile limits written into the lease terms.

[6] Fleet and lease auction volumes are higher around the typical lease mileage limits of 36,000, 48,000, and 60,000 miles.

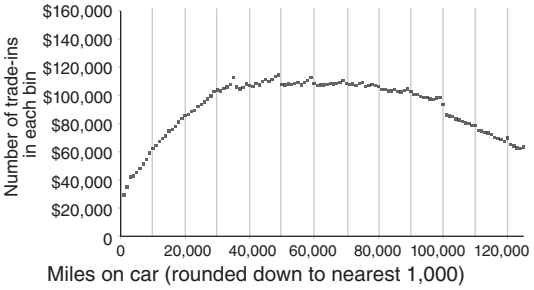

FIGURE 3. TRADE-IN VOLUME BY MILEAGE

collectively, grouped into 1,000-mile bins.[7] The pattern is similar to the retail volume data in Figure 2, with a higher volume of trade-ins whose mileage is just under the threshold than just over it.[8] This is particularly true of the 100,000-mile threshold.[9] Taken together, these volume results suggest that limited attention changes not only the prices at which vehicles transact, but also potentially changes the composition of vehicles that trade in markets.

III. Estimating the Inattention Parameter

Building on the inattention framework developed in DellaVigna (2009), LPS propose a simple model of left-digit bias which captures the idea that the leftmost digit of a number is fully salient to consumers, but that consumers do not fully incorporate finer details of large numbers. On the basis of the model, LPS estimate a structural parameter that captures the degree of inattention in their wholesale transaction data. We repeat the procedure here and compare the degree of inattention implied by the retail market patterns to that implied by the patterns in the wholesale auction market.

A used vehicle is a durable good whose value depreciates with mileage, $V = K - \alpha m$, where K is the value of the vehicle when new, m is the mileage of the vehicle, and α is the per mile rate of depreciation. If buyers are only partially attentive to mileage, the *perceived value* of a used vehicle is $\hat{V} = K - \alpha \hat{m}$, where $\hat{m}$ is the perceived mileage. In our empirical results, we allow consumers to have left-digit bias, meaning that the leftmost digit of the odometer reading is correctly perceived by the buyer, but that digits to the right are accorded less attention. We capture this in our empirical specification by allowing digits to the right of the first digit to be weighted at only $(1 - \theta)$ in the formulation of perceived mileage, where $\theta \in (0,1)$. We jointly estimate α, the depreciation rate of retail used vehicle prices, and θ, the inattention parameter implied by discontinuities in retail prices at 10,000-mile thresholds, by estimating the following regression:

$$(1) \quad Price_{ij} = \gamma + \alpha m_{ij} + \alpha\theta MileageRemainder_{ij} + \mu_j + \varepsilon_{ij}.$$

$Price_{ij}$ is the observed transaction price paid in transaction i for vehicle j. The covariate m_{ij} is the odometer mileage at the time of sale. $MileageRemainder_{ij}$ is defined as m_{ij} modulo 10,000 for vehicles with mileage between 10,000 and 99,999 and as m_{ij} modulo 100,000 for vehicles with mileage of 100,000 or more. For example, if $m = 78{,}123$, then $MileageRemainder = 8{,}123$. μ_j represents "vehicle-type" fixed effects for vehicle j, defined as the cross-product of make, model, model year, and trim level. The inclusion of these vehicle-type fixed effects allows us to improve the precision of the estimates and to account for potential selection issues that may arise from the volume patterns documented in Figure 2 if the composition of vehicles differs on either side of a threshold. To allow for

[7] There are fewer observations of trade-ins than of sales, and the trade-in data are noisier than the volume data, which is why we aggregate to 1,000-mile bins; noisier effects exist when looking at 500-mile bins.

[8] This pattern cannot be explained by what customers are paid for their trade-ins. The actual cash value at which the dealer books the trade-in falls as vehicles cross a 10,000 mile increment, consistent with the wholesale price results, but the amount that dealers pay customers does not fall by as much, meaning that vehicle buyers are actually paid a little more relative to what their vehicles are worth for vehicles just *over* a 10,000-mile increment.

[9] A simple supply and demand model would suggest that vehicles in higher volume would trade at lower prices, all else equal—in particular, under similar demand conditions. The fact that these vehicles sell at higher prices is further evidence that inattention is an important driver of these prices. Other "supply" effects may in principle operate if buyers were interested in purchasing vehicles within very narrow mileage intervals; however, this is not the case in general, and people, when shopping for a used car, typically consider wide mileage ranges.

Table 1—Structural Model Estimates

Sample	30K	40K	50K	60K	70K	80K	90K	100K
Retail—all								
Discontinuity ($)	240	167	310	317	365	324	366	402
Mileage depreciation rate (α)	0.135	0.125	0.131	0.123	0.118	0.098	0.102	0.086
Inattention parameter (θ)	0.178	0.134	0.237	0.258	0.308	0.329	0.360	0.467
	(0.006)	(0.007)	(0.008)	(0.009)	(0.011)	(0.015)	(0.017)	(0.024)
Wholesale								
Discontinuity ($)	172	196	283	236	227	214	177	180
Mileage depreciation rate (α)	0.060	0.074	0.081	0.066	0.059	0.047	0.042	0.039
Inattention parameter (θ)	0.285	0.266	0.348	0.360	0.387	0.451	0.425	0.461
	(0.0171)	(0.0154)	(0.016)	(0.0209)	(0.0235)	(0.0288)	(0.0317)	(0.0346)
Retail—low income								
Discontinuity ($)	248	162	305	311	379	295	361	381
Mileage depreciation rate (α)	0.126	0.116	0.120	0.115	0.113	0.098	0.099	0.086
Inattention parameter (θ)	0.197	0.139	0.255	0.270	0.336	0.303	0.364	0.443
	(0.008)	(0.010)	(0.012)	(0.014)	(0.016)	(0.021)	(0.024)	(0.033)
Retail—high income								
Discontinuity ($)	235	169	296	318	342	353	352	401
Mileage depreciation rate (α)	0.145	0.133	0.142	0.130	0.121	0.096	0.102	0.087
Inattention parameter (θ)	0.163	0.127	0.209	0.245	0.282	0.367	0.344	0.460
	(0.008)	(0.009)	(0.011)	(0.013)	(0.016)	(0.024)	(0.026)	(0.038)

a flexible functional form for depreciation, we estimate equation (1) separately by 10,000-mile ranges of mileage between 15,000 and 105,000 miles (e.g., between 15,000 and 25,000 miles, between 25,000 and 35,000 miles, and so on).

The results of the estimation are reported in Table 1. The first panel *Retail—all* shows the results using the retail data. The first row of the panel displays the estimated discontinuity in residual price, net of "vehicle type" fixed effects (μ_j), at each mileage threshold from 30,000 through 100,000.[10] The second row of the panel reports the estimated depreciation rate, in dollars per mile. This estimated depreciation rate decreases with mileage, from 13.5 cents per mile of usage for vehicles between 25,000 and 35,000 miles to 8.6 cents per mile for vehicles between 95,000 and 105,000 miles.

The estimated inattention parameter and its standard error are reported in the last two rows of the panel. The estimated degree of inattention ranges between 0.134 for some of the lowest mileage vehicles, to 0.467 for the highest mileage vehicles. This implies that buyers are more inattentive to mileage for vehicles with high mileage than for vehicles with low mileage. This pattern of rising inattention for vehicles with higher mileage could arise if buyers of higher-mileage vehicles (which tend to be less expensive) are particularly inattentive. The pattern could also potentially reflect some degree of rational inattention. Because the price of high mileage vehicles actually decreases less with mileage than the price of low mileage vehicles does, it may be somewhat less important for buyers to pay attention to variations in mileage for higher mileage vehicles.

The second panel of Table 1 reports the analogous results estimated for vehicles sold in the wholesale auction sample used by LPS. The discontinuities in wholesale prices at 10,000-mile increments are in most cases smaller (on average by about 40 percent) than the discontinuities in retail prices at the corresponding increments. Despite these smaller discontinuities, however, the estimated inattention parameter is larger in the wholesale sample than it is in the retail sample. While this result seems counterintuitive initially, it can be explained by how estimates of inattention relate to the underlying rate at which a vehicle's value depreciates

[10] These discontinuities are smaller than the discontinuities in Figure 1 because the vehicle-type fixed effects absorb some variation in raw prices. The discontinuity at 20,000 miles is similar but suppressed due to space constraints.

by mileage. The more quickly prices depreciate with mileage, the smaller the degree of inattention required to generate a price discontinuity of a given size. With slower rates of depreciation, customers must be more inattentive to generate the same size price discontinuities. Retail prices, as can be seen in Figure 1, are marked up considerably over wholesale auction prices. Consistent with this, wholesale auction prices are estimated to depreciate at roughly half the rate of retail prices. In our data, the rate at which retail prices depreciate is enough higher than the rate at which wholesale prices depreciate that, even though the price discontinuities are also larger in the retail prices, we estimate a lower rate of inattention in the retail data. This result has important implications for interpreting the structural behavioral parameters. In particular, this result suggests that if one hopes to quantify inattention it is crucial to understand the underlying dynamics of the market. In this case, and perhaps more generally as well, attempting to measure an end-consumer structural parameter using data from an intermediate market can significantly bias findings.

In the last two panels of Table 1, we separate customers into two groups based on the average income of the census block group in which they live. Buyers are categorized as low income if they live in a census block group with income less than or equal to $46,597 and high income otherwise. The estimated inattention parameters for any vehicle mileage range are generally higher for low income buyers than for high income buyers, but the differences are very small.

IV. Conclusion

In this paper, we examined the extent to which customers are inattentive to mileage in retail transactions for used vehicles. Prices and volumes of vehicles with mileage just under 10,000-mile thresholds are higher than for vehicles with mileage just over 10,000-mile thresholds, suggesting that vehicle buyers are partially inattentive to mileage. These results show clearly that the literature exploring the effects of salience and limited attention in decision making can be extremely important for understanding the dynamics of important, well-functioning markets where buyers and sellers have large stakes. The results also show that the effect of biases can propagate through related markets; in this case, from retail markets to wholesale markets.

In this paper we also show that transaction prices can be used to estimate structural parameters from a simple model of consumer-level inattention. Estimating the model allows us to explore patterns of inattention that cannot be inferred simply from the observed price discontinuities. Our findings suggest, for example, that consumers are more inattentive to mileage for vehicles with higher mileage. However, we find little effect of income differences on how attentive consumers are. Importantly, we show that inferences about inattention depend on the characteristics of the market. In particular, our results suggest that it may be misleading to estimate a consumer-level structural parameter on the basis of data from an intermediate market.

REFERENCES

Busse, Meghan, Jorge Silva-Risso and Florian Zettelmeyer. 2006. "$1,000 Cash Back: The Pass-Through of Auto Manufacturer Promotions." *American Economic Review* 96 (4): 1253–70.

DellaVigna, Stefano. 2009. "Psychology and Economics: Evidence from the Field." *Journal of Economic Literature* 47 (2): 315–72.

Lacetera, Nicola, Devin G. Pope, and Justin R. Sydnor. 2012. "Heuristic Thinking and Limited Attention in the Car Market." *American Economic Review* 102 (5): 2206–36.