Online Appendix for

The Value of Urgency: Evidence from Real-Time Congestion Pricing

BY ANTONIO M. BENTO, KEVIN ROTH, AND ANDREW WAXMAN*

(for reference only; not for publication)

This appendix provides details on the construction of the data, the tabular results for robustness tests using alternate specifications, and descriptive figures. In Appendix A, we provide further details on the data, including the rationale for the choice of the I-10 W, background information on the I-10 W, and details regarding matching of the aggregate PeMS flow and speed data to repeat transaction-level transponder data. Appendix B provides a presentation of regression discontinuity estimates of the ExpressLanes opening on mainline and ExpressLanes speeds. the full derivation of the conceptual framework presented in section III.A of the paper. Appendix C elaborates on the conceptual framework for our empirical approach laid out in section III. Appendix D provides proofs of the identification of marginal willingness-to-pay for travel time savings from the ExpressLanes toll under continuous and discrete segment length. Appendix E presents a version of Vickrey's (1969) bottleneck model of optimal tolling under dynamic congestion with and without the value of urgency. Appendix F provides further details on our instrumental variables identification strategy to address measurement error in time savings. Appendix G includes descriptive figures related to each of the datasets and the ExpressLanes policy. Appendix H presents additional tables outlining descriptive statistics of our data and alternate specifications as robustness checks.

* Bento: University of Southern California and NBER, Sol Price School of Public Policy. Lewis Hall 214 (email: abento@usc.edu); Roth: Laurits R. Christensen Associates (email: kdroth@lrca.com); Waxman: University of Texas at Austin, LBJ School of Public Affairs (email: awaxman@utexas.edu).

Appendix A. Additional Data Discussion

This appendix provides further details on the datasets discussed in Section II.

1. Background on I-10 W & ExpressLanes

Corridor Selection.—Of the two ExpressLanes roadways, the I-10 corridor near downtown LA was selected for our central analysis for several reasons. The I-10 had a later start date than the I-110 ExpressLanes, which resulted in a higher rate of adoption of transponders at program start on the I-10. In addition, the I-110 ExpressLanes started just before the Thanksgiving holiday when traffic patterns would be expected to deviate from regular commuting, and there was a blackout of transponders along the I-110 corridor right after the program start.

Of the two directions of travel along the I-10, the westbound direction was selected for the following reasons. First, the I-10 W corridor travels east of Downtown Los Angeles (running from El Monte to Downtown) and is the predominant morning commuting direction as it connects a major residential center to a major employment center. As a result, it is one of the most congested morning weekday commuting corridors in the country. Second, data was available for the I-210 W, a competing route 5 miles north of the I-10. Travel times for this alternate route allow us to test the robustness of our assumptions about the commuting patterns on the I-10 W as shown in Appendix Table H.6. Third, while the I-10, in general, has one of the highest detector concentrations of any freeway, the detector coverage in the westbound direction is particularly high (3.5 per mile in the mainline lanes, 2.73 per mile in the HOV lanes) as shown in Appendix Figure F.1. This density ensures that the travel times reported by PeMS are not overly dependent upon a small set of detectors.

Background on the I-10 and the ExpressLanes Program.—The 10.5-mile section of the I-10 W analyzed is shown in Appendix Figure F.1. It runs between the suburb of El Monte and downtown LA. With the exception of the 3+ occupant requirement during peak travel times, this route is fairly representative in terms of size and design for the LA region. The road generally has barriers on both sides with a shoulder for stopped vehicles on the right.

On February 23rd, 2013, Los Angeles converted the High Occupancy Vehicle (HOV) lanes on the I-10 into a High Occupancy Toll (HOT) facility, as part of the ExpressLanes program. This was the second of such conversion in Los Angeles, the first being the I-110 ExpressLanes, which opened on November 10th, 2012. For our main results we consider the initial period of the policy between February 25th, 2013 to December 31st, 2013. By starting on February 25th, we have allowed sufficient time for drivers in Los Angeles to learn how to use the ExpressLanes.

The program opened the lanes to Single Occupant Vehicles (SOV) who were charged a toll debited from a FasTrak account linked to a required transponder in the vehicle. The ExpressLanes function such that once the maximum price is reached the lane is closed to further SOV traffic. The lane was never closed during the period considered on the I-10 W.

The ExpressLanes are designed around six segments, which each have separate tolls that adjust every five minutes to the level of demand in the lane. Drivers pay a total toll which is the sum of segment tolls. Drivers can access these segments at four entry points (WT01, WT02, WT03, and WT05) shown in Appendix Figure F.1. They can exit at four exit points (WT03, WT04, WT05, and WT06), corresponding to 11 possible segment combinations. At entry points drivers see posted total toll rates for a full and a partial trip: for example, for those entering at WT01, rates shown correspond to an exit at WT04 or WT06. Once a vehicle enters the ExpressLanes, the set of segment tolls are locked in for the duration of the vehicle's trip across all possible segments even if the price for subsequent vehicles changes. If a driver takes a trip that is shorter than the posted trips (say, WT01 to WT03 or WT01 to WT05), then the displayed tolls bound the toll the driver would pay (since the displayed tolls would include the segments used). We test the robustness of our results to these in-between segment combinations in Appendix Table G.17.

In our sample, total tolls range between $0.55 and $14.70, with a mean toll on the longest corridor of $5.23. Between entry points the ExpressLanes are separated from the mainline lanes by a solid double white lane marker that drivers may not cross. Crossing this marker is a moving violation. The program funds cameras at entry and exit points that read license plates to toll vehicles without transponders and additional California Highway Patrol officers that patrol the road segment.

Entry into the ExpressLanes from the mainline is limited access at noted points, with a fine of $481 for occupancy violations or for crossing the double-yellow buffer between the ExpressLanes and mainline lanes. Several park-and-ride lots exist along the I-10 to encourage carpool formation, and vanpool availability was expanded in conjunction with the opening of the ExpressLanes. The Metrolink San Bernardino Line, a regional commuter rail option, tracks a significant portion of the route. The I-10 was selected as one of the targeted corridors for the ExpressLanes project based on its heavy morning congestion and the pre-existence of one HOV lane. As part of this program, the HOV lane was expanded to two lanes to allow for greater capacity.

A subtle design element to the I-10 Westbound ExpressLanes is the HOV policy. Prior to the ExpressLanes program, HOV lane access on this road required three or more people per vehicle during the morning peak (5-9 AM) and afternoon peak (4-8 PM) times, and two or more people per vehicle otherwise. Nearly all other HOV lanes in CA require two or more occupants during peak hours. Because this policy allows toll-paying ExpressLanes drivers to avoid the cost of carpool formation, the 3+ regulation may affect the decision of drivers to break their carpool, forgo the carpool formation cost and pay to drive in the I-10 as a SOV driver. For those not carpooling before the policy, the 3+ versus 2+ regulation only has an impact in so far as it creates a larger initial travel time differential between the HOV and mainline lanes.

This differential, however, should not vary greatly across freeways, as regulators have set these occupancy requirements to keep congestion in HOV lanes similar across all roads, implying that despite the 3+ regulation on the I-10 we may expect to observe similar effects of the ExpressLanes policy on HOV lanes on other freeways. Moreover, we find that the share of trips with the transponder switched to HOV-2+ mode is relatively small (11.3 percent), both the result of the fact that the toll is the same for SOV and HOV-2+ vehicles during the morning peak, so that it would need to be the case that the savings from shared vehicle use outweighed the carpool formation cost for HOV-2+ driving to be preferable to SOV driving in the

ExpressLanes. Second, because drivers are tolled the same amount during the morning peak regardless of whether the transponder is set to SOV or HOV-2+, it seems possible that a non-trivial share of tolled drivers might be occupied by two persons where the driver has simply left the transponder in the SOV position because the toll to be paid is no different.

2. Additional Data

In addition to our main dataset for the I-10 W during the AM Peak from PeMS sensor data and ExpressLanes trip, toll and individual data, we perform robustness checks with several additional datasets. The use of a Weekend Control Group strategy to account for time-invariant unobservables uses trips in the I-10 W during weekends. We also estimate the homogenous agent model on the I-10 W during the afternoon peak (4-8PM), as well as the I-10 E, I-110 N and I-110 S during the AM and PM peaks during the period of our main sample (February-December 2013). Additional robustness data on weather, gasoline and vehicle prices are described below.

Weather.—In Appendix Table G.23, we differentiate our results based on local weather patterns as a robustness check to the main results. We differentiate days with positive ("Rainy") and zero ("Dry") precipitation based on weather station data from the National Climatic Data Center. To match weather measures to the travel time data from PeMS, we follow the algorithm used in Auffhammer and Kellogg (2011). First, the Vincenty distance of each airport weather station to each PeMS detector is calculated using their geographical coordinates. The closest station to roughly two-thirds of the detectors is Hawthorne and Fullerton for the remainder. The weather data from these stations are matched to the travel time data for the I-10 W. After these records have been matched, 0.07% of the travel time records are not matched to a full set of weather measures. These missing weather measures are imputed by regressing the observations where the closest station (Fullerton or Hawthorne) was active, for the relevant variable, onto the same variable for the remaining eight stations. The predicted values from that regression were used to replace the missing values. No weather measures were subsequently missing.

Gasoline Prices.— In Appendix Table G.23, we differentiate our results based on the lagged weekly average regular reformulated price of gasoline for the Los Angeles area as reported by the Energy Information Administration.

Vehicle Prices—In Appendix Table G.15, we examine the relationship between individual-level estimates of the value of urgency and value of time and the value of vehicles registered to these individuals. Individual-level vehicle make, model and year come from Metro transponder account information, which we match to data on vehicle Manufacturer’s Suggested Retail Price (MSRP) from Ward’s Automotive Yearbooks (1945-2013). Vehicle prices are in 2000 dollars and are depreciated by an annual rate of 20%. Of the 31,331 vehicle-individual observations, 6,727 do not match based on these criteria for various reasons. For the unmatched observations, we attempt to match them to the nearest (in time) Wards MSRP for which there is data, within a five-year window. Of the 6,727 observations that do not initially match, 3,127 individual-vehicles remain unmatched after attempting to match within a 5-year window. These are matched by year and make to an average make-level MSRP.

US Census American Community Survey.—To characterize incomes by zip codes, hourly average wage equivalents, and usual time departing for and arriving at work, we use the 2013 5-year ACS data for Los Angeles County. To convert income into hourly wage equivalents, we divide annual income for employed workers with positive nonfarm income, not working from home by 1,600, assuming 8 hour work days and 200 work days per year.

Appendix B. Regression Discontinuity Estimates of ExpressLanes Opening

We use local linear Regression Discontinuity Design (RDD) to demonstrate the independence of mainline congestion to the ExpressLanes. Flow and speed are compared before and after the opening of the I-10W ExpressLanes with levels in previous days acting as a comparison group. These parameters allow us to calculate the number of agents affected by the policy, and the travel time and reliability changes created by the policy.

In our main specification, outcome variable $\log(speed_t)$ on date t, is regressed on $1(ExpressLanes_t)$, an indicator variable for observations after the opening of the ExpressLanes, a vector of covariates $\boldsymbol{X}_t$, and a linear trend in date $f(Date_t)$.

(B.1) $$\log(speed_t) = \alpha + \beta \cdot 1(ExpressLanes_t) + \boldsymbol{\gamma}^i \boldsymbol{X}_t + f(Date_t) + \varepsilon_t$$

The coefficient of interest, β, is the treatment effect of the ExpressLanes policy on speeds. We focus our results on the AM peak (5-9AM), given this period is the focus of our mane results. We use the effective start date of the ExpressLanes on February 23, 2013.[1] The vector of covariates $\boldsymbol{X}_t$ includes controls for day of week-month, hour of the day, logged gasoline price, weather (linear and quadratic precipitation and visibility), detector fixed effects, and the one hour lagged logarithm of travel time on a competing route (I-210W). As people choose freeway routes base on travel updates in the hour before they leave home, we include travel time on the I-210W lagged by one hour. Standard errors are clustered at the week.

Equation (B.1) includes a linear trend in date, $f(Date_t)$. Imbens and Lemieux (2008) show that omitted time varying factors are controlled for with a linear trend within some local bandwidth of the discontinuity. We use a local linear method with a 60-day bandwidth to control for omitted factors.[2] This local linear framework which has been shown to provide for better inference when time is forcing variable

[1] As the dependent variable is logged, a one-unit increase in $1(ExpressLane_t)$ would imply a percentage increase in speeds of $\exp(\beta - 1)$.

[2] A triangular kernel is used in all specifications. We use this bandwidth because it gives the best sense of the robustness of the results, with bandwidths larger than 65 day tended to giving similar result to 65 days while those below 55 gave similar results as 55 days.

(Gelman and Imbens, 2014) and because we are limited to data 6 months before the start of the policy when road construction to add a second HOV lane occurred.[3]

The beginning of the ExpressLanes policy identifies the short-run effect of the policy on mainline speeds. As panel A of Appendix Table G.2 illustrates, across all bandwidths, there is no statistically significant impact of the opening on mainline speeds. The explanation for this is straightforward: the size of commuters leaving the mainline lanes to use the ExpressLanes is small enough to have no effect on speeds or flows in that lane, and much of this effect is offset by reallocation from elsewhere in the transportation system.

Panel B of Appendix Table G.2 shows the same regression results for the opening of the ExpressLanes, where prior to opening, users were only HOV drivers. A consistent reduction in speeds occurs at ExpressLanes opening. We estimate a statistically significant speed decrease of 2.9% (1.73 MPH) in the ExpressLanes across all bandwidths. The effect estimated here includes both the increase in SOV traffic and the removal of carpools without transponders. The negative estimate suggest that latter effect dominates the former.

[3] Gelman and Imbens (2014) suggest causal effects based on higher order polynomials may be misleading.

Appendix C. Identification of Marginal Willingness-to-Pay from Toll Hedonic

We assume the value of urgency and travel time savings to be non-negative and ignore the role of reliability in subsequent analysis.

1. *Continuous ExpressLanes Use*

For illustrative purposes, suppose vehicle transponders tracked the distance traveled in the ExpressLanes and charged a dynamic, throughput maximizing toll that varied by mile. Therefore, the travel time saved would be at least a weakly monotonic function of trip length, ℓ_{it}: $\Delta TT_{it} = f(\ell_{it})$, where f is continuous, differentiable, nondecreasing and concave.

The WTP function for an individual driver would then be

$$WTP_{it} = \delta + \theta \Delta TT(\ell)_{it}$$

These assumptions would yield the WTP function shown below in Figure F.8. In this instance, longer trips along the ExpressLanes would correspond to greater travel time savings. Thus willingness to pay would increase accordingly.

Define the dynamic, throughput maximizing toll as:

$$C_{it} = g(\ell),$$

where, where g is continuous, differentiable, nondecreasing and convex. The last assumption of convexity could be removed without loss of generality. Under this toll, longer trips would incur higher total tolls as indicated by the Total Toll.

Therefore, the hedonic price function is defined in equilibrium by the tangency between the WTP curve and the price function. Point identification of the hedonic price function requires us to identify MWTP from the tangency between trips along the price function and WTP as in Panel A of Figure F.8.

2. *Discrete Segments*

Now we will relax the assumption that drivers can consume distance in the ExpressLanes continuously, but rather we will account for the fact that they are restricted to discrete number of subsegments. For illustrative purposes, we use the example of a lane with four subsegments, although our logic still holds with more subsegments. Indeed, one can, in principle, bound the estimates more precisely with more subsegments as will be shown.

Just as in the continuous case, traveling along more sub-segments of the ExpressLanes ensures greater travel time savings although the savings scale both with the distance traveled and the amount of mainline congestion. As such, the total toll paid increases in a strictly monotonic way as more subsegments are used since the total toll paid is the sum of individual tolls along subsegments.

With segments, there is non-linearity in the price function so tangency is no longer guaranteed as in Panel B of Figure F.8. This provides an additional reason that the toll reflects a lower bound on WTP in our model. To understand how preferences are bounded, it is important to understand that a driver will choose to drive in as much of the ExpressLanes to guarantee that $WTP - TotalToll \geq 0$. In Panel B, this corresponds to the driver choosing to drive segments 1 and 2 for a total toll of C_2 and a travel time savings of ΔTT_2. This revealed choice provides four conditions allowing us to bound δ and θ:

1. $\delta + \theta \Delta TT_2 > C_2$ - For chosen segments, $WTP > TotalToll$.
2. $\delta + \theta \Delta TT_2 - C_2 > \delta + \theta \Delta TT_3 - C_3$ - For chosen segments, $WTP - TotalToll$ is bigger than that for using one more segment (segment 3).
3. $\delta + \theta \Delta TT_2 - C_2 > \delta + \theta \Delta TT_4 - C_4$ - For chosen segments, $WTP - TotalToll$ is bigger than that for using two more segments (segments 3 and 4)
4. $\delta + \theta \Delta TT_2 - C_2 > \delta + \theta \Delta TT_1 - C_1$ - For chosen segments, $WTP - TotalToll$ is bigger than that for using one less segment (segment 2).

Conditions 2 and 3 can be rearranged to derive bounds on the value of time, θ:

(C.1) $$\theta < \min\left\{\frac{C_3 - C_2}{\Delta TT_3 - \Delta TT_2}, \frac{C_4 - C_2}{\Delta TT_4 - \Delta TT_2}\right\}.$$

Note that a precise bound on θ can be written if we know whether the price function with sub-segments is convex (the first term in the min) or concave (the second term). This would then identify which of the expressions to the right of the inequality is smaller.

(C.1) can be substituted into condition 4 to provide a bound on δ:

$$\begin{aligned} \delta \quad & > C_2 - C_1 - \theta(\Delta TT_2 - \Delta TT_1) \\ & > C_2 - C_1 - \min\left\{\frac{C_3 - C_2}{\Delta TT_3 - \Delta TT_2}, \frac{C_4 - C_2}{\Delta TT_4 - \Delta TT_2}\right\}(\Delta TT_2 - \Delta TT_1)^{\cdot} \end{aligned}$$

As with θ, a more precise bound can be written based on the above inequality when convexity of the price function is known.

We have therefore derived an upper bound on the value of travel time savings and a lower bound on the value of urgency that helps to demonstrate identification of marginal willingness-to-pay from the ExpressLanes toll with discrete segment use.

Appendix D. A Bottleneck Model with Urgency

Here we briefly review the Vickrey (1969) bottleneck model using the framework of Arnott et al. (1993). We focus exclusively on the essential features of the model needed to understand the key results that guide much of the discussion in later sections.

Basic Assumptions.—N identical individuals travel from home to work. N is assumed to be fixed, and trip demand is completely inelastic. Travel is uncongested except at a bottleneck with a capacity of s cars per unit of time. If the arrival rate at the bottleneck exceeds s, a queue develops. Travel time from home to work is:[4]

$$T(t) = T^f + T^v(t) \tag{D.1}$$

Where T^f is free-flow travel time, $T^v(t)$ is variable travel time and t is departure time from home. Let $D(t)$ be the queue length (i.e, number of cars). Then, a driver that departs at time t faces a queuing time equals queue length divided by bottleneck capacity:

$$T^v(t) = \frac{D(t)}{s}, \tag{D.2}$$

with $r(t)$ denoting the departure rate function from home, and $\hat{t}$ the most recent time at which there was no queuing, then:

$$D(t) = \int_{\hat{t}}^{t} r(u)du - s(t - \hat{t}) \tag{D.3}$$

All individuals have preferred arrival time t^*. The private travel cost function is taken to be linear in travel time and schedule delay, measured by time early or time late[5]:

[4] Without loss of generality, we assume that T^f equals zero. Thus, an individual arrives at the bottleneck as soon as he leaves home and arrives at work immediately upon leaving the bottleneck.
[5] Consistent with the literature, we assume that the travel cost function is linear for analytical exposition. In the empirical section below, we generalize this function.

(D.4) $$C(t) = \alpha T^v(t) + \beta(time\ early) + \gamma(time\ late)$$

Where α is, as before, the value of time, β is the per-hour unit cost of arriving early at work, and γ is the per-hour unit cost of arriving late at work. Consistent with empirical literature (Small, 1982), we assume that $\gamma > \alpha > \beta$. We refer to $\beta(time\ early) + \gamma(time\ late)$ as the value of *schedule delay costs*.[6]

Each individual decides when to leave home. In doing so, (6) implies that the individual trades off travel time and schedule delay. In addition, individuals are assumed to have full information about the departure time distribution.[7] Equilibrium in the bottleneck model is achieved when no individual can reduce her travel costs by altering her departure time, taking all other drivers' departure times as fixed.

Graphical Representation of the Bottleneck Equilibrium.—The equilibrium is depicted in Appendix Figure F.9. The beginning of the rush hour is denoted by t_q (that is, the departure time of the first individual), and $t_{q'}$ the end of the rush hour. Let $\tilde{t}$ represent the departure time of the individual that arrives just on-time (at t^*). Agents who depart after $\tilde{t}$ arrive late. Conversely, agents who depart before $\tilde{t}$ arrive early. Therefore, the individual who departs at $\tilde{t}$ is the only individual who faces no scheduling costs. The vertical distance between the cumulative departures schedule and the cumulative arrivals schedule is queue length in cars and the horizontal distance is travel time (denoted as $\mathrm{D}(t')$ and $T^v(t')$, respectively, in the figure). Cumulative departures for agents who arrive before $t^*$are shown in segment AB (with slope $\frac{\alpha s}{\alpha-\beta}$).[8] For agents who will arrive after t^*, cumulative departures are given by BC (with slope $\frac{\alpha s}{\alpha+\gamma}$). In turn, cumulative arrivals are displayed by AC, which rise with slope s. The maximum travel occurs for the agent who departs at $\tilde{t}$, and arrives exactly at t^*. The queue builds up at a constant rate from t_q, when the

[6] Note that time early equals $Max\ [0, t^* - t - T^v(t)]$, and time late equals $Max\ [0, t + T^v(t) - t^*]$

[7] While this assumption may not always be realistic where traveling to an unfamiliar location ours is a setting where drivers commute regularly, have a wide range of traffic information and are making a decision having already observed congestion.

[8] To calculate the slope of segment AB note that, the cost of an early arrival trip is $\alpha T^v(t) + \beta[t^* - t - T^v(t)]$. Total differentiation of (D.2) and (D.3) with respect to t and using (D.2), it follows that $r(t) = \frac{\alpha s}{\alpha-\beta}$.

first individual leaves, until $\tilde{t}$. The queue then dissipates, again at a constant rate, reaching zero at $t_{q'}$ when the last person departs.

Since the first individual to depart at t_q and the last individual to depart at $t_{q'}$ incur only schedule delay costs, the following must hold in equilibrium:

(D.5) $$\beta\left(t^* - t_q\right) = \gamma\left(t_{q'} - t^*\right)$$

Further, since the bottleneck operates at capacity throughout the rush hour, and the length of the rush hour is $\frac{N}{s}$:

(D.6) $$t_{q'} = t_q + \frac{N}{s}.$$

These imply that the first person leaves home at:

(D.7) $$t_q = t^* - \frac{\gamma}{\beta+\gamma}\frac{N}{s},$$

and the last individual leaves at:

(D.8) $$t_{q'} = t^* + \frac{\beta}{\beta+\gamma}\frac{N}{s}.$$

The peak individual, who arrives at exactly t^* , leaves home at $\tilde{t}$:

(D.9) $$\tilde{t} = t^* - \frac{\beta}{\alpha}\frac{\gamma}{(\beta+\gamma)}\frac{N}{s},$$

and the resulting fraction of late individuals in this model is given by:

(D.10) $$\frac{\beta}{\beta+\gamma}.$$

Which with the standard ratio of parameters from the literature $\beta{:}\gamma = 1{:}4$ would imply that twenty percent of individuals would be late.

Implications of the Bottleneck Model with Schedule Delays.—So far we have only considered the possibility that the road is a single lane that is congested during the rush hour. We now allow for the possibility that the road also has free flow ExpressLanes, and consider the case of a solo driver who can pay a toll. If it is always the case that $\pi > \alpha T^v(t) + \beta(t^* - t)$ for $t \in [t_q, \tilde{t}]$, then no early drivers are willing to pay the toll. In contrast, for an individual who is late and arrives at time $\bar{\bar{t}}$, the willingness to pay to access the ExpressLanes and arrive on time is $(\alpha + \gamma)(\bar{\bar{t}} - t^*)$. Therefore, the willingness to pay per hour to access the ExpressLanes would simply be $\alpha + \gamma$, a constant that at best can only approximate the behavior of individuals for which the time differential between the mainline and HOV lane is relatively high.

Bottleneck Models with Scheduled Constraint and the Value of Urgency.—We now generalize the Arnott et al. (1993) model to explicitly consider a schedule constraint, which in turn allows individuals to reveal preferences for urgency. In the presence of a schedule constraint, the private costs of a trip become:

$$C(t) = \alpha T^v(t) + \beta(early\ time) + \gamma(late\ time) + \delta(being\ late) \tag{D.11}$$

We refer to δ as the value of urgency. As before, we can proceed to find the first and last individual in the rush hour, and the peak individual who arrives just on time. Similar to equation (D.5), the first and last drivers must be indifferent, leading to:

$$\beta\left(t^* - t_q^{SC}\right) = \gamma\left(t_{q'}^{SC} - t^*\right) - \delta, \tag{D.12}$$

and (D.6), (D.7), and (D.8) become:

$$t_q^{SC} = t^* - \frac{\gamma}{\beta + \gamma}\frac{N}{s} - \frac{\delta}{\beta + \gamma}, \tag{D.13}$$

$$t_{q'}^{SC} = t^* + \frac{\beta}{\beta + \gamma}\frac{N}{s} - \frac{\delta}{\beta + \gamma}, \tag{D.14}$$

and

$$\tilde{t}^{SC} = t^* - \frac{\beta}{\alpha}\frac{\gamma}{\beta + \gamma}\frac{N}{s} - \frac{\beta}{\alpha}\frac{\delta}{\beta + \gamma}. \tag{D.15}$$

The introduction of a scheduling constraint alters the equilibrium in several important ways. First, rush hour starts and ends earlier by $\frac{\delta}{\beta+\gamma}$. The individual that arrives just on time also leaves earlier in a schedule constraint model, but only by

$\frac{\beta}{\alpha}\frac{\delta}{\beta+\gamma}$. As a result, the cumulative departures up to $\tilde{t}^{SC}$ are substantially higher than in a model without a schedule constraint. Perhaps more interestingly, the presence of a discrete penalty for being late causes the queue to immediately dissipate after $\tilde{t}^{SC}$. In fact, by virtue of the Nash equilibrium there will be a time period immediately after $\tilde{t}^{SC}$ for which no new drivers enter the queue. Consider hypothetically a driver that could have chosen to depart at $\tilde{t}+\varepsilon$, as ε converges to zero in the limit one can ignore schedule delay costs. It is easy to demonstrate that:

$$\alpha(t^* - \tilde{t}^{SC}) \neq \alpha\big(t^* - (\tilde{t}+\varepsilon)\big) + \delta \tag{D.16}$$

precisely because of the presence of the discrete penalty for being late, the next individual to depart after $\tilde{t}$ will only depart at:

$$\check{t} = \tilde{t}^{SC} + \frac{\delta}{\alpha}. \tag{D.17}$$

After $\check{t}$ the queue starts building again. The intuition is rather simple. Since individuals that fail to depart by $\tilde{t}$ will be late and incur a cost of δ, it becomes optimal for some of them to actually depart later, creating a discontinuity in the second segment of the peak. The equilibrium is depicted in Appendix Figure F.9. Bottleneck Model Departures with and without Urgency panel B.

We also note that the introduction of δ fundamentally alters the prediction of the fraction of individuals that are late in the model. This becomes:

$$\frac{\beta}{\beta+\gamma} - \frac{\delta/(\beta+\gamma)}{N/s}. \tag{D.18}$$

As discussed in the next section, with our estimate of $\delta = \$3$, lower values of β and γ and a rush hour of 4 hours, the percent of late individuals will decrease to about 7%.

Implications of the Bottleneck Model with a Schedule Constraint.—Now consider a road with free flow ExpressLanes. Assuming that the toll is higher than $\alpha - \beta$, no early drivers are willing to pay the toll and late drivers continue to use the mainline lanes until the last possible second that switching to the ExpressLanes will get them to their destination at time t^*. An agent who leaves at time t will be willing to pay $(\alpha + \gamma) \cdot [(t + D(t)s) - t^*] + \delta$ to avoid mainline travel of $[(t + D(t)s) - t^*]$. This individual will use the mainline lanes until time almost t^* and then pay the toll to arrive at t^*. That is, if this individual saves τ minutes, her willingness to pay is $\delta + (\alpha + \gamma)\tau$ implying a WTP per hour of $\delta/\tau + (\alpha + \gamma)$.

A major insight of including urgency in the bottleneck model is that the resulting willingness to pay her hour is declining in τ, the time differential between lanes giving rise to the shape of the distribution of willingness to pay found in Figure 3 Panel A.

Tolling Equilibria.—Based on the preceding analysis and as in Vickery (1969) and Arnott et al. (1993), we can rewrite equations (D.4) and (D.11) to account for an optimal congestion toll:

(D.4’) $$C(t) = \alpha T^v(t) + \beta(time\ early) + \gamma(time\ late) + \tau(t)$$

and

(D.11’) $$C(t) = \alpha T^v(t) + \beta(early\ time) + \gamma(late\ time) + \delta(being\ late) + \tau(t).$$

Rearranging each results in the following optimal toll schedules without a schedule constraint:

(D.19) $$\tau(t) = \begin{cases} 0 & \text{if } t < t_q \\ a - \beta(t^* - t) & \text{if } t_q < t \leq t^* \\ a - \gamma(t - t^*) & \text{if } t^* \leq t < t_{q'} \\ 0 & \text{if } t > t_{q'}, \end{cases}$$

and with a schedule constraint:

(D.20) $$\tau^{SC}(t) = \begin{cases} 0 & \text{if } t < t_q^{SC} \\ a^{SC} - \beta(t^* - t) & \text{if } t_q^{SC} < t \leq t^* \\ a^{SC} - \gamma(t - t^*) - \delta & \text{if } t^* < t < t_{q'}^{SC} \\ 0 & \text{if } t > t_{q'}^{SC}, \end{cases}$$

Recall, as shown in the previous section, that the beginning and end of the queue under a schedule constraint occurs earlier than without one: $t_q^{SC} < t_q < t^* < t_{q'}^{SC} < t_{q'}$.

Here a and a^{SC} are the average total travel cost. These are

(D.21) $$a = \frac{\beta\gamma}{\beta+\gamma}\frac{N}{s},$$

and

(D.22) $$a^{SC} = \frac{\beta\gamma}{\beta+\gamma}\frac{N}{s} + \frac{\beta}{\beta+\gamma}\delta = a + \frac{\beta}{\beta+\gamma}\delta,$$

so that at t^*, the toll is higher under a schedule constraint than not since $a^{SC} > a$.[9] In Figure F.10, we plot the distribution of optimal tolls.

A few details become clear from the comparison. First, note from equations (D.19) and (D.20), that the slope of the toll functions must be the same, $-\beta$ before t^* and $-\gamma$ after, where the former is smaller in magnitude than the former. Second, because the queue forms earlier under schedule constraints, for $t_q^{SC} < t < t^*$, $\tau^{SC}(t) > \tau(t)$, that is the schedule constrained toll is higher before the desired arrival time. Third, because the queue ends earlier under schedule constraints, for $t_{q'} > t > t^*$, $\tau^{SC}(t) < \tau(t)$, that is the schedule constrained toll is lower after the desired arrival time. Fourth, mathematically, there must be a difference in the vertical intercept of the schedule constrained toll function before and after the desired arrival time equal to δ and indicated in the figure. Fifth, from equations (D.21) and (D.22), we know that for early arrival, the schedule constrained toll will be larger by $\tau^{SC}(t) - \tau(t) =$

[9] Formulae for average total travel cost can be derived from substituting equations (D.7) into (D.4) and (D.13) into (D.11), and dividing by *N*, recognizing that all commuters have the same trip cost as shown in Arnott, de Palma and Lindsey (1990).

$a^{SC} - a = \frac{\beta}{\beta+\gamma}\delta,\ t \leq t^*$. Whereas for late arrival, $\tau^{SC}(t) - \tau(t) = a - (a^{SC} - \delta) = -\frac{\gamma}{\beta+\gamma}\delta,\ t > t^*$. Under standard assumptions of β, γ and $\delta = \$3$, this means the toll under the model with urgency is \$0.60 higher that without urgency prior to t^* and \$2.40 lower after t^*. Moreover, if we assume that the rush hour period is 4 hours consistent with LA Metro's designation of the AM peak period on the ExpressLanes corridor, then N/s = 4. Lastly, if follow Hall (2018) and assume that schedule delay early costs are a tenth of the value of time, $\beta = 0.1\ \alpha$, and that the value of time corresponds to 50% of the median wage in LA, so roughly \$10 per hour, then we can calculate optimal tolls at t^* without urgency: $\tau(t^*) = a = \frac{\beta\gamma}{\beta+\gamma}\frac{N}{s} = \$3.20$ and with the value of urgency as \$3.80.

Appendix E. Further Details on IV Strategy

Following the approach of Aizer, et al. (2018), we use moments in the distribution of the potentially mismeasured variable as an instrument to address measurement error as discussed in section IV.C of the paper. Our instrument set is informative because it is likely to be correlated with actual travel time perceptions. The set indicated by *K* in equation (E.1), includes average time savings one hour, one week and two weeks after the trip by hour of day, day of week and road segment. We use leads, as opposed to lags, in travel time, because leads are likely to be highly correlated to contemporaneous time savings during a given hour, day of week and road segment, but unlikely to be affected by any unobserved contemporaneous factor affecting the driver when a particular trip is taken.

Although our multiple measures of travel time savings were taken at different times and may capture differences in the driver's underlying perceptions, each measure can still be interpreted as an (imperfect) measure of the driver's underlying travel time savings perceptions. The source of the measurement error is the inexactitude of the time savings measure, that is the plausibly random variation in the length of time between measures and the trip. As such, we believe it is likely that measurement errors will be largely uncorrelated. Specifically:

$$\Delta TT_{i,s,t} = \pi_0 + \sum_{k \in K} \pi_k \Delta\overline{TT}_{s,k} + \epsilon_{i,s,t}, \tag{E.1}$$

where $\Delta\overline{TT}_{s,k}$ is average travel time savings on segment *s*, for hour, day of the week lead *k*, and π_0 is a regression constant.

To implement this IV strategy for individual-level regressions, we need to account for the fact that the second stage only includes trips for which we see the account in the ExpressLanes, whereas the first-stage includes all trips one hour, one week and two weeks after the trip during that hour of day. We follow the split-sample IV approach of Angrist and Krueger (1995) by estimating the first-stage regression of travel time savings on our instruments and reliability using all individuals except for one. Then in the second stage we regress the toll paid by the excluded individual on a constant, reliability for the trips that account took, and the first stage predicted value of time savings. This is repeated for all individuals in our sample.

Since reliability is positively correlated with travel time savings, we would want to also instrument for reliability. In practice, however, and shown in section V, given the limited explanatory power of reliability in our model and the fact that theory does not give a clear rationale for how drivers form expectations in this context, the case for an instrument is less clear.

Appendix References

Aizer, Anna, Janet Currie, Peter Simon, and Patrick Vivier. 2018. "Do Low Levels of Blood Lead Reduce Children's Future Test Scores?" *American Economic Journal: Applied Economics* 10 (1): 307–41.

Angrist, Joshua D., and Alan B. Krueger. "Split-sample instrumental variables estimates of the return to schooling." *Journal of Business & Economic Statistics* 13, no. 2 (1995): 225-235.

Arnott, Richard, André Palma, and Robin Lindsey. 1993. "A Structural Model of Peak-Period Congestion: A Traffic Bottleneck with Elastic Demand." *American Economic Review* 83 (1): 161–79.

Auffhammer, Maximilian, and Ryan Kellogg. "Clearing the air? The effects of gasoline content regulation on air quality." *American Economic Review* 101, no. 6 (2011): 2687-2722.

Colella, Fabrizio, Rafael Lalive, Seyhun Orcan Sakalli, and Mathias Thoenig. "Inference with arbitrary clustering." (2019). https://dx.doi.org/10.2139/ssrn.3449578

Gelman, Andrew, and Guido Imbens. "Why high-order polynomials should not be used in regression discontinuity designs." *Journal of Business & Economic Statistics* 37, no. 3 (2019): 447-456.

Hall, Jonathan D. 2018. "Pareto Improvements from Lexus Lanes: The Effects of Pricing a Portion of the Lanes on Congested Highways." *Journal of Public Economics* 158: 113–25.

Imbens, Guido W., and Thomas Lemieux. "Regression discontinuity designs: A guide to practice." *Journal of Econometrics* 142, no. 2 (2008): 615-635.

Small, Kenneth A. 1982. "The Scheduling of Consumer Activities: Work Trips." *American Economic Review* 72 (3): 467–79.

Vickrey, William S. 1969. "Congestion Theory and Transport Investment." *American Economic Review* 59 (2): 251–60.

Appendix F. Additional Figures

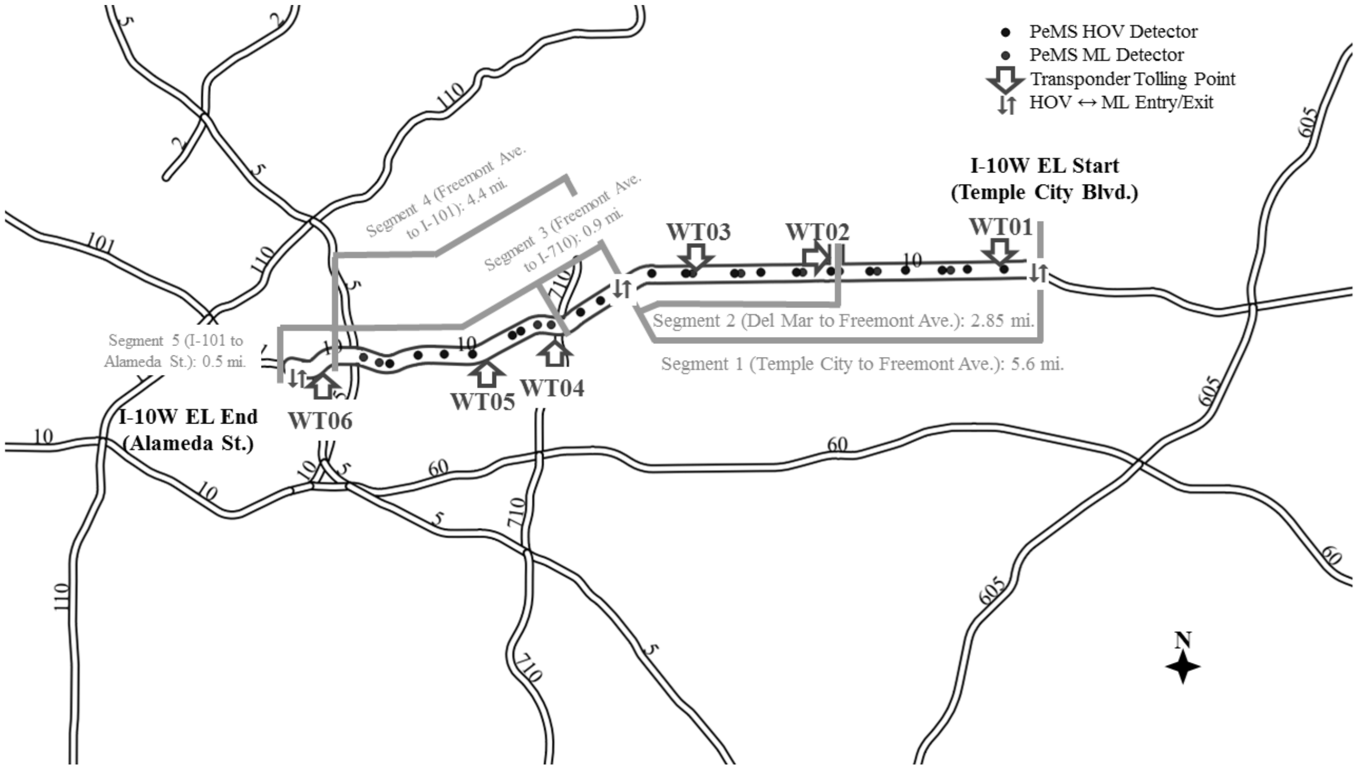


FIGURE F.1. I-10 W EXPRESSLANES DESIGN

Notes: The figure displays the I-10 W ExpressLanes design, which includes 5 separately tolled segments along its 10.5-mile stretch West of Downtown Los Angeles (indicated by the light grey lines). The beginning and end of each segment is defined by a transponder detector and license plate scanner at each tolling plaza (indicated in the map with an arrow) that identifies vehicles entering and exiting the ExpressLanes. This corridor has one of the highest densities of PeMS flow and speed detectors in California as shown by the small circles.

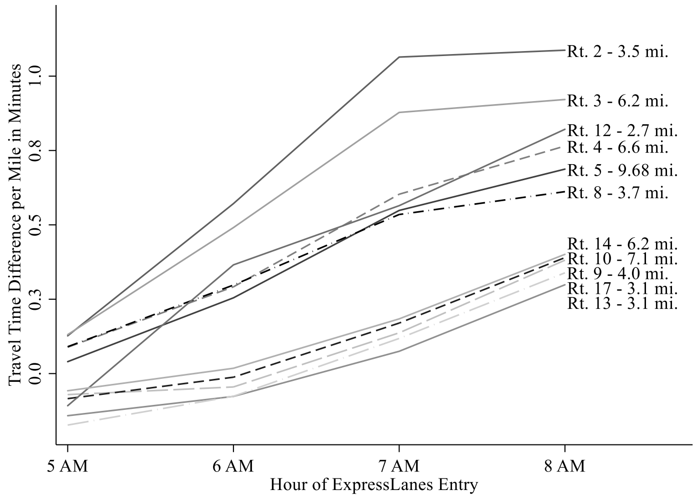
PANEL A: APPROACH TO EXPRESSLANES ENTRANCE

PANEL B: EXPRESSLANES TOLL DISPLAY

FIGURE F.2. I-10 W EXPRESSLANES SIGNAGE

Notes: The figure displays the I-10 W ExpressLanes approach from the Temple City Blvd. entrance (WT01). Drivers see that the ExpressLanes entrance is approaching and then see a sign indicating the total toll they will pay for a full or partial trip. The toll displayed is locked in upon entry for any combination of segments the driver chooses. After October 20th, 2013 in our sample, an additional sign also showed the time savings for each trip. *Source:* Google Street View.

Panel A: Travel Time Savings



Panel B: Reliability

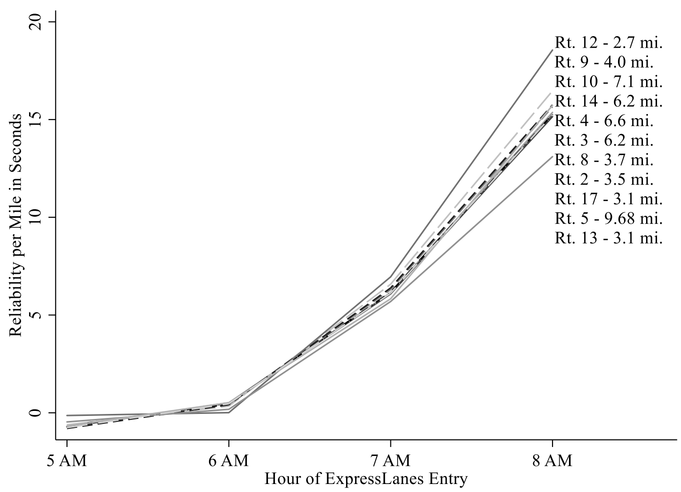


Figure F.3. Segment-Level Variation in Time Savings and Reliability by Hour

Notes: The figures plot the considerable variation in average travel time savings and reliability by route and hour of entry to the I-10 W ExpressLanes on workdays. Segment names and distances are indicated to the right of each line. Travel time difference, measured in hours per mile, is the time saved by taking the ExpressLanes compared with Mainline Lanes, from Mainline speeds reported by PeMS, divided by the trip distance. Reliability is the difference between lanes in the spread of travel times between the 50th and 80th quantiles divided by the trip distance. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.

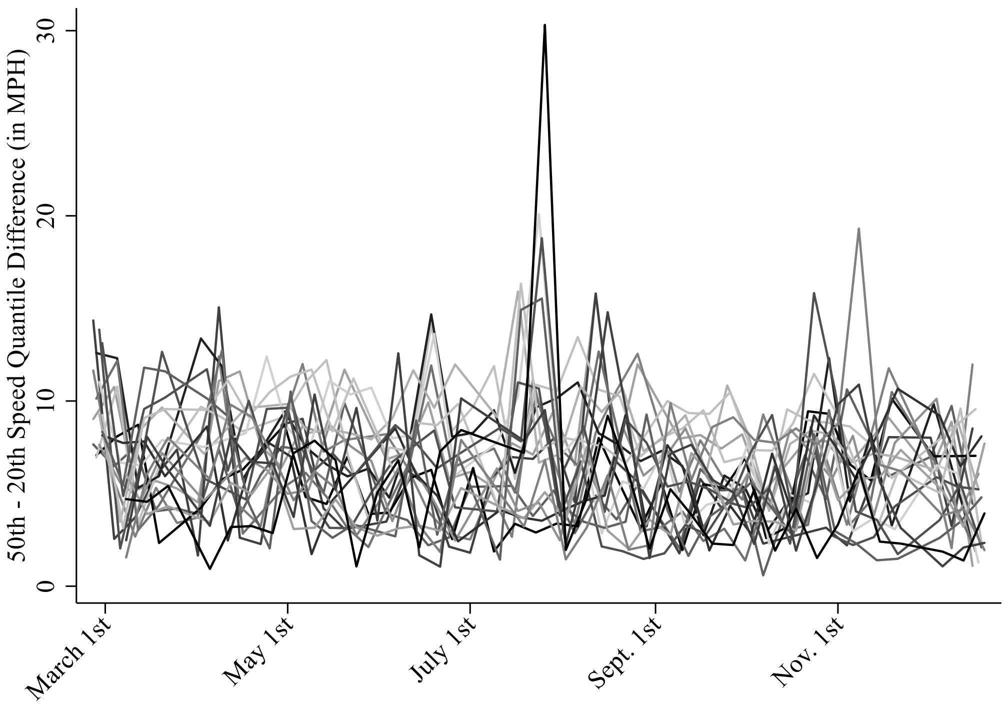


FIGURE F.4. VARIATION IN MAINLINE SPEED DISTRIBUTION BY HOUR AND DAY-OF-WEEK

Notes: This figure plots 20 time series of the difference between the 50th and 20th quantiles of speed for the I-10 W during the AM peak (5-9AM). Each line corresponds to this value for an AM peak hour (5, 6, 7, 8 AM) and weekday (Monday-Friday), illustrating substantial variation in the distribution of 5-minute speeds within a weekday-hour from one week to the next. Speed for mainline speeds are those reported by PeMS. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.

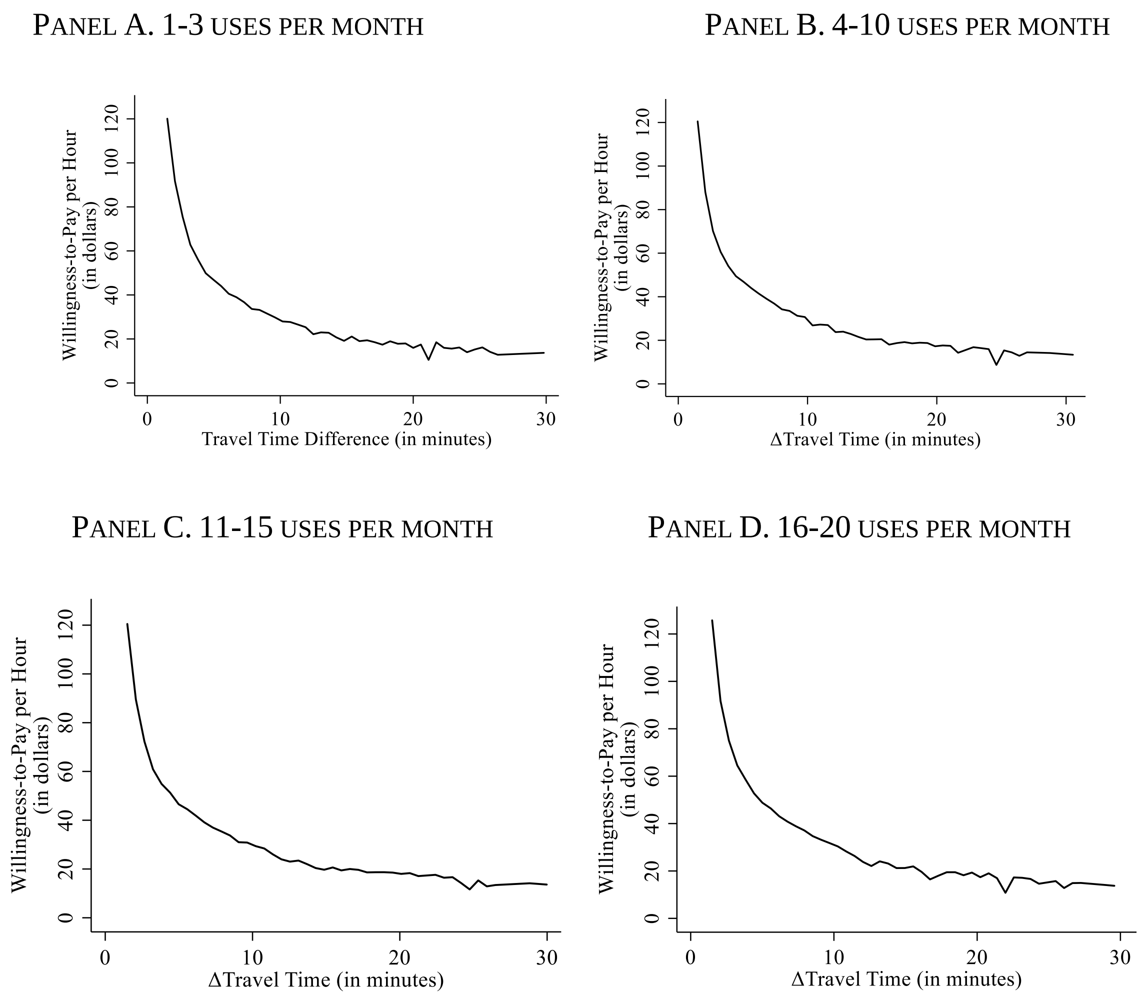
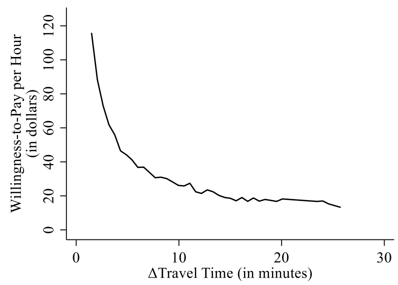


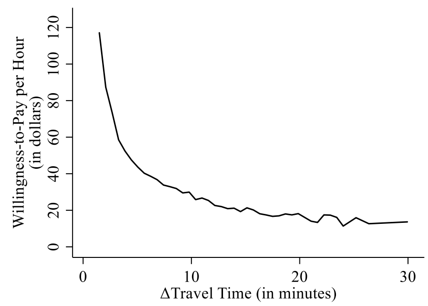
FIGURE F.5. AVERAGE WILLINGNESS-TO-PAY PER HOUR OF TRIPS IN THE EXPRESSLANES BY MONTHLY AM PEAK TRIP FREQUENCY

Notes: This figure displays the average willingness-to-pay (WTP) per hour for travel time savings while assessing the I-10 W ExpressLanes as in Figure 2, but for subsamples of the trips in our data. Each panel considers a subset of trips taken by individuals that appear in the ExpressLanes during the AM peak for the indicated number of during the same month. Panel A includes 65,526 trips, panel B 132,885, panel C 93,529 and panel D 59,316. The WTP per hour is calculated using a kernel-weighted local polynomial smoothing for the ratio of the total toll paid for each trip over the travel time difference between the mainline lanes and the ExpressLanes. The vertical axis is truncated at $120, although the actual values are much higher (See Table 1). The smoother for all panels is an Epanechnikov kernel with a bandwidth of 0.05. ΔTravel Time is calculated based on mainline speeds from PeMS and ExpressLanes time stamps and the actual distance traveled for each trip in the ExpressLanes. Both panels are generated using trip-level transponder data for the morning peak hours (5-9AM) of workdays in the first 10 months of the program, excluding holidays. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.

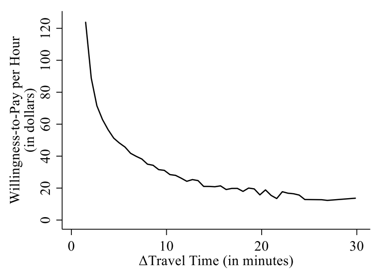
PANEL A. 1ST APPEARANCE



PANEL B. 2ND-5TH APPEARANCE



PANEL C. 30TH-50TH APPEARANCE



PANEL D. ≥100TH APPEARANCE

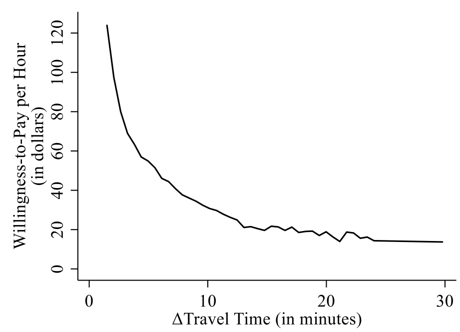


FIGURE F.6. AVERAGE WILLINGNESS-TO-PAY PER HOUR OF TRIPS IN THE EXPRESSLANES BY NUMBER OF PREVIOUS AM PEAK EXPRESSLANES APPEARANCES

Notes: This figure displays the average willingness-to-pay (WTP) per hour for travel time savings while assessing the I-10 W ExpressLanes as in Figure 2, but for subsamples of the trips in our data. Each panel considers a subset of trips taken by individuals that have previously appeared in the ExpressLanes during the AM peak for the indicated number of trips since the start of the program. Panel A reflects 20,912 trips, Panel B 51,063, Panel C 143,248 and Panel D 15,683. The WTP per hour is calculated using a kernel-weighted local polynomial smoothing for the ratio of the total toll paid for each trip over the travel time difference between the mainline lanes and the ExpressLanes. The vertical axis is truncated at $120, although the actual values are much higher (See Table 1). The smoother for all panels is an Epanechnikov kernel with a bandwidth of 0.05. ΔTravel Time is calculated based on mainline speeds from PeMS and ExpressLanes time stamps and the actual distance traveled for each trip in the ExpressLanes. Both panels are generated using trip-level transponder data for the morning peak hours (5-9AM) of workdays in the first 10 months of the program, excluding holidays. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.

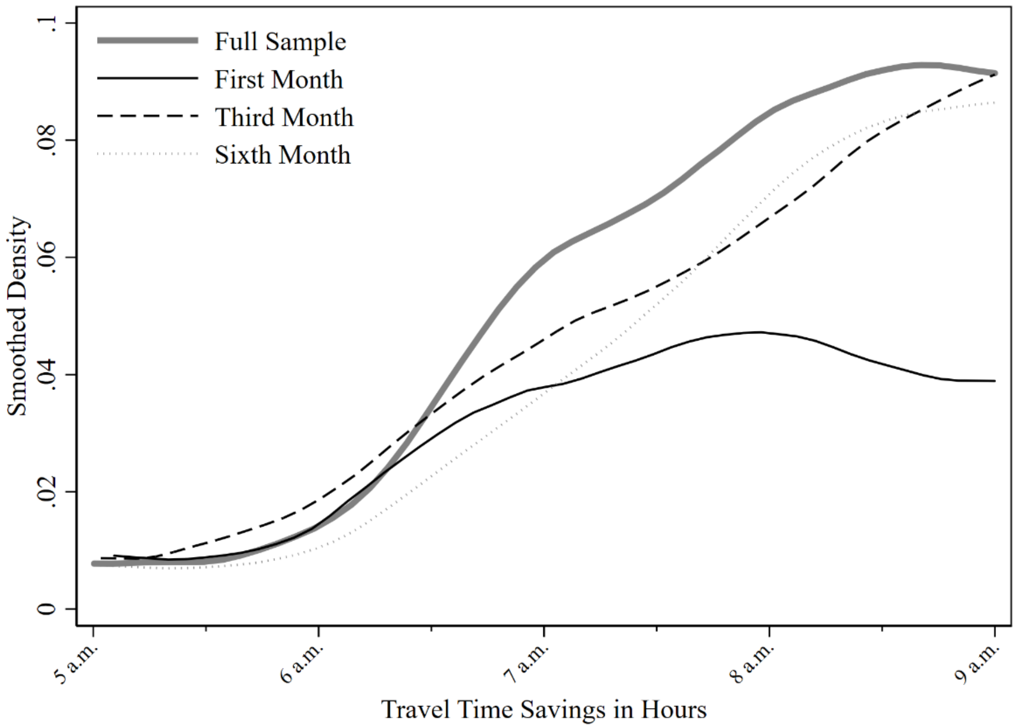


FIGURE F.7. AVERAGE TIME SAVED OVER AM PEAK BY MONTH OF PROGRAM

Notes: This figure plots the kernel-weighted locally smoothed estimate of five-minute time saved, which is the difference between ExpressLanes and mainline travel times for commuters in our data.

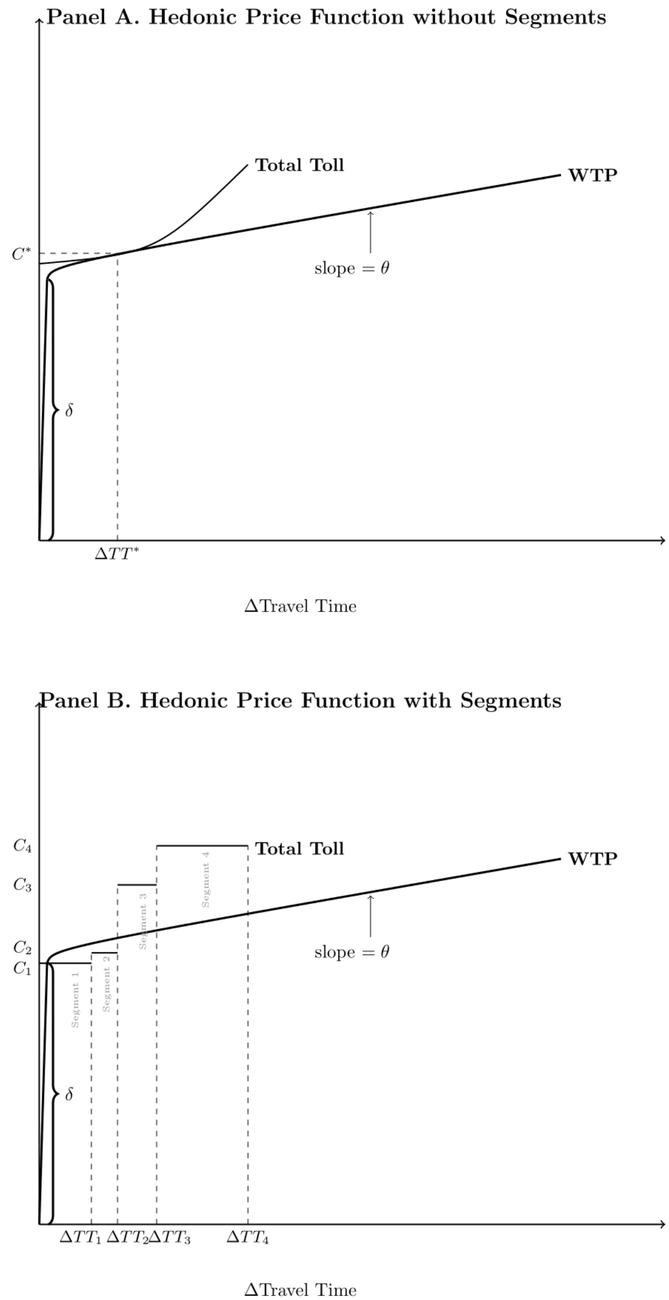


FIGURE F.8. IDENTIFICATION OF WTP FROM TOLL HEDONIC

Notes: The figure displays the willingness-to-pay for travel time savings given value of urgency δ and value of time θ in the ExpressLanes with continuous segment length (Panel A) and discrete segment length (Panel B). Tangency between WTP and the price function reveals MWTP in the continuous case, while the differences between cumulative segment prices provide bounds on these parameters.

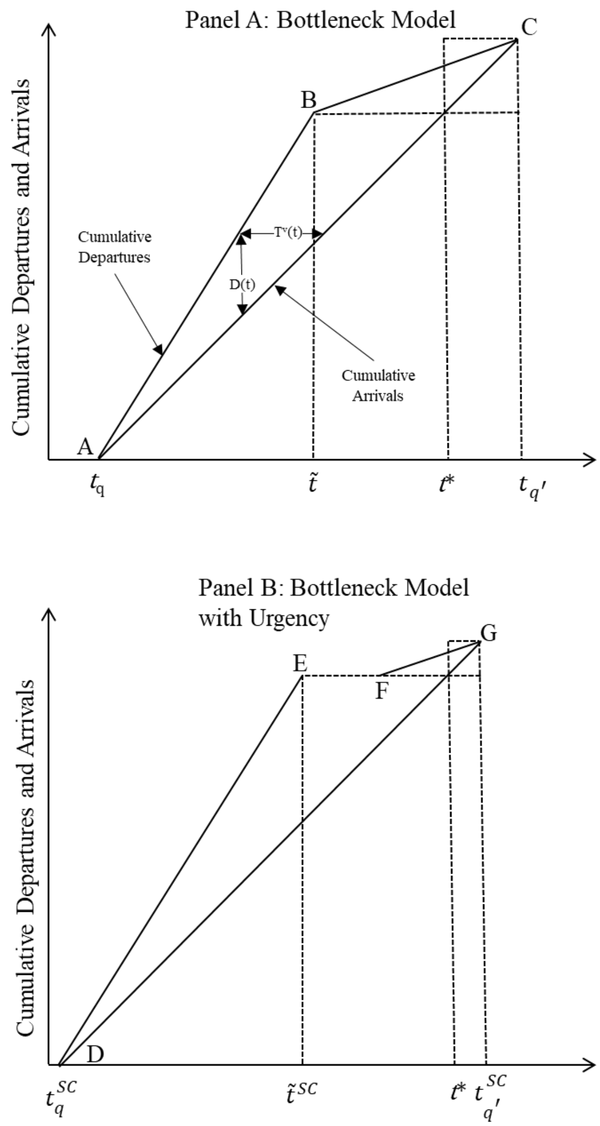


FIGURE F.9. BOTTLENECK MODEL DEPARTURES WITH AND WITHOUT URGENCY

Notes: The figures depict the behavior of individual commuters during a daily commute in the bottleneck model. Panel A describes the bottleneck model with only per-hour penalties for being early or late, while Panel B describes the behavior of individuals with indirect utility that includes a discrete cost for being late associated with urgency. Solid lines along the triangle refer to the boundaries of the queue formed at various points of the peak. The vertical dashed line refers to the preferred arrival time t*, while t_q and $t_{q'}$ refer to the beginning and end of the bottleneck, respectively. Horizontal distances between the solid lines, denoted by Tv(t) in Panel A, refer to time spent in the queue, while vertical distances, denoted by D(t), refer to the mass of individuals in the queue at a given time. The distance EF in Panel B refers to the later shift in the mass of departures as a result of urgency.

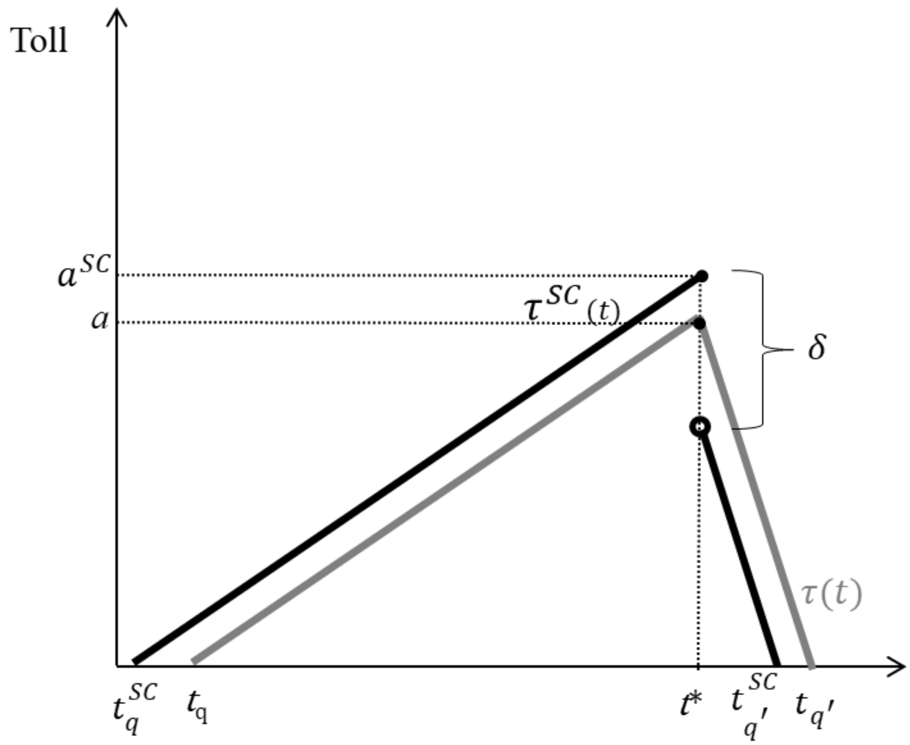


FIGURE F.10. OPTIMAL TOLL SCHEDULES FOR BOTTLENECK MODEL WITH AND WITHOUT URGENCY

Notes: The figure depicts optimal toll schedules over the rush hour period with ($\tau^{SC}(t)$ in black) and without ($\tau(t)$ in gray) urgency. The horizontal axis displays time over the peak period. t_q^{SC} and t_q are the start of the rush hour period and $t_{q'}^{SC}$ and $t_{q'}$ the end with and without urgency, respectively. t^* denotes the common desired arrival time, and δ is the value of urgency, which reflects the difference in optimal tolls when arrival occurs just before and just after $t^*$when discrete lateness penalties exist.

Appendix G. Additional Tables

Table G.23—Homogeneous Agent Hedonic Price Function Estimates: Gas Price and Weather Robustness

Table G.24—Homogeneous Agent Hedonic Price Function Estimates: Seasonality

TABLE G.1—ENTRY-EXIT FREQUENCY MATRIX

I	II	III	IV	V
	Exit Plaza			
Entry Plaza	WT03	WT04	WT05	WT06
WT01	111,446	126,106	16,533	146,939
WT02	0	11,030	1,079	24,033
WT03	—	333	286	8,145
WT05	—	—	—	20,302

Notes: This table reports the frequency of observations by entry and exit toll plaza for the morning peak (5-9 AM) on workdays from February 25th, 2013 until December 30th, 2013 in the Metro transponder data. Trips with zero distance traveled and the 6.2% of observations with negative time saving, are removed. WT01 and WT02 are entry only. WT04 and WT06 are exit only.

TABLE G.2—RDD: EXPRESSLANES OPENING EFFECT DURING AM PEAK

	I	II	III
dependent variable	log(speed)	log(speed)	log(speed)
bandwidth (days)	55	60	65
Panel A: Mainline Lanes			
1[ExpressLanes Opening]	0.046	0.057	0.063
	(0.040)	(0.039)	(0.039)
R^2	0.715	0.713	0.712
Observations	74,075	76,379	81,179
Panel B: ExpressLanes			
1[ExpressLanes Opening]	-0.033***	-0.032***	-0.032***
	(0.004)	(0.005)	(0.005)
R^2	0.711	0.710	0.710
Observations	54,537	56,169	59,577

Notes: Values shown are the coefficients from 6 separate regressions of the logarithm of speed on the regressands during the AM Peak (5-9AM). Standard errors, clustered by week, are in parentheses. **1**[ExpressLanes Opening] is a dummy variable equal to one on or after February 23, 2013. Covariates include the logarithm of lagged gas price, the logarithm of speed for the I-210W, dummy variables for day of the week, dummies for hour of the day, and quadratics in rainfall and visibility. All covariates, except the ExpressLanes opening dummy, are interacted with dummy variables corresponding to each detector, and a triangular kernel is used in all regressions. Flow is the number of cars passing the average detector entering the regressions. Weekends, holidays and observations where any of the 30 second observations are missing are dropped.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.3—TRIP- & INDIVIDUAL-LEVEL WILLINGNESS-TO-PAY ESTIMATES BY DECILE OF TRAVEL TIME SAVINGS

II	III	IV	V	VI	VII	VIII
Panel A. Trip-Level Characteristics						
ΔTravel Time			Average WTP per Hour			
in Hours	in Minutes	Average Toll Paid	Full Time Period	February & March	June	September
0.01	0.39	$3.20	$1,977	$1,730	$1,910	$1,220
0.02	1.01	$3.10	$190	$147	$242	$134
0.03	1.66	$3.12	$115	$94	$158	$86
0.04	2.37	$3.17	$81	$72	$116	$66
0.05	3.11	$3.29	$64	$55	$85	$55
0.06	3.88	$3.57	$55	$45	$70	$48
0.08	4.69	$3.81	$49	$39	$62	$44
0.09	5.64	$4.15	$44	$34	$56	$41
0.12	6.95	$4.49	$39	$29	$46	$38
0.18	11.04	$4.95	$28	$25	$40	$28
0.07	4.08	$3.69	$264	$227	$278	$176

Panel B. Individual-Level Characteristics					
ΔTravel Time (decile)	Average Uses per Month	Average Hourly Wage in Zip Code	Average Toll Paid	Modal Vehicle Registered to Individual	Average Vehicle Value
1	8.8	$19.35	$3.20	Honda Accord	$9,543
2	9.5	$19.40	$3.10	Honda Accord	$9,512
3	9.8	$19.47	$3.12	Honda Accord	$9,553
4	9.9	$19.47	$3.17	Honda Accord	$9,443
5	9.8	$19.65	$3.29	Toyota Camry	$9,477
6	9.9	$19.71	$3.57	Honda Accord	$9,476
7	9.8	$19.73	$3.81	Honda Accord	$9,523
8	9.8	$19.76	$4.15	Honda Accord	$9,607
9	9.8	$19.79	$4.49	Honda Accord	$9,793
10	9.6	$20.00	$4.95	Honda Accord	$9,943
Average	9.7	$19.63	$3.69	Honda Accord	$9,587

Notes: The table calculates the average time savings, toll paid and implied WTP for travel time saved by decile of travel time saved for I-10 W ExpressLanes use during the morning peak (5-9 AM) on workdays. Columns II-V cover the period from February 25th, 2013 until December 30th, 2013 while VI-VIII cover the indicated subsamples. "Time Savings" is the travel time saved by driving in the ExpressLanes over the mainline lanes, calculated from Metro transponder information on vehicle distance traveled and speed compared with the speed recorded by PeMS in the mainline lanes. "Average Hourly Wage in Zip Code" is based on annual wage income 2013 ACS data for Los Angeles assuming 2,040 hours worked per year. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Each decile for the full time period contains 46,624 trips, for February and March contains 3,261 trips, for June contains 4,615 trips and for September contains 7,001 trips.

TABLE G.4—MONTHLY FREQUENCY BY TRAVEL TIME SAVINGS DECILE

I	II	III	IV	V	VI	VII
ΔTravel Time (decile)	One Month of Use	1x per Month	2-5x per Month	6-10x per Month	11-20x per Month	>20x per Month
1	5.20%	3.87%	31.61%	34.12%	24.33%	0.69%
2	5.99%	2.98%	26.98%	33.40%	29.38%	1.12%
3	6.26%	2.68%	24.53%	33.00%	32.19%	1.18%
4	6.73%	2.61%	23.12%	33.13%	33.20%	1.04%
5	6.66%	2.62%	23.56%	32.74%	33.33%	0.92%
6	6.29%	2.51%	23.17%	32.96%	33.93%	0.98%
7	6.32%	2.62%	23.35%	32.89%	33.83%	0.81%
8	6.09%	2.83%	23.55%	32.36%	34.08%	0.92%
9	6.08%	2.97%	23.68%	31.86%	34.31%	0.91%
10	6.08%	3.06%	24.73%	32.06%	33.08%	0.80%

Notes: The table presents the usage patterns of individuals in the I-10 W ExpressLanes by decile of travel time savings during the morning peak (5-9 AM) on workdays. First, we categorize individuals according to average number of trips (in any decile) per month. Then values given are the number of trips in that decile by agents with frequency of the listed column, implying that rows sum to 100%. Because the first month the agent adopts a transponder may not by typical, we construct average monthly use excluding the initial observed month. Agents who only use the lane for one month of data are given in the first column. Monthly use numbers are rounded up to the nearest integer. Data cover workdays during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Each decile for the full time period contains 46,624 trips.

TABLE G.5—MOST COMMON VEHICLES BY DECILE OF TRAVEL TIME SAVINGS

I	II	III	IV
ΔTravel Time (decile)		Top 3 Cars	
1	Honda – Accord	Honda – Civic	Toyota – Camry
2	Honda – Accord	Honda – Civic	Toyota – Camry
3	Honda – Accord	Honda – Civic	Toyota – Camry
4	Honda – Accord	Toyota – Camry	Honda – Civic
5	Toyota – Camry	Honda – Accord	Honda – Civic
6	Honda – Accord	Toyota – Camry	Honda – Civic
7	Honda – Accord	Honda – Civic	Toyota – Camry
8	Honda – Accord	Toyota – Camry	Honda – Civic
9	Honda – Accord	Toyota – Camry	Honda – Civic
10	Honda – Accord	Toyota – Camry	Honda – Civic
Whole Sample	Honda – Accord	Toyota – Camry	Honda – Civic

Notes: The table displays the most common three vehicle models in the I-10 W ExpressLanes by decile of time saved during the morning peak (5-9 AM) on workdays. We report the vehicle make and model registered to individuals most commonly for each decile. Time savings are calculated from transponder information on vehicle distance traveled and speed compared with PeMS mainline speed data. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Each decile for the full time period contains 46,624 trips.

TABLE G.6—REGRESSION OF DISTANCE ON EXIT TIME

	I	II	III	IV	V
Exit Time	0.27***	0.27***	0.27***	0.26***	0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exit Time^2				0.06***	
				(0.02)	
Toll in Dollars per Mile	-3.59***	-3.13***	-3.13***	-3.58***	-2.62***
	(0.07)	(0.09)	(0.07)	(0.07)	(0.05)
Constant	8.61***	8.33***	8.33***	8.59***	6.67***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.03)
Limitations		Acct FE	Transponder FE		Removing Full Segment
R^2	0.103	0.659	0.675	0.103	0.198
Observations	334,127	334,127	334,127	334,127	232,053

Notes: The table provides additional evidence for the influence of schedule constraints by considering how drivers' consumption of distance along the I-10 W ExpressLanes responds to variation in average exit time during the AM Peak (5-9AM). Values shown are the coefficients of 5 separate regressions of the total distance traveled by commuters in the ExpressLanes on the regressands. Exit time, measured in hours, is the difference for each trip between the time exiting the lanes and the average for each individual's transponder. Column V reports the same model as column I but with trips travelling the full ExpressLanes corridor removed. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.7—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: STANDARD ERROR CLUSTERING

	I	II	III	IV	V	VI
	Robust	Day	Week	Month	Individual	Week-Segment
Constant	2.89***	2.89***	2.89***	2.89***	2.89***	2.89***
	(0.00)	(0.03)	(0.05)	(0.08)	(0.01)	(0.47)
ΔTravel Time	8.30***	8.30***	8.30***	8.30***	8.30***	8.30***
	(0.04)	(0.63)	(0.77)	(0.65)	(0.10)	(2.81)
ΔReliability	22.67***	22.67***	22.67***	22.67***	22.67***	22.67***
	(0.12)	(2.11)	(3.39)	(4.24)	(0.27)	(5.00)
R^2	0.22	0.22	0.22	0.22	0.22	0.22
Observations	433,623	433,623	433,623	433,623	433,623	433,623

Notes: The table examines the effects of differing levels of clustering on the standard errors. Values shown are the coefficients of 6 separate regressions of the toll paid on the regressands. Standard errors are in parentheses. Column I reports heteroskedastic robust standard errors, while columns II-VI cluster by the indicated variable. Column VI calculates two-way clustered standard errors following Cameron, Gelbach and Miller (2011). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80^{th} and 50^{th} quantiles. Data cover workdays during the morning peak (5-9AM). Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.8—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: STANDARD ERROR ROBUSTNESS

Panel A. Newey-West SEs by 5 Minute Interval

	I	II	III	IV
Constant	2.89***	2.89***	2.89***	2.89***
	(0.48)	(0.00)	(0.00)	(0.00)
ΔTravel Time	8.30**	8.30***	8.30***	8.30***
	(2.88)	(0.05)	(0.05)	(0.05)
ΔReliability	22.67***	22.67***	22.67***	22.67***
	(4.61)	(0.13)	(0.14)	(0.15)
R^2	0.22	0.22	0.22	0.22
Observations	433,226	433,226	433,226	433,226
Time Lag	5 min	10 min	15 min	20 min

Panel B. Arbitrary Spatial Correlation (Colella, et al., 2019)

	I	II	III	IV
Constant	2.89***	2.89***	2.89***	2.89***
	(0.01)	(0.01)	(0.02)	(0.02)
ΔTravel Time	7.92***	7.92***	7.92***	7.92***
	(0.22)	(0.26)	(0.30)	(0.32)
ΔReliability	23.76***	23.76***	23.76***	23.76***
	(0.59)	(0.70)	(0.79)	(0.86)
R^2	0.22	0.22	0.22	0.22
Observations	42,069	42,069	42,069	42,069
Time Lag	1x	2x	3x	4x

Notes: The table examines the effects of accounting for temporal autocorrelation using Newey-West (1987) corrected standard errors. Values shown are the coefficients of 4 separate regressions of the toll paid on the regressands. "Time Lag" accounts for temporal autocorrelation by account based on the last 1-4 appearances in the ExpressLanes. The sample has been restricted to accounts appearing five or more times in our data. Standard errors are in parentheses. Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80^{th} and 50^{th} quantiles. Data cover workdays during the morning peak (5-9AM). Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.9—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: MODEL WITHOUT RELIABILITY

	I	II
Constant	2.887***	2.960***
	(0.481)	(0.513)
ΔTravel Time	8.345**	11.330***
	(2.868)	(3.014)
ΔReliability	22.742***	
	(4.624)	
R^2	0.22	0.15
Observations	426,761	426,761
Chow Test Constant p-value	0.08	
Chow Test Travel Time p-value	0.00	

Notes: Values shown are the coefficients of two regressions of the toll paid on the regressands. Data cover workdays during the morning peak (5-9AM). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80th and 50th quantiles. Reliability less than 0.01 hours (36 seconds) is set to zero in individual-specific regressions. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors in all regressions are clustered by road segment and are presented in parentheses. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level

TABLE G.10—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: INCLUDING NEGATIVE TRAVEL TIME DIFFERENCE & NEGATIVE RELIABILITY

	I	II	III	IV
Constant	2.84***	2.911***	2.86***	2.93***
	(0.48)	(0.42)	(0.48)	(0.42)
ΔTravel Time	8.021**	7.21*	8.04**	7.23*
	(3.00)	(3.590)	(3.02)	(3.61)
ΔReliability	24.76***	25.48***	24.12***	24.82***
	(5.24)	(5.70)	(5.03)	(5.52)
R^2	0.220	0.208	0.218	0.206
Observations	433,623	462,537	433,623	462,537
ΔTravel Time > 0	Yes	No	Yes	No
Reliability < 0 zeroed	No	No	Yes	Yes

Notes: The table examines the robustness of the central specification to the zeroing of negative reliability and the inclusion of trips with negative time savings. Values shown are the coefficients of 4 separate regressions of the toll paid on the regressands. Data cover workdays during the morning peak (5-9AM). ΔTravel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. ΔReliability is the difference in the spread of the 80th and 50th quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.11—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: RELIABILITY MOMENTS AND WINDOW ROBUSTNESS

Panel A. Reliability Moments	I	II	III	IV
Constant	2.85***	2.84***	2.76***	2.87***
	(0.48)	(0.48)	(0.47)	(0.47)
ΔTravel Time	8.11**	8.02**	8.63**	10.99***
	(3.02)	(3.00)	(2.90)	(3.09)
ΔReliability – 75-50 Quantile	31.51***			
	(6.66)			
ΔReliability – 80-50 Quantile		24.76***		
		(5.24)		
ΔReliability – 90-50 Quantile			12.03***	
			(1.82)	
ΔReliability – Standard Deviation				0.06
				(0.03)
Observations	433,623	433,623	433,623	433,623
R^2	0.22	0.22	0.24	0.16
AIC	1,512,162	1,510,246	1,496,897	1,543,628
BIC	1,512,195	1,510,279	1,496,930	1,543,661
Panel B. Reliability Window	15 Days	30 Days	60 Days	90 Days
Constant	2.87***	2.84***	2.83***	2.82***
	(0.49)	(0.48)	(0.49)	(0.49)
ΔTravel Time	9.28**	8.02**	7.31**	6.30**
	(3.06)	(3.00)	(2.91)	(2.67)
ΔReliability	9.98***	24.76***	30.63***	36.71***
	(2.16)	(5.24)	(6.34)	(7.30)
Observations	451,878	433,623	398,136	346,915
R^2	0.19	0.22	0.24	0.27
AIC	1,580,000	1,510,000	1,380,000	1,190,000
BIC	1,580,000	1,510,000	1,380,000	1,190,000

Notes: The table examines the robustness of the central specification to the inclusion of reliability measures. Values shown are the coefficients of 8 separate regressions of the toll paid on the regressands. Panel A reports coefficients for models where we vary the moments differenced between mainline lanes and ExpressLanes, and we use a 30 day moving window by day of week and hour to construct each measure. Panel B reports reliability constructed as the 80^{th}-50^{th} quantile spread in time savings calculated using a moving window using different sizes: 15-90 days by day of week and hour. AIC and BIC are Akaike and Bayesian Information Criteria. Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80^{th} and 50^{th} quantiles. Data cover workdays during the morning peak (5-9AM). Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

Table G.12—Homogeneous Agent Hedonic Price Function Estimates: Individual Fixed Effects

	I	II	III	IV
Constant	2.887***	3.055***	2.733***	2.693***
	(0.481)	(0.005)	(0.016)	(0.018)
ΔTravel Time	8.345**	7.849***	7.393***	7.627***
	(2.868)	(0.061)	(0.058)	(0.061)
ΔReliability	22.742***	11.664***	15.929***	16.101***
	(4.624)	(0.195)	(0.207)	(0.205)
R^2	0.22	0.17	0.22	0.23
Observations	426,761	426,761	426,761	426,761
Implied Value of Urgency from Individual Fixed Effects in $ per Trip				
25th Quantile		2.13	1.80	1.76
Mean		3.06	2.73	2.69
75th Quantile		3.98	3.68	3.65
sd(Individual FEs)			0.99	0.99
sd(Time FEs)			0.38	0.16
Individual FE		X	X	X
Hour FE			X	X
Hour-DOW FE				X

Notes: This table is based on a model that assumes a common value of time and reliability across the sample, but an individual-specific value of urgency, using within variation to explain the latter and between to explain the former. Time-fixed effects (by hour or hour-by-day-of-week) also control for time-specific urgency across trip appearances in the sample. Values shown are the coefficients of 4 separate regressions of the toll paid during the AM peak period (5-9 AM) on the regressands. Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80th and 50th quantiles. Three rows report the mean, 25th and 75th quantiles of the individual-level fixed effects corresponding to varying estimates of the value of urgency across individuals in our sample. Data cover workdays during the morning peak (5-9AM). Sd(.) reports the standard deviation of individual and time fixed effects. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Robust standard errors are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.13—HEDONIC PRICE FUNCTION ESTIMATES: TWO-STAGE LEAST SQUARES FIRST-STAGE

	I	II	III	IV	V
Instrument:	Leads	Mean I-10W Travel Time Savings	Mean I-10W Travel Time Savings after Oct. 20	I-210W Inverse Speeds	I-10E Travel Time Savings
ΔTravel Time (1 hour lead)	0.456***				
	(0.027)				
ΔTravel Time (1 week lead)	0.220***				
	(0.024)				
ΔTravel Time (2 week lead)	0.107*				
	(0.051)				
ΔReliability	0.605***	0.643***	0.817***	0.581***	0.543***
	(0.099)	(0.143)	(0.111)	(0.141)	(0.146)
ΔTravel Time (Hourly-DOW Mean)		0.804***	0.745***		
		(0.192)	(0.140)		
Inverse Contemporaneous I-210W Speed				2.673***	
				(0.635)	
ΔTravel Time I-10E					0.944***
					(0.212)
Constant	-0.002	0.006	0.001	-0.002	0.011
	(0.002)	(0.006)	(0.005)	(0.008)	(0.007)
R^2	0.589	0.265	0.267	0.255	0.523
Observations	221,127	411,053	411,053	302,504	329,111
Kleiberg-Paap F-Statistic	2,342	18	28	18	20

Notes: The table shows the coefficients from five regressions of the realized travel time saved on the regressands. Each column reports first-stage IV estimates from a different set of instruments. Column I corresponds to the first-stage of the split sample instrumental variable heterogeneous estimates reported in column IV of Table 2 as well as homogeneous IV estimates reported in Appendix Table H.21. Data cover workdays during the morning peak (5-9AM). The dependent variable, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Travel Time leads are constructed for the same 5-minute time window 1 hour, 1 week and 2 weeks in the future. ΔTravel Time (Hourly-DOW Mean) is the average travel time savings for the corresponding hour and day of the week, while in column III, the same variable is constructed from the subsample of our data during which travel time savings signs were posted. I-210W Inverse Speeds are the inverse of contemporaneous average hourly speeds along the I-210W, a parallel commuting corridor to the I-10W that does not have ExpressLanes. ΔTravel Time I-10E is the contemporaneous travel time savings from the I-10 ExpressLanes in the opposite direction on average by hour and day of week. Reliability is the difference in the spread of the 80^{th} and 50^{th} quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.14—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: TWO-STAGE LEAST SQUARES SECOND-STAGE

	I	II	III	IV	V
Instrument:	Leads	Mean I-10W ΔTravel Time	Mean I-10W ΔTravel Time after Oct. 20	I-210W Inverse Speeds	ΔTravel Time I-10E
Constant	2.409***	2.760***	2.562***	2.856***	3.202***
	(0.377)	(0.477)	(0.424)	(0.518)	(0.597)
ΔTravel Time	17.231***	10.646**	14.277***	8.045*	4.995***
	(5.755)	(5.071)	(4.488)	(4.157)	(1.422)
ΔReliability	47.180***	20.456**	16.439*	24.146***	23.469***
	(7.275)	(9.483)	(8.633)	(8.238)	(6.501)
R^2	0.286	0.214	0.184	0.232	0.175
Observations	221,127	411,053	411,053	302,504	329,111

Notes: The table shows the coefficients from five regressions of the total toll paid on the regressands. Each column reports second-stage two-stage least squares estimates from a different set of instruments. Column I corresponds to a homogenous agent model for the individual-level estimates reported in column IV of Table 2. Data cover workdays during the morning peak (5-9AM). ΔTravel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance, and is instrumented for by the indicated instrument sets. Travel Time leads are constructed for the same 5-minute time window 1 hour, 1 week and 2 weeks in the future. ΔTravel Time (Hourly-DOW Mean) is the average travel time savings for the corresponding hour and day of the week, while in column III, the same variable is constructed from the subsample of our data during which travel time savings signs were posted. I-210W Inverse Speeds are the inverse of contemporaneous average hourly speeds along the I-210W, a parallel commuting corridor to the I-10W that does not have ExpressLanes. ΔTravel Time I-10E is the contemporaneous travel time savings from the I-10 ExpressLanes in the opposite direction on average by hour and day of week. ΔReliability is the difference in the spread of the 80^{th} and 50^{th} quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.15—REGRESSION OF INDIVIDUAL-LEVEL ESTIMATES ON VEHICLE PRICES

	I	II	III
Dependent Variable:	Value of Urgency ($/trip)	Value of Time ($/hour)	Value of Reliability ($/hour)
Vehicle Price in 1,000s of 2013 Dollars (MSRP)	0.006***	-0.102***	-1.290***
	(0.001)	(0.008)	(0.046)
Constant	2.138***	7.688***	44.764***
	(0.008)	(0.085)	(0.596)
R^2	0.002	0.008	0.038
Observations	22,979	22,979	20,155
Correlation coefficient of dependent variable with VOT	-0.59	1.00	-0.09

Notes: This table examines the effect of vehicle value on estimates of the value of urgency and the value of time. Values shown are the coefficients of 3 regressions of individual-level estimates from Table 2, column II of urgency, value of time or value of reliability on the regressands. Vehicles reported to Metro in transponder registration are matched to Wards Auto Database MSRPs by vehicle make, model and year. Vehicle prices are depreciated by an annual rate of 20%. Regressions are weighted by inverse of individual-level regression standard error of dependent variable from individual-level regressions reported in Table 2. Data cover workdays during the morning peak (5-9AM). Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.16—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: OTHER CORRIDORS

	I	II	III	IV	V	VI
	I-10 East		I-110 North		I-110 South	
	AM Peak	PM Peak	AM Peak	PM Peak	AM Peak	PM Peak
Constant	1.98**	1.55**	3.71***	2.40***	2.19***	2.58***
	(0.66)	(0.57)	(0.33)	(0.20)	(0.26)	(0.26)
ΔTravel Time	6.21	12.70	17.40***	7.28***	10.10	4.92
	(5.26)	(7.65)	(3.32)	(1.58)	(5.80)	(4.47)
ΔReliability	71.03	30.20**	75.94***	33.32***	87.36***	55.52***
	(55.01)	(10.19)	(17.67)	(10.15)	(15.25)	(16.77)
R^2	0.08	0.43	0.10	0.19	0.12	0.06
Observations	19,007	285,147	433,800	211,131	213,806	555,460
Average Toll	2.36	2.5	4.48	2.71	2.44	2.84
Urgency's Share of WTP	0.84	0.62	0.83	0.89	0.9	0.91
Average ΔTravel Time in Hours	0.06	0.01	0.04	0.02	0.02	0.04
Average ΔTravel Time in Minutes	3.63	0.44	2.48	1.39	1.29	2.18
Average ΔReliability in Hours	0.01	0.03	0.01	0.01	0.01	0.01
Average ΔReliability in Minutes	0.01	1.69	0.04	0.26	0.02	0.09

Notes: The table examines the central specification using trips from other ExpressLanes corridors in Los Angeles: the other direction of the I-10 and trips on the I-110. Values shown are the coefficients of 6 separate regressions of the total toll paid on the regressands. Morning Peak periods occur during non-holiday weekdays between 5-9 AM and afternoon peak periods are 4-8 PM. Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80th and 50th quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.17—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: SEGMENT HETEROGENEITY

	I	II	III	IV	V	VI
Route number	2	3	4	5	7	8
Entry Plaza	WT01	WT01	WT01	WT01	WT02	WT02
Exit Plaza	WT03	WT04	WT05	WT06	WT03	WT04
Constant	1.99***	2.24***	3.97***	4.47***	—	1.37***
	(0.06)	(0.05)	(0.08)	(0.14)	—	(0.05)
ΔTravel Time	7.57***	6.83***	12.95***	9.51***	—	11.09***
	(0.60)	(0.57)	(1.28)	(1.07)	—	(1.25)
ΔReliability	-7.76*	-2.40	11.50**	4.39		1.51
	(3.38)	(2.27)	(4.83)	(2.68)		(2.87)
R^2	0.16	0.31	0.34	0.3	—	0.2
Number of Observations	111,446	126,106	16,533	146,939	0	11,030

Route number	9	10	12	13	14	17
Entry Plaza	WT02	WT02	WT03	WT03	WT03	WT05
Exit Plaza	WT05	WT06	WT04	WT05	WT06	WT06
Constant	4.22***	4.51***	1.74***	4.51***	4.42***	3.39***
	(0.14)	(0.13)	(0.11)	(0.10)	(0.11)	(0.08)
ΔTravel Time	4.23*	3.02**	8.82***	-0.33	5.42**	3.19*
	(1.82)	(0.71)	(1.67)	(2.39)	(1.52)	(1.28)
ΔReliability	-4.71	-2.75	-0.26	-6.91**	-0.08	13.39
	(5.08)	(2.20)	(5.01)	(2.91)	(3.37)	(10.25)
R^2	0.03	0.04	0.15	0.00	0.04	0.00
Observations	1,079	24,033	333	286	8,145	20,302

Notes: The table examines the robustness of the central specification to a restriction on the trips entering the regression that take place on the listed road segment. Values shown are the coefficients from 11 separate regressions of total toll on the regressands for the indicated route. Data cover workdays during the morning peak (5-9AM). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80^{th} and 50^{th} quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses. Standard errors, clustered by month, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.18—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: OTHER FUNCTIONAL FORM

	I	II	III	IV	V	VI	VII
	Higher Order Terms					Non-Linear Power Model	
Constant	2.89***	2.84***	3.00***	3.19***	β_0	2.83***	
	(0.48)	(0.31)	(0.30)	(0.30)		(0.32)	
ΔTravel Time	8.30**	9.27	-1.68	-18.61			
	(2.88)	(13.63)	(15.64)	(13.55)			
ΔTravel Time^2		3.89	162.27	514.40***	β_1	7.29	4.87**
		(74.65)	(121.56)	(124.99)		(4.61)	(1.64)
ΔTravel Time^3		-31.31	-752.22*	-3,405.54***	β_2	0.90	0.12*
		(110.98)	(372.86)	(610.69)		(0.67)	(0.06)
ΔTravel Time^4			969.18**	8,898.96***			
			(389.22)	(1383.62)			
ΔTravel Time^5				-7,973.01***			
				(1147.69)			
ΔReliability	22.67***	22.19***	21.78***	21.59***	β_3	22.57***	24.79***
	(4.61)	(5.34)	(5.22)	(5.34)		(5.27)	(6.20)
Observations	433,623	433,623	433,623	433,623		433,623	433,623
AIC	1,512,541	1,511,412	1,509,235	1,506,824		1,512,370	1,526,171
BIC	1,512,574	1,511,467	1,509,301	1,506,901		1,512,414	1,526,204
% of WTP from VOT	0.16	0.17	0.12	0.07		0.17	0.95

Notes: The table examines the robustness of models with urgency to functional form assumptions. Given the functional forms of models in columns I and III, the WTP implied by the estimates becomes negative when travel time savings exceed 43.4 and 31.7 minutes, respectively. "Non-Linear Power Model" in columns VI and VII estimates a power model using maximum likelihood of: $Toll = \beta_0 + \beta_1(\Delta Travel\ Time)^{\beta_2} + \beta_3 \Delta Reliability + \varepsilon$. Column VII excludes the constant term β_0.Values shown are the coefficients of five regressions of the toll paid on the regressands. Data cover workdays during the morning peak (5-9AM). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80th and 50th quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses. *** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.19—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: MODELS WITHOUT A CONSTANT

	I	II	III	IV	V
ΔTravel Time	32.32***	57.80***	84.00***	114.07***	147.65***
	(2.98)	(8.81)	(12.46)	(16.26)	(19.21)
ΔTravel Time^2		-151.04***	-487.51***	-1082.42***	-2037.42***
		(15.49)	(56.91)	(149.36)	(313.89)
ΔTravel Time^3			803.97***	3891.95***	12133.72***
			(114.73)	(658.20)	(2448.81)
ΔTravel Time^4				-4456.12***	-30954.77***
				(904.12)	(7511.27)
ΔTravel Time^5					27847.87***
					(7646.72)
ΔReliability	34.84***	24.16**	25.42**	26.42***	26.08***
	(6.90)	(8.70)	(8.52)	(7.68)	(6.80)
Observations	433,623	433,623	433,623	433,623	433,623
AIC	1,938,562	1,801,141	1,729,194	1,686,791	1,659,345
BIC	1938,584	1,801,174	1,729,238	1,686,846	1,659,411

Notes: The table examines the robustness of models without urgency to functional form assumptions. Values shown are the coefficients of five regressions of the toll paid on the regressands. Data cover workdays during the morning peak (5-9AM). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80th and 50th quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.20—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: EXPECTED VS. REALIZED TRAVEL TIMES

	I	II	III	IV
	Whole Sample	Whole Sample	After Oct. 22, 2013	After Oct. 22, 2013
Constant	2.84***	2.68***	3.15***	3.03***
	(0.48)	(0.38)	(0.43)	(0.44)
ΔTravel Time	8.02**		7.98	
	(3.00)		(4.42)	
E[ΔTravel Time]		12.05		13.11*
		(7.58)		(6.99)
ΔReliability	24.76***	20.14**	15.68***	8.74
	(5.24)	(8.04)	(4.26)	(7.59)
Observations	433,623	433,623	82,657	82,657
R^2	0.22	0.21	0.14	0.16
Mean ΔTravel Time in Minutes	4.08	4.02	4.42	3.80

Notes: This table explores the impact of using of expected rather than realized travel times in hedonic price regressions to reflect different driver perceptions. Values shown are the coefficients of 4 separate regressions of the toll paid during the AM peak period (5 – 9 AM) on the regressands. "E[ΔTravel Time]" is the sample average by day-of-week, segment and five-minute interval of the time saved, measured in hours, by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80th and 50th quantiles. Data cover workdays during the morning peak (5-9AM). ΔReliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.21—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: I-210W AS A SUBSTITUTE ROUTE

	I	II	III
	Whole Sample	I-210 W Below Mean Speed	I-210 W Above Mean Speed
Constant	3.15***	2.94***	2.79***
	(0.57)	(0.52)	(0.42)
ΔTravel Time I-210 W	8.31***		
	(0.93)		
ΔTravel Time I-10 W		8.66**	5.00
		(2.81)	(3.92)
ΔReliability I-10 W	19.47***	19.98***	35.93***
	(2.79)	(4.87)	(6.20)
R^2	0.20	0.21	0.21
Observations	433,623	237,839	195,784

Notes: The table examines the robustness of the result to the extent that the approximately parallel, untolled I-210 W acts as substitute for the mainline I-10W lanes. Values shown are the coefficients of 3 separate regressions of the toll paid during the AM peak period (5 – 9 AM) on the regressands. Column I uses counterfactual travel time savings of the ExpressLanes relative to the I-210 W instead of the I-10 W. Column II uses counterfactual travel time savings from the I-10 W mainlines as in our central specifications, but restricts the sample to times when speeds along the I-210 W are below average. Column III uses the same travel time savings variable, but restricts the sample to times when speeds along the I-210 W are above average. Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes on the I-10 W or I-210 W, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability, measured in hours, is the difference between lanes in the spread of travel times between the 80^{th} and 50^{th} quantiles. Data cover workdays during the morning peak (5-9AM). Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.22—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: RESTRICTED TIME WINDOWS

	I	II
Constant	2.29***	3.04***
	(0.25)	(0.30)
ΔTravel Time	15.99*	-3.14
	(7.41)	(8.01)
ΔReliability	25.57***	35.15***
	(2.19)	(4.13)
R^2	0.10	0.12
Observations	108,942	188,911
Limit on ΔTravel Time	3-5 min	<3 min

Notes: The table tests the robustness of the central specification to restrictions to the sample based on ΔTravel Time. Values shown are the coefficients from 2 regressions of the toll paid on the regressands. Data cover workdays during the morning peak (5-9AM). Travel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80th and 50th quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.23—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: GAS PRICE AND WEATHER ROBUSTNESS

	I	II	III	IV
	Gas Price < $4	Gas Price > $4	Dry	Rainy
Constant	3.01***	2.77***	2.89***	2.84***
	(0.51)	(0.43)	(0.48)	(0.34)
ΔTravel Time	8.61**	6.23*	8.29**	9.42
	(2.73)	(3.08)	(2.82)	(6.73)
ΔReliability	17.78***	34.09***	22.52***	24.55***
	(4.14)	(5.39)	(4.63)	(5.18)
R^2	0.194	0.247	0.217	0.193
Observations	253,671	179,952	408,720	24,903

Notes: The table examines the robustness of the result to the periods of time where gas prices were above and below $4 and with and without rainfall based on nearby weather stations described in Appendix A. Values shown are the coefficients of 4 separate regressions of the toll paid on the regressands. The gas price is the lagged weekly regular reformulated price of gasoline for the Los Angeles area as reported by the Energy Information Administration. The sample is partitioned for observations where weekly regular reformulated gasoline price for Los Angeles is below $4 (column I) and above $4 (column II), where hours on a given date with zero precipitation ("Dry" – column III) and otherwise ("Rainy" – column IV). Data cover workdays during the morning peak (5-9AM). ΔTravel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. ΔReliability is the difference in the spread of the 80^{th} and 50^{th} quantiles of travel time savings between the mainline and ExpressLanes. Reliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.
*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

TABLE G.24—HOMOGENEOUS AGENT HEDONIC PRICE FUNCTION ESTIMATES: SEASONALITY

	I	II	III	IV	V	VI
Constant	2.94***	2.39***	2.38***	2.67***	2.20***	2.33***
	(0.50)	(0.41)	(0.44)	(0.45)	(0.32)	(0.45)
ΔTravel Time	11.05***	10.64***	10.52***	11.51***	11.22***	11.54**
	(3.03)	(3.14)	(3.20)	(3.31)	(3.48)	(3.76)
ΔReliability	22.67***	22.74***	23.77***	22.52***	22.55***	23.03***
	(4.61)	(4.60)	(4.53)	(4.66)	(4.71)	(4.79)
R^2	0.22	0.22	0.23	0.22	0.23	0.24
Observations	433,623	433,623	433,623	433,623	433,623	433,623
Quarter Fixed Effects		X				
Month Fixed Effects			X			
Day-of-Week Fixed Effects				X		
Quarter x Day-of-Week Fixed Effects					X	
Month x Day-of-Week Fixed Effects						X

Notes: The table examines the robustness of models with urgency to variation due to seasonal conditions by using a series of fixed effects models. Values are the coefficients of six regressions of the toll paid on the regressands. Column I reports baseline estimates from column I of Table 2 in the main text. Data cover workdays during the morning peak (5-9AM). ΔTravel Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline speeds reported by PeMS, for the chosen trip distance. Reliability is the difference in the spread of the 80^{th} and 50^{th} quantiles of travel time savings between the mainline and ExpressLanes. ΔReliability less than 0.01 hours (36 seconds) is set to zero. Trips with zero distance traveled and the 6.2% of observations with negative time saving are removed. Transponders registered to public sector, corporate or unknown accounts (2% of the entire sample) are dropped. Untolled HOV-3 trips (33% of sample) are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Standard errors, clustered by road segment, are in parentheses.

*** Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.