Avoiding Traffic Congestion Externalities?
The Value of Urgency

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I. Introduction

Since Becker (1965), the value of time is defined as the opportunity cost of time and is a fraction of an individual's hourly wage (Johnson, 1966; DeSerpa, 1971). The value of time is also the first-order parameter used in cost-benefit analysis and project evaluation, including, for example, in areas such as recreation (Smith, 1981; Bockstael and McConnell, 1981), health improvements (Grossman, 1972), and the measurement of the benefits of changes in speed-limit and seatbelt policies (Ashenfelter and Greenstone, 2004). In the context of transportation infrastructure projects, once the travel time savings these projects generate are calculated, estimates of the value of time are used to infer the resulting economic benefit of the project. A direct consequence of Becker's (1965) framework is that the value of time is constant. As a result, when measured on a per hour basis, the benefits of transportation infrastructure projects should be constant too.

Does this theoretical conjecture hold empirically when taken to the marketplace? Panel A of Figure 1 plots the kernel-smoothed estimates of the willingness to pay (WTP) per hour against travel time saved for drivers that use ExpressLanes in California. ExpressLanes allow for the possibility of entering a faster lane in a freeway, upon the payment of a toll. Theory would suggest that the estimate of the WTP for travel time savings per hour should be a flat line, linked to the hourly wage. Instead, the data reveals a surprising hyperbolic shape. When drivers save substantial amounts of time, the WTP per hour tends towards levels found in the literature,[1] but as the time saved decreases, the value increases dramatically.[2] Panel

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[1] Prior empirical studies have generally found this parameter is half the local hourly wage, roughly $10 per hour in the Los Angeles area, but some models of scheduling would allow for values up to 3 times larger (Small, 2012). See column VII of Table 1, where the zip code for each account has been matched to 2008-2012 ACS Census data to report composition-weighted averages of hourly wages by hour of the day and decile of travel time savings, which vary between $19-$20.

[2] The figure is truncated at $120 per hour but continues to substantially higher values.

B of Figure 1 shows that these observations with high implied values and small time savings are not outliers. These small time savings trips form the bulk of all uses. Seen on a per-hour basis, these implied WTP appear to be absurd. For example, for the 10% of observations with time savings less than 0.39 minutes, the implied WTP per hour, is $1,977.44, nearly 200 times the standard estimate of the value of time.

For the shape of the WTP per hour displayed in panel A to be plausible, either the valuation of time changes with the amount of time saved, which is inconsistent with theory, or the simple Becker-style value of time framework misses important aspects of the behavior of drivers, and the determinants of their willingness to pay for travel time savings. The purpose of this paper is twofold: First we aim to provide a potentially plausible explanation for the observed pattern of the willingness to pay for travel time savings observed in the data, and reconcile this patterns with the classical value of time framework proposed by Becker. Second, we aim to decompose the various determinants of this willingness to pay, allowing us to infer their relative importance.

We demonstrate that the bulk of the willingness to pay to access ExpressLanes comes from what we term the *value of urgency*. We define urgency as a discrete WTP to meet a time constraint. This is to say that it is a WTP that does not scale with time. Unlike the value of time which is intrinsically linked to income and individual characteristics, the value of urgency is linked with the circumstances of a particular trip and is not a function of total time late but rather a discrete cost incurred when the agent does not achieve a critical deadline. By providing the first empirical estimates of the value of urgency, we also argue that this parameter is the first-order parameter for cost-benefit analysis of priced road infrastructure, and, ignoring it may result in misallocation of road infrastructure funds.

Although absent in the empirical literature, the idea that individuals may exhibit preferences for urgency is surprisingly intuitive. When entering ExpressLanes individuals reveal their preferences for urgency because, unlike other toll roads, they have the ability to purchase the amount of ExpressLane distance that they need to avoid arriving late. Individuals have preferences for urgency because they are schedule constrained, and face potential penalties for being late that are discontinuous and do not scale up with the amount of time that they are late. A direct implication of the urgency concept is that when making decisions, drivers may put substantial weight on their dichotomous decision of being late (or not), and less on saving 1 versus 2 minutes. Perhaps the best anecdotal evidence of preferences for urgency come from the fact that small time savings trips form the bulk of all uses of ExpressLanes. Urgency also explains the infrequency of use, because what consumers are paying for is not a few fungible minutes to add to their day but the removal of congestion costs when a shock to congestion arises such that on-time arrival using the mainline lanes becomes impossible. If these users truly valued travel time savings per se, we would expect them to appear in the lane for nearly every commute.

Our central estimate of the value of urgency is \$2.94, while the estimate of the value of time is \$11.05, only slightly higher than half the local wage, the ratio generally found to be the value of time in the literature (Small, 2012). This means that, with an average varying-toll of \$3.69, the value of urgency represents 81% of the value for the average toll and, as a consequence, should be the first-order effect in a cost-benefit analysis of priced road infrastructure like ExpressLanes. Or, in other words, road infrastructure projects that can be priced may ex-ante fail cost benefit analysis if urgency is ignored, and instead, the project is evaluated exclusively based on the value of travel time savings.

To measure the willingness to pay for avoiding congestion while entering ExpressLanes, we have assembled an unusually rich dataset that includes individual-level transponder information of all ExpressLanes trips and tolls provided by the Los Angeles Metropolitan Transportation Authority (METRO).

Specifically, the data includes the time of entry/exit in the lane, and extent of the use of the lane, and the toll paid. We combine this individual level data with date on travel times observed in unregulated mainline lanes from the California Department of Transportation's (CALTRANS) Freeway Performance Measurement System (PeMS) traffic detectors.

We use these data to estimate a hedonic-style price function where real-time tolls paid are related to the amount of travel time saved and a constant that potentially captures the idea of urgency. The estimation allows us to recover the first estimates of the value of urgency and confirm earlier estimates of the value of time. Importantly, the unusually rich data used is ideal to overcome standard concerns of using hedonic price functions to measure welfare, and allow us to recover individual bid functions for entering the ExpressLanes and avoid congestion. Observing the same individuals repeatedly in the ExpressLanes provides several methodological advantages: First, by experiencing varying levels of congestion and tolls, the repeated nature of the data allows for a simple test of the functional form, which, in turn, reveals the presence of preferences for urgency. Second, the nature of the data also allows us to exclude individual attributes that otherwise could be correlated with the level of congestion through the potential use of individual effects. Third, when estimating hedonic price functions, we consider models where drivers have homogeneous preferences or heterogeneous preferences. The heterogenous model, which estimates individual level hedonic functions, yields the 'bid curves' for users of the lane—the relevant object for examining welfare. Because these two specifications yield similar estimates, we implicitly provide a test for rejecting sorting that could have occurred if higher income individuals were using the lane for shorter trips. Such sorting, which we find little evidence for, would normally prohibit the use of the hedonic function for welfare analysis without further assumptions (Banzhaf, 2016; Chay and Greenstone, 2005; Brown and Rose, 1987). This is possible because unlike many repeated sales data sets that examine the same good purchased on different occasions by different individuals, our data, uniquely, allows us to examine the same individual over multiple purchases with different prices and congestion levels.

This paper also contributes broadly to the literature on urban and transportation economics that provides estimates for key travel demand parameters using structural models and stated preference surveys (sometimes combined with revealed preference data) (Small, Winston, and Yan, 2005). These surveys typically ask respondents to choose between tolled and untolled lanes on an average day. In contrast to all these studies we identify preferences for urgency in a purely revealed preference setup, which is made possible by the ExpressLanes program which varies tolls and allows drivers the ability to purchase sub-portions of the lane. By observing individuals making choices about lane usage day after day under different tolls, congestion levels, and potential schedule constraints, we have the ideal environment to uncover drivers' preferences for urgency along with their implied value of travel time.

II. Program Background and Data

A. The ExpressLanes Program

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 the ExpressLanes program.[3] The goal of the program was to increase the total throughput of these roads and to raise funds to maintain the corridors.[4] Maximum

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[3] This was the second such conversion in Los Angeles, the first being the I-110 ExpressLanes, which opened on November 10th, 2012. We limit the scope of our study from the pre-policy expansion of the HOV lanes on December 1st, 2012 to December 31st, 2013. More details on the timing of ExpressLanes implementation can be found in Appendix A.

[4] The program opened the lanes to Single Occupant Vehicles (SOV) who were charged a per-mile toll ranging from $0.10 to $15.00, debited from a FasTrak® account linked to a required transponder in the vehicle. The ExpressLanes function such

throughput is maintained along the ExpressLanes through a level-of-service system that adjusts prices every five minutes. The policy is designed to minimize costs to pre-existent carpoolers, who are ensured free-flow conditions by the mandated minimum speed of 45 mph and the continued ability to use the ExpressLanes free of charge.[5] Drivers may enter or exit the ExpressLanes at 6 separately-priced locations along the I-10 W.[6] At these entry points drivers see posted toll rates, ranging between $0.55 and $14.70 in our sample, and once a vehicle enters the lane the corresponding toll rate is locked in for the duration of its trip even if the price for subsequent vehicles changes.[7]

Compared with fixed- or peak-toll lanes, the ExpressLanes program has two unique features that present a unique opportunity to recover the first estimates of the value of urgency. First the ExpressLanes adjust price to maintain a constant speed. While other toll lanes may, generally, provide faster travel than an untolled alternative, the ExpressLanes guarantee congestion free driving. Second the ExpressLanes allow drivers multiple points of entry and exit. This allows them flexibility to change their decisions based on conditions and consume exactly the amount of distance desired. This is often only a few miles—considerably shorter distances that other toll roads where drivers must commit to a decision and are unable to opt out of the lane if conditions improve.[8]

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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.

[5] Carpools are required to use a transponder but are not charged when it is set to HOV 3+ during peak times or HOV 2 during off-peak hours.

[6] These exit and entry points are indicated by arrows in Appendix Figure B.1.

[7] 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 the California Highway Patrol officers that patrol the road segment.

[8] Varied subsegment use by drivers is substantial, with a large proportion of observed trips exiting either at mid-way points along the corridor or at the end as documented in Appendix Table C.4.

B. Data

Our empirical demonstration of the value of urgency is conducted with a confidential dataset where individuals trade time for money. Our data combine transponder-level travel information of all ExpressLanes trips provided by Los Angeles Metropolitan Transportation Authority (Metro) with travel times observed in mainline lanes from the California Department of Transportation's (CALTRANS) Freeway Performance Measurement System (PeMS) traffic detector data. This section describes each data source and presents some key summary statistics related to the value of urgency.

Sample Composition.—The dataset of ExpressLanes trips along the I-10 westbound from LA Metro allows us to observe individual trips associated with the same transponder account.[9] Our data include information on times, points of entry and exit, the toll charged, the primary vehicle registered to it and the zip code for the billing address.[10] Our full dataset contains 982,056 observations on this route spanning the period from February 22nd, 2013 to December 31st, 2013. We focus on the 466,232 trips that occur during the AM peak on accounts registered to private households. We focus on the AM peak period (5-9 AM) for three reasons. First this is the peak window of usage because the road is traveling towards the CBD. Second these trips are likely work commutes with identical punishment function for late arrival and finally the congestion levels allow drivers less opportunity for passing

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[9] With the exception of the final set of regressions, all regressions can be replicated without account level information, therefore we remove this identifier to honor the confidentiality agreement signed with Metro and assure the anonymity of program users. We focus on the I-10 W corridor as it has one of the highest PeMS detector counts per mile, one every 0.18 miles on average, and the westbound direction is the predominant commuting direction during the AM peak. Our focus on the AM peak is motivated by the fact that drivers faced with congested roads during this period have little discretion to deviate from the average speed on the road, which is not true when it is in free flow.

[10] For ExpressLanes trips, we compute travel time based on the difference between the timestamp for entry and exit to the lanes.

which increases measurement error in calculating the hypothetical mainline travel time had the driver not used the ExpressLanes.

Key Variable Construction.—We construct an estimate of the hypothetical mainline travel time from road segment average speeds reported by detectors in the I-10 W mainline lanes from the California Department of Transportation's Freeway Performance Measurement System (PeMS).[11] Travel time in the mainline lanes is calculated as the distance traveled in the ExpressLanes divided by the average speed from PeMS speed detectors on a parallel stretch of the mainline lanes during the same 5 minute interval as the start of the trip.[12] This is done by matching each ExpressLanes trip observed in our transponder data to the average speeds observed in the mainline lanes from PeMS for the same starting time. Trip-level travel time savings in our analysis is then the difference between the realized travel times in the ExpressLanes and that for the hypothetical same distance trip taken at the same time along a parallel stretch of the mainline lanes of the I-10 W.[13] In most figures and regressions we omit the 6.2% of trips where the mainline speed implies negative time savings but include these observations in robustness checks.[14]

Reliability is often highlighted in the transportation literature as a willingness to pay for reduced uncertainty in travel time when choosing between routes (Brownstone and Small, 2005). In our setting this uncertainty has largely been

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[11] PeMS generates real-time 5-minute speed and flow data for HOV and mainline lanes from loop-detectors embedded in all major California divided highways based on calibrated flow and occupancy observations taken every 30 seconds.

[12] That individuals would infer travel times in the mainline based on contemporaneous speeds is consistent with the fact that the speed data from PeMS as well as other sources is widely available from news outlets, and mobile technology like Waze that tracks the speed of users provides extremely accurate travel time predictions based on contemporaneous travel conditions.

[13] This is the appropriate comparison to make because during the peak commuting period, the Nash Equilibrium in routing serves to equalize average travel times between substitute commuting routes, so travel times in the mainline of the I-10 W are consistent with the lowest possible travel time commutes for any untolled route in the transportation system. We focus our analysis on accounts registered to private individuals for whom travel time savings likely correspond to trips to work. .

[14] Trips with negative travel time savings appear to occur when mainline speeds are abnormally high, suggesting passing is possible and our measure of counterfactual mainline speed is subject to error. Median mainline speeds are in excess of 65 mph for these negative trips, while those with positive time savings have a median mainline speed less than 40 mph.

resolved and a driver is deciding whether or not to endure the congested lane or purchase the uncongested route. While it is unclear if this concept is appropriate to apply once trip speed has been realized, we construct this measure following the literature at the route level using PeMS data as an additional robustness check. [15]

C. *Further Evidence of Urgency*

Table 1 shows that even these high value user infrequently use the lane at 8.8 times per month—a frequency that inexplicability increases as WTP per hour decreases across the deciles.[16] If these users in the first decile truly valued their time at this level, we would expect them to appear in the lane for nearly every commute.

D. *Initial Evidence of Scheduling*

Figure 2 depicts the kernel smoothed density of demand over the morning peak. Vertical lines indicate the key hours of 7:00, 7:30, and 8:00 AM when work start times or morning appointments may be common. It is clear from the graph that demand for the ExpressLanes rises 10-15 minutes before these times, and then falls immediately afterwards. This evidence suggests that drivers may be using the ExpressLanes to ensure on-time arrival based on scheduling needs.[17] This observation begins to create the basis for understanding the value of urgency.

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[15] We calculate this measure as the difference between the median and the 20th quantile of speed over the segment in that month.

[16] As noted in Appendix the most common vehicles in this first decile are the Honda Accord, Honda Civic, and Toyota Camry—surprisingly inexpensive vehicles.

[17] While it is useful to characterize demand patterns to understand the causes of urgency, the empirical framework laid out section IV does not require us to estimate demand for ExpressLanes use explicitly, but rather infer the implied willingness to pay through a revealed preference framework.

III. Econometric Methods

In this section, we describe the hedonic model used to recover the first estimates of the value of urgency. An advantage of the approach taken is that it narrows the scope of confounding factors of concern to omitted variable bias and those caused by sorting due to heterogeneous preferences, both of which are laid out in section III.B. In cases where the data make it possible (which is rare) to estimate a second stage of the hedonic model, this would in principle allow for consideration of a range of individual characteristics that may help to better understand the distribution of individual MWTP such as preferred departure times, schedule constraints, multi-model travel among others. While these patterns are clearly an interesting research topic, as the hedonic literature has shown (Ekeland, et al., 2004), they are not necessary to credibly estimate the underlying hedonic price functions and thus demonstrate the value of urgency.

A. Estimating the Value of Urgency

In our data we observe driver a paying observed toll, $toll_{a,s,t}$, on ExpressLane segment s on date t to save travel time $TT_{a,s,t}$. We begin by estimating a homogeneous agent model where our basic empirical strategy for recovering the value of urgency is:

$$(1) \quad toll_{a,s,t} = \delta + \theta TT_{a,s,t} + \varepsilon_{a,s,t}.$$

Equation (1), by regressing a price on a vector of characteristics, is a hedonic regression where the coefficients represent the willingness to pay for that characteristic.[18] In our setting the coefficient on travel time saved, θ, represents the

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[18] Here the relevant "market" as related to a standard hedonic model of housing is a five-minute interval on a particular day. The choice is between the ExpressLanes and the mainline lines, and the alternative-specific attributes for which we will recover hedonic price functions are travel time difference between the lanes and in later models reliability and exit time. The

WTP that scale with time, while δ, the constant, is the WTP that is constant in the amount of time saved. The value of urgency, which does not scale with time, is captured by δ.[19] A more restricted model would omit the constant implicitly assuming it is zero. If the value of the toll payment only reflects benefits that scale with time then θ will capture the full value and the constant will be insignificant. But if δ is statistically significant, it shows that there is an element that does not scale with travel-time savings. Generally, hedonic theory does not dictate the functional form of covariates (Cropper, Deck, and McConnell, 1988) but in the case of travel time savings, they should be linked to the opportunity cost of wages and so we assume they are linear in hours but examine the fit of higher order terms of travel time. Because we pair a segment with the nearest mainline detectors to measure these speeds, we cluster the standard errors in all regressions by segment.

B. Econometric Identification Challenges.

Consistent estimation of equation (1) poses two challenges. The first is that there may be heterogeneity and sorting across the population into differing types. The second is that unobserved factors may co-vary with the observed characteristics.

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attributes of the unchosen mainline lane alternative are constructed based on the hypothetical travel time the driver would have experienced in the lane with the same time of entry as discussed in section II.B. Here our identifying assumption is that a driver observed in the ExpressLanes on a particular day during a particular five-minute interval would have been in the mainline lanes had we not observed them in the ExpressLanes. As noted above, during peak commuting periods the Nash equilibrium of route choice serves to make travel time in the mainline the lowest unpriced travel time alternative, though we do validate the robustness of this assumption in Appendix Tables C.9 and C.10 by comparing travel times in the ExpressLanes to the I-210 W instead. Note also that this requires no assumption about what lane or mode of transportation the driver might take on other days when we do not observe them in the ExpressLanes.

[19] There is also an implicit assumption that drivers using the ExpressLanes are not early. If drivers were early, the implied value of time would be much lower than observed in our estimation. Traditional estimates of the value of time for early individuals are roughly one-quarter of the wage (Small, 2012), which would be roughly $5 per hour in the Los Angeles area. As we show in Section IV models with and without urgency during the morning peak have market-clearing prices that are well above this value. Furthermore scheduling models suggest that the benefits from early arrival scale with time; our detection of a statistically significant constant is evidence against this possibility.

Our goal is to estimate the average WTP for urgency while accounting for these potentially confounding effects.

If high-income individuals self-select into trips with small time savings while low-income individuals sort into trips with longer time savings, the assumption of a single preference structure may bias our estimates and render the homogeneous agent model given by equation (1) useless for welfare analysis. We can estimate individual bid curves with account level measures of the value of urgency and time by estimating the regression

$$(2) \quad toll_{a,s,t} = \delta_a + \theta_a TT_{a,s,t} + \varepsilon_{a,s,t}$$

separately for each account with multiple trips. Estimation of equation (2) is possible because we are able to follow an individual across multiple transactions which few other datasets allow.[20] Not only can we examine heterogeneity of individual preferences but, more importantly, we are also able to test if that heterogeneity sorts such that the hedonic price function is invalid for welfare.

The second challenge, more frequently addressed in the hedonic literature but no less challenging, has been to obtain estimates of the hedonic price function that are not biased by factors that co-vary with the characteristic of interest. We begin by examining the stability of our estimates to the inclusion of potentially omitted characteristics, such as reliability and exit time, which can be included as additional covariates. But we are particularly concerned that the constant is also capturing another time invariant amenity such as smoother pavement or a feeling of superiority of being in the lane.[21]

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[20] While other studies have examined repeated sales data for hedonic estimation, they examine the repeat sale of the same item, such as a home, exposed to different levels of an amenity (for example pollution or school quality) to different individuals.

[21] Note that this travel time invariant amenity cannot be lower congestion as congestion in the mainline lanes is what generates a travel time differential.

Rather than attempt to explicitly control for these potentially confounding effects, we generate a lower bound on urgency in the morning peak period that excludes these omitted variables by including off-peak trips in our estimation. Trips taken in the morning peak are likely to be work trips where the punishment for late arrival is larger than for off-peak trips. What is important is that any time invariant amenities of the ExpressLanes are present in both the morning peak and off-peak times of day.

This allows us to estimate

$$(3) \quad toll_{a,s,t} = \delta_{WE} + \delta_{MP}1(MP_t) + \theta_{MP}TT1(MP_t) + \theta_{WE}TT + \mu + \varepsilon_{a.s.t}$$

where $1(MP_t)$ is an indicator for trip t taken in the morning peak, and μ is a constant ExpressLanes amenity. In this specification, the constant will measure the sum of δ_{WE} and μ. The coefficient δ_{MP} measures the morning peak urgency premium—how much extra punishment failure to achieve on time arrival has—compared with a weekend trip. For an omitted factor to bias our estimate of δ_{MP} it must be independent of travel time savings (and the level of congestion that generates those savings) and an amenity that exists only during the weekday morning peak and not during the weekend.

IV. Results

A. Central Estimate of the Value of Urgency

Table 2 reports the results from estimating equation (1) and examines the robustness of the results to sample restrictions, additional covariates, and changes to functional form.[22] Panel A column I represent our central specification, which estimates equation (3), a homogeneous agent model that follows directly from theory. We estimate the constant at 2.94 and a coefficient on travel time saved (in hours) of 11.05, both statistically significant at the 1% level. Our central estimate of the value of urgency is \$2.94, while the estimate of the value of time is \$11.05 We note that \$11.05 is only slightly higher than half the local wage, the ratio generally found to be the value of time in the literature (Small, 2012).

B. Relevance of the Value of Urgency

The results provided above give estimates of the value of urgency and value of time, but they do not assess the relative contribution of each component to the welfare generated for these drivers. To decompose the effect we can compare the value of urgency with the average toll, which is \$3.69. Urgency represents 81% of the value for the average toll.

The relevance of urgency can also be seen in the context of a cost-benefit analysis. To assess the benefit of the ExpressLanes, a policy maker using the standard value of time model would evaluate the time saved by agents using ExpressLanes at half the local wage in L.A. From this value, which would be roughly our estimate above, the projected benefits would be \$221,363, which barely surpasses the infrastructure costs during that time period of \$215,250.[23] The policy actually generated \$1.31 million. Without the value of urgency, an *ex ante* analysis would underestimate the benefits of the program by an order of magnitude during this time frame. Even a value of time two or three times that of the standard, would be off by more than 100

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[22] Standard errors for these regressions are estimated by clustering by road segment traveled for each trip observation. In Appendix Table E.7, we examine other levels of clustering including two-way clustering (Cameron, Gelbach, and Miller, 2011) to address the spatial and temporal correlation (Anderson, 2014). Of these, clustering at the segment level produces the largest standard errors.

[23] Source: Correspondence with LA Metro, 04/15/14. This corresponds to the operation and maintenance costs of the corridor including weekends, holidays, across all hours of the day.

percent. As we show in the following sections the addition of other regressors, such as reliability, and tests for omitted, travel-time invariant factors can explain a small portion of the WTP but without urgency any available model under reasonable assumed parameters would poorly predict the revenue generated by this program.

V. Robustness Checks and Alternative Explanations

We argued and provided evidence that the pattern displayed in Figure 1 is most plausibly and parsimoniously resolved by incorporating scheduling that includes a cost of urgency. Such a discrete cost, divided by ever-smaller time gives rise to the hyperbolic shape noted in Figure 1. Drivers facing an urgency cost would be willing to pay a flat amount, possibly only a few dollars, to remove the congestion externality, but when evaluated on a per-hour basis would generate absurd values. To reveal the value of urgency it is critical that what the agent is paying for is not simply more time but rather the time necessary to meet a critical deadline, something our setting is well poised to elicit. These conditions will arise wherever the benefit of a good decreases in a discontinuous way. What agents are paying for is the ability to jump a queue or obtain sufficiently faster action to meet a scheduling deadline. This deadline may be for routine or extraordinary tasks. For example grocery stores may drop prices to clear inventories by a sell-by date, airline passengers may pay for expedited passport processing or faster check in lines, and patients seeking organ donor matches may pay to jump a queue (Bergstrom, Garratt, and Sheehan-Connor 2009).[24] Allowing for urgency is consistent with theoretical models, but prior models of scheduling have, almost universally, assumed this cost is zero and that all costs scale with time, mostly for reasons of mathematical tractability rather than based on empirical evidence. There is no

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[24] Urgency is particularly relevant in transportation models of scheduling (Small 1982) including models examining reliability (Brownstone and Small 2005) and bottleneck models (Arnott, de Palma, and Lindsey 1993). During the morning commute to work urgency is likely to play a large role whenever late arrival increases the probability of being fired.

reason to make this assumption. While using the value of time alone is appropriate in many cases, in others, such as ours, it is not—with significant implications for public policy. While we do not expect this phenomenon to be unique to this setting, it is unique in that it allows us detect and measure this novel cost and to exclude other possible explanations besides urgency.

There are, however, several other possible explanations for this pattern including a time-invariant lane-specific amenity, such as pavement quality, or heterogeneity and sorting over the value of time, which we will now systematically argue are not generating this pattern.

A. Threats to Measuring Travel Time Savings

There are two types of measurement error of time saved that may have implications for our estimates: researcher measurement error and driver perception error. While we have extremely detailed information on individual speeds in the ExpressLanes, there is somewhat less certainty about what speed the driver would have achieved outside of them. During low demand hours the 5-minute average speed in the mainline lanes may obscure the ability of drivers to pass and achieve travel times very different than the average. Our estimates in Table 2 are for the morning peak because during these hours the road is sufficiently congested to prevent substantial passing. This helps to guarantee that the measured speed is reflective of what drivers in that lane would have been forced to experience as they have less discretion over speed.[25]

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[25] Furthermore using a side street during the morning peak is less likely to offer an improvement over mainline travel. When congestion is high, a Nash equilibrium ensures that indirect routes will have faster speed but equal travel time to a direct but congested route. As further robustness, we examine alternative specifications of travel time difference: In Appendix Table C.8, as a bounding exercise, we consider certain extreme driver miscalculations of travel times (e.g., twice the time savings, random guess) and find almost no effect on the value of urgency. In Appendix Table C.9, we control for periods when the I-210 W, an imperfect substitute for the I-10 W was traveling at or below its average speeds. In Appendix Table C.10 we construct travel time difference between the I-10 W ExpressLanes and the I-210 W mainline lanes (rather than those on the I-10), and in Appendix Table C.8 we calculate travel time difference based on past realizations of mainline speeds. In all cases, our estimates of the value of urgency remain close to the $2.94 baseline estimate.

We are also concerned that drivers may not accurately perceive their time savings. First we note that the ability of drivers to enter or exit the lanes at multiple points makes substantial errors unlikely. If a driver saves less time than anticipated it is possible to leave the lanes. Second this error must be substantial to explain the magnitude of the constant. Only if all drivers systematically mistook their time savings by 16 minutes, regardless of travel time savings would the constant be reduced to zero. We can also eliminate trips with relatively small travel time savings, which may be occasions where the individual mistakenly took the ExpressLanes. When trips less than 5 minutes are eliminated we find that the estimate of urgency increases to \$3.57.[26] Furthermore we can examine the time period after October 20th, 2013. On this date, signs were posted giving the expected travel time savings helping to resolve any ambiguity that may have existed. We find the point estimate changes minimally to \$3.23. None of these estimates are statistically different from one another and these exercises suggest that the presence of constant is not due to driver mistakes.

B. Other Potential Controls

To this relatively simple model we next introduce reliability and exit time, two potentially important regressors in Panel B. Although we think that most uncertainty over travel times is resolved when the individual can observe traffic levels, there is the possibility that some drivers may know that particular times of the commute are more likely to result in an unexpected delay. When we include a measure of reliability in column I we find that urgency is \$2.84, the estimate of travel time is \$8.02, and the value of reliability is \$24.76.[27] Drivers may also be

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[26] Further sample restrictions to travel time savings are considered in Appendix Table C.11, which demonstrate only moderate variation in the value of urgency.

[27] In Appendix Table C.12, we consider an alternative definition which only controls for reliability in the mainline lanes. Appendix Table C.13 also considers the effect of including negative travel time savings trips on these results.

willing to tolerate slightly negative times in the ExpressLanes if they believe travel times are more certain. In column II of Panel B we include the 6.2% of trips with negative travel times, which results in minimal changes to the parameter estimates. Finally we include exit time in column III.[28] While we do find a statistically significant estimate of 0.23 for exit time in hours, it is small and minimally affects the estimate of urgency.[29]

C. Alternative Functional Forms

The evidence in Panels A and B show that if a constant is included the estimate of urgency is substantial. However it is not clear that this model is the best possible fit to the data. Panel C compares our baseline model with a model where the constant is omitted in column II. The AIC and BIC show that the fit is worse than our model with a constant.[30] Surprisingly even column III where a squared term in travel time is introduced performs worse than the simple model with a constant. While additional flexibility will eventually provide a better fit, the parameters do not align with intuition and theory. The estimate of the squared term is so substantially negative that trips well within the range observed in our data decrease in total (not just marginal) WTP.

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[28] If what largely determines the WTP for access to the ExpressLanes are schedule delay costs as opposed to schedule constraint costs, later exit times could generate higher willingness to pay. While theoretically these costs should be captured in travel time, we include a regressor for the travel time difference in hours between the exit time for the trip and the average exit time across trips registered to that account. In Appendix Table C.14, we also regress the distance traveled along the ExpressLanes on exit times to give an indication that lateness via exit time corresponds to longer ExpressLanes trips. Other statistics on segment choice are provided in Appendix Table C.3, C.4 and C.15.

[29] We also consider the potential effect of other confounding factors on our results: Burger and Kaffine (2009) document the response of freeway speeds to changes in the price of gasoline, so in Appendix Table C.16 we consider days when gasoline is above or below $4 per gallon and find little effect. As inclement weather may reduce driver speeds and/or be correlated with unexpected schedule delays, and we also consider the effect of rainy days on our results and find no meaningful effect.

[30] In Appendix Table C.17 we consider a variety of models with higher order terms. We find that even when higher order terms are included in a model with a constant, the constant remains highly statistically significant.

D. Other Time-Invariant Lane Characteristics: Bounding Urgency from Below

One particular concern with the estimates in the homogenous model is that the estimate of the constant will capture not only urgency but also any other time-invariant amenity in the ExpressLanes. If such an amenity exists it cannot take the form of congestion, which would generate travel time savings, but could take the form of a belief that the ExpressLanes are safer or a smoother ride than the mainline lanes. In this section we take advantage of the fact that trips taken in the off-peak likely have a lower punishment for late arrival.

In Table 3 we exploit the heterogeneity in urgency by including off-peak hour to our estimation to bound urgency from below following equation (3). The constant will not capture urgency on weekend trips and any lane specific, time-invariant amenities while the indicator for a morning peak trip gives the additional urgency of morning peak commuting trips. By introducing the weekend as a control group, the morning peak indicator gives the lower bound on morning peak urgency as a statistically significant \$2.02. In column II we include account fixed effects to absorb any time-invariant preferences that are not common to all individuals, for example beliefs about safety. This minimally changes the estimated lower bound of morning peak urgency at \$1.95.[31] While this estimate will exclude many potentially confounding factors we view this lower bound as overly conservative.

E. Estimating Heterogeneous Individual Bid Curves

It is well known that the hedonic envelope may obscure substantial heterogeneity in bid functions across individuals. The concern is that our findings may be the result of sorting by income where high income individuals use the road

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[31] We also find that value of time on the weekends is very low, likely because weekend time savings have lower opportunity cost. The sum of weekend and morning peak travel time is \$11.06, nearly identical to the homogeneous agent model.

for short time savings, while low income individuals use the road for larger time savings. Such a pattern could give rise to the hyperbolic shape and when estimated assuming homogeneity in the bid curve it would give rise to a statistically significant constant.

There are several ways we can address this concern. First we note that the drivers who consume small time savings, and have the highest VOT in a model without urgency, use the lane infrequently. Returning to Table 1, we note that drivers in the lowest decile of time savings use the lane on average 8.8 times per month, less than any other group. Although not impossible, it seems unintuitive that agents with extremely high value of time would consume so little of it and less frequently than groups with a lower valuation. While these lanes are often derided as 'Lexus Lanes' we find that the most common vehicles in this lowest decile, Toyota Corollas and Honda Accords,[32] are not typically driven by people we would anticipate earning roughly $8 million a year. Nevertheless the repeated sales nature of our data allows us to run account-by-account regressions, which directly addresses this concern by estimating individual bid functions rather than assuming a uniform value of time and urgency.

Table 4 gives the mean, bootstrapped standard error, and inner quartile of estimated coefficients from an account-by-account regression for each of the 10,337 accounts with more than 10 transactions. This assumes that each account holder has his or her own urgency and value of time. We find that the average urgency in the population is $3.26 with bootstrapped standard errors of that mean given in parentheses. In brackets we give the inner quartile of measures showing

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[32] See Appendix Table C.2.

that across accounts there is substantial heterogeneity in the estimated parameters.[33] Half of all account holder urgency estimates fall between \$2.29 and \$4.13.[34]

In column II we use the subset of 1,121 accounts with 5 or more observations on the weekend and 5 in the morning peak to bound the urgency of individual accounts from below. We find the account-level lower bound of urgency is on average \$2.42. While the richness of our data allow us to estimate these parameters without assuming homogeneous preferences, these restrictions require many observations to be thrown out; nevertheless, it is surprising how even these specifications present a similar picture to the homogeneous agent model presented in Table 2 column I.

VI. Conclusion

In an ideal setting where drivers are observed making choices of lanes depending on varying tolls, level of congestion, and schedule constraints, we study drivers' willingness to pay to avoid congestion. The nature of the data unfolds a new important aspect of drivers' preferences that we call urgency. We find that the bulk of the valuation of time saved does not scale with the amount of time saved. For the average peak-morning trip the value of urgency is \$3 and that the value of time is \$11 per hour, roughly half the local wage. This analysis demonstrates that a cost-benefit analysis without the value of urgency explains less than 19 percent of the WTP revealed by drivers in our data. We find no evidence that this departure from the standard theory can be resolved by standard scheduling models, reliability measures, driver heterogeneity, or controls for time-invariant lane amenities.

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[33] We also estimate the values of urgency and time during the afternoon peak and on other corridors of the ExpressLanes in Appendix Table C.18. We find that while there is heterogeneity, the qualitative results remain.

[34] While our data is not linked to income or demographic information of the agent, we do have the make and model of their vehicle. In Appendix Table C.19 we regress values of urgency and values of time on the value of the car registered to each account in our data. We find that drivers of inexpensive vehicles tend to have lower VOT, consistent with theory, but have higher urgency. We suspect that these drivers are shift workers who face strict punishment for late arrivals, while drivers of more expensive vehicles have a higher value of time but are less likely to be punished for only a few minutes of delay.

The presence of urgency has three broad implications. First it can alter the direction of cost-benefit analysis for priced road infrastructure. Second it suggests the need to reconsider the way researchers solicit stated preferences and demand for projects that generate time savings. Future survey work may improve prediction of the benefits of such projects by solicit willingness to pay to avoid being late and the frequency at which individuals are late, and not just focus on travel time saved from an average trip. Third, other non-market valuation exercises may find that aspects of other amenities or externalities do not scale with quantity or have thresholds that are more important than marginal improvements.

Beyond soliciting accurate willingness to pay and accurate cost-benefit analysis, preferences for urgency are also important for policy makers considering the efficiency and distributional implications of dynamic pricing. During periods of congested travel in the mainline lanes, the high price to enter the ExpressLanes ensures only drivers with the highest WTP for time savings will enter the lane. Because urgency inflates the value of small time savings, the first to enter the lane may not be the richest individuals but rather those with the most pressing schedule constraint. While real-time pricing of electricity has been of interest to economists as a way to reduced supplier costs, our findings suggest dynamic pricing may also improve rationing to congestible goods on the demand side. For example, power supply in developing nations or even organ donation markets may benefit from dynamic pricing that orders recipients over congested and uncongested networks. By pricing rather than rationing access to service, real time pricing may generate large welfare benefits from a small number of extremely sensitive users.

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FIGURES AND TABLES

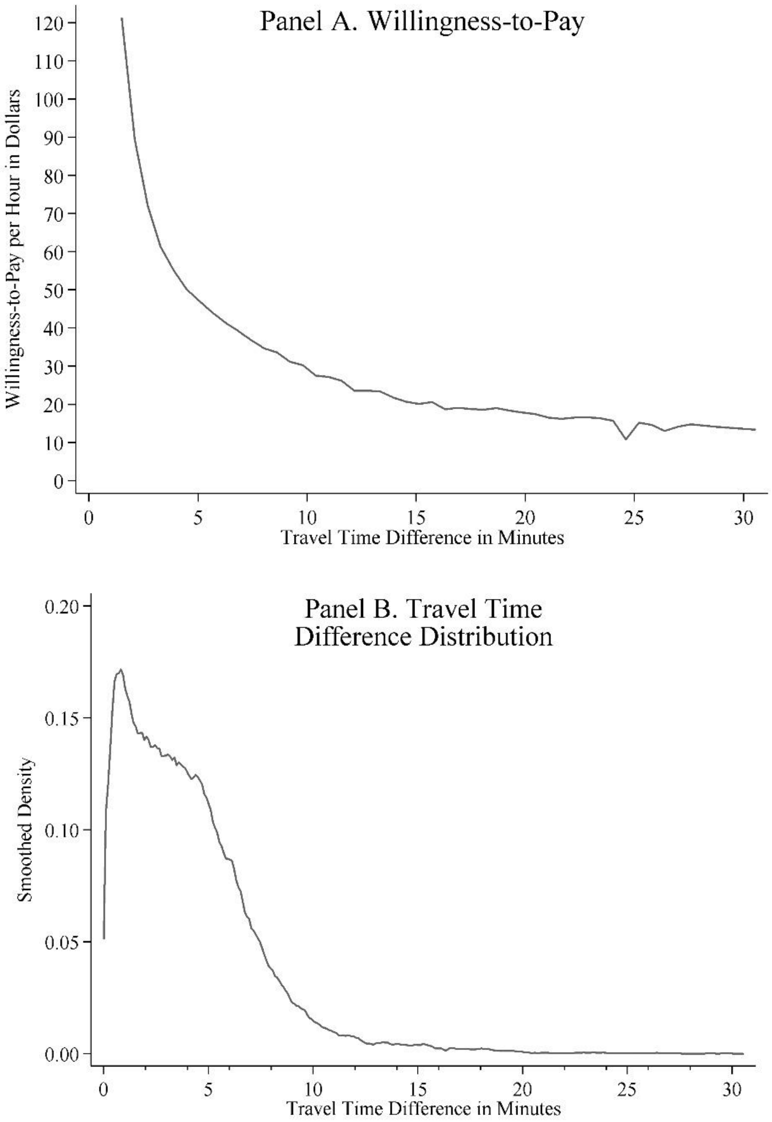

FIGURE 1. WILLINGNESS-TO-PAY PER HOUR AND DEMAND FOR TRIPS IN THE EXPRESSLANES

Notes: Panel A displays our lower bound estimate of willingness-to-pay for use of the ExpressLanes calculated using 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. Panel B displays the smoothed distribution of the trip-level travel time difference between the mainline lanes and the ExpressLanes. The smoother for both panels uses an Epanechnikov kernel with a bandwidth of 0.05. Travel times are 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 of work days in the first 10 months of the policy, excluding holidays. Panel A considers (for illustrative purposes) only trips for travel time difference greater than 90 seconds, while panel B considers the entire travel time distribution. 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 are dropped. Observations from PeMS where any of the 30 second observations are missing are also dropped.

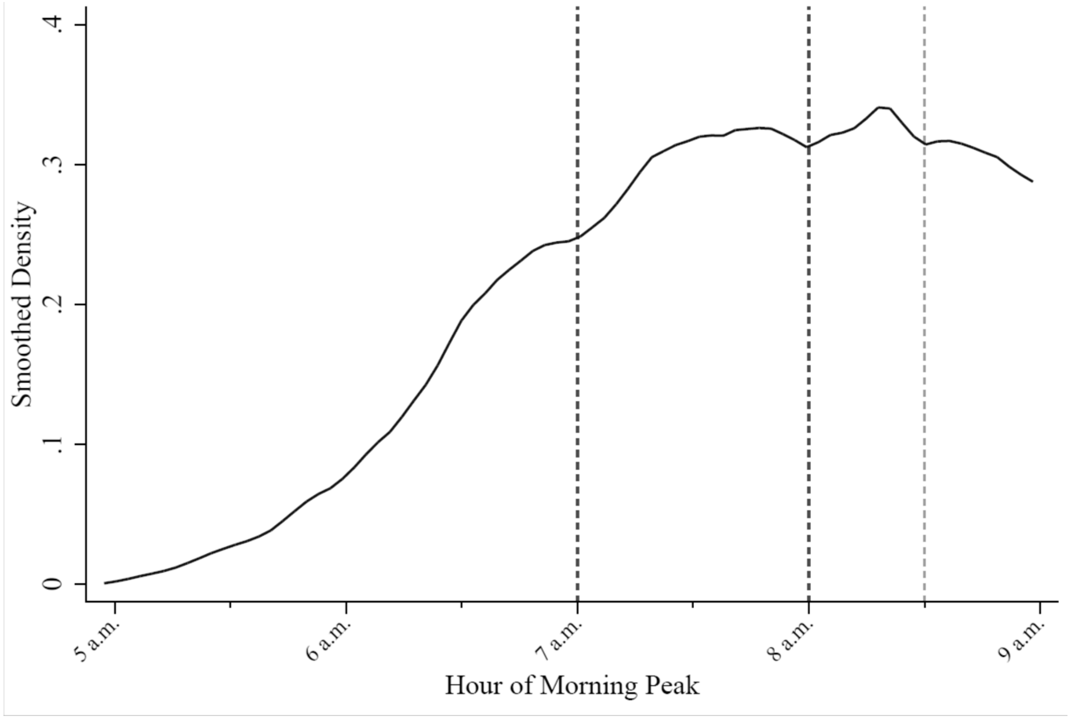

FIGURE 2. I-10 W EXPRESSLANES TRIP DENSITY DURING AM PEAK

Notes: The figure plots the kernel smoothed density of trips on the I-10 W ExpressLanes over the morning peak. Vertical dashed lines correspond to times with a discernible trough in the distribution indicating potential "bunching" around preferred arrival times of 7 AM, 8 AM and 8:30 AM. 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 are dropped. Observations from PeMS where any of the 30 second observations are missing are also dropped.

Table 1—Trip-Level Summary Statistics by Decile of Travel Time Savings

I	II	III	IV	V	VI	VII	VIII
	Time Savings						
Decile of Time Savings	in Hours	in Minutes	Average ExpressLanes/HOV Speed in MPH	Average Mainline Speed in MPH	Average Distance Traveled in Miles	Average Uses per Month	Average Hourly Wage in Zip Code
1	0.01	0.39	65.3	60.3	5.8	8.8	$19.35
2	0.02	1.01	67.4	55.9	6.1	9.5	$19.40
3	0.03	1.66	66.6	50.0	6.2	9.8	$19.47
4	0.04	2.37	66.1	44.7	6.1	9.9	$19.47
5	0.05	3.11	66.0	40.6	6.1	9.8	$19.65
6	0.06	3.88	65.8	37.7	6.3	9.9	$19.71
7	0.08	4.69	65.5	34.6	6.3	9.8	$19.73
8	0.09	5.64	64.7	32.7	6.7	9.8	$19.76
9	0.12	6.95	63.8	30.9	7.3	9.8	$19.79
10	0.18	11.04	62.0	25.8	8.1	9.6	$20.00
Average	0.07	4.08	65.3	41.3	6.5	9.7	$19.63

Notes: Unless otherwise indicated, all data cover work days for the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. "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 calculated based on the reported zip code for each transponder and 2008-12 ACS Census mean zip code data, assuming an assumed average household with two wage-earners and 2,040 working hours per year. "Average Uses per Month" excludes the first month that a transponder appears in the data to control for learning behavior. 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 are dropped. 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 2—Regression of Total Toll on Time Differentials

Panel A. Baseline Regressions			
	I	II	III
Constant	2.94***	3.57***	3.15***
	(0.50)	(1.10)	(0.56)
Time in hours	11.05***	7.24**	10.67***
	(3.03)	(2.58)	(2.37)
Trip Restriction	> 0 minutes	>5 minutes	Post 10/20/2013
Obs	466,232	146,365	221,673
Panel B. Adding Covariates			
Constant	2.84***	2.91***	2.82***
	(0.48)	(0.42)	(0.49)
Time in hours	8.02**	7.21*	8.22**
	(3.00)	(3.61)	(3.06)
Reliability	24.76***	25.48***	26.01***
	(5.24)	(5.70)	(5.49)
Exit Time			0.23**
			(0.07)
Trip Restriction	> 0 minutes	None	> 0 minutes
Obs	433,623	462,537	417,194
Panel C. Changing Functional Form			
Constant	2.94***		
	(0.50)		
Time in hours	11.05***	37.59***	62.27***
	(3.03)	(3.94)	(9.12)
Time in hours^2			-158.39***
			(18.82)
Trip Restriction	>0 minutes	>0 minutes	>0 minutes
Obs	466,232	466,232	466,232
AIC	1,655,287	2,106,127	1,951,494
BIC	1,655,310	2,106,138	1,951,516

Notes: Values shown are the coefficients of nine regressions of the toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Observations from morning peak hours are included with weekends and holidays removed.

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

Table 3—Weekend as a Control Group I-10 West

	I	II
Constant	0.91***	NA
	(0.12)	
1(Morning Peak)	2.02***	1.95***
	(0.50)	(0.38)
Time in Hours	2.85**	0.94
	(1.00)	(1.24)
Time in Hours*1(Morning Peak)	8.21***	7.75***
	(2.33)	(1.61)
Obs	504,163	504,163
Account Fixed Effects	N	Y

Notes: Values shown are the coefficients of two regressions of the toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Observations from morning peak hours are included with weekends and holidays removed.

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

Table 4—Account Level Regressions I-10 West

	I Morning Peak		II Weekend Control Group
Constant	3.26	Constant	0.79
	(0.01)		(0.01)
	[2.29, 4.13]		[0.50, 1.04]
Travel Time	9.70	1(Morning Peak)	2.42
	(0.14)		(0.02)
	[3.95, 14.73]		[1.46, 3.35]
		Travel Time	3.46
			(0.08)
			[1.29, 5.22]
		Travel Time x Morning Peak	7.07
			(0.24)
			[1.54, 11.06]
Number of Accounts	10,337		1,121

Notes: Values shown are the coefficients of regressions of the toll paid on the regressands. Values shown are the average coefficient across regressions, with the inner quartile of values given in brackets. Standard errors of the mean, calculated by randomly sampling from the mean and standard error of individual coefficients 500 times, are given in parenthesis. 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. For column II toll paid is regressed on a constant (urgency), an indicator for morning peak observations (the minimum urgency of the morning peak), travel time saved, and travel time saved interacted with morning peak.

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

For Online Publication

Online Appendix for

The Value of Urgency: Evidence from Congestion Pricing Experiments

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-10W, background information on the I-10W, and details regarding matching of the aggregate PeMS flow and speed data to repeat transaction-level transponder data. Appendix B includes descriptive figures related to each of the datasets and the ExpressLanes policy. Appendix C presents additional tables outlining descriptive statistics of our data and alternate specifications as robustness checks.

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Appendix A. Additional Data Discussion

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

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.[1]

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. Second, data was available for the I-210W, 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 Tables C.9 and C.10. Third, while the I-10, in general, has one of the highest detector concentrations of any freeway in general, 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 B.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—The 10.5-mile section of the I-10 W analyzed is shown in Appendix Figure B.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 L.A. region. The road generally has barriers on both sides with a shoulder for stopped vehicles on the right. 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

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[1] 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.

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.

Appendix Table C.1 presents average weekday travel time differences between the ExpressLanes and the mainline lanes. During the morning peak, travel times are between zero and forty-five minutes lower in the ExpressLanes than the mainline lanes, with the average at about 7 minutes.

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 (5:00 to 9:00 A.M.) and afternoon peak (4:00 to 7:00 P.M.) 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 differ 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.

Weather—In Appendix Table C.16, we differentiate our results based on local weather patterns as a robustness check to the main results. 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-10W. 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.

Vehicle Prices—In Appendix Table C.19, we examine the relationship between account-level estimates of the value of urgency and value of time and the value of vehicles registered to these accounts. Account-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). Of the 31,331 vehicle-account 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 account-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.

APPENDIX REFERENCES

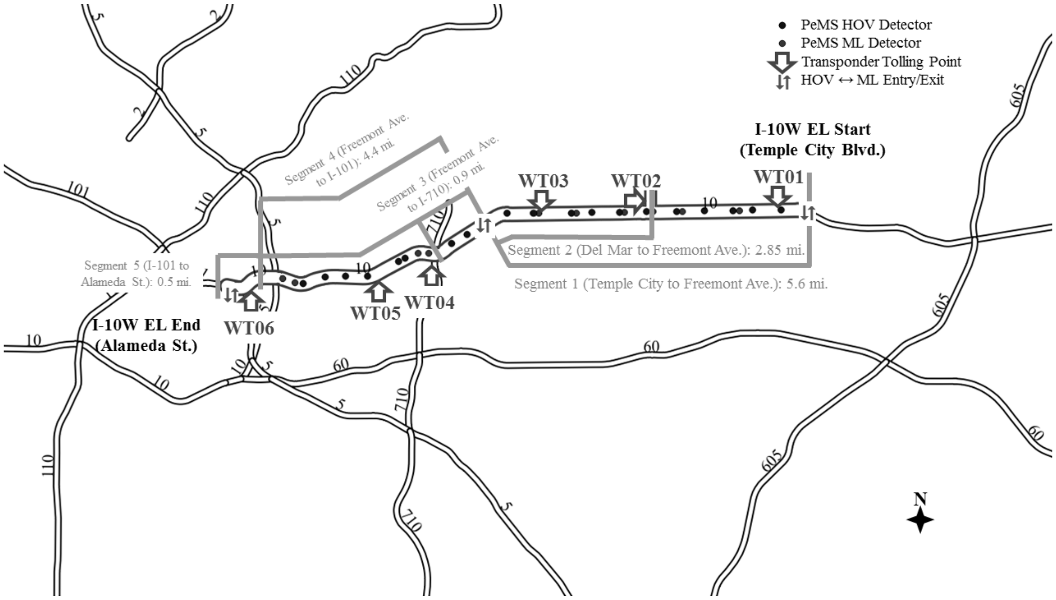
Auffhammer, Maxmilian, and Ryan Kellogg. 2011. "Cleaning the Air?: The Effects of Gasoline Content on Air Quality." *American Economic Review*. 101 (6): 2687-722.

Appendix B. Additional Figures

Figure B.1. I-10W ExpressLanes Design

Figure B.2. Mean and 20th Quantile of Speed by Hour

Figure B.3. Estimated Distribution of Value of Time and Urgency



Appendix Figure B.1. I-10W ExpressLanes Design

Notes: The figure displays the I-10W ExpressLanes design, which includes 5 separately tolled segments along its 10.5 mile stretch West of Downtown Los Angeles (indicted 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 indicated by the small circles.

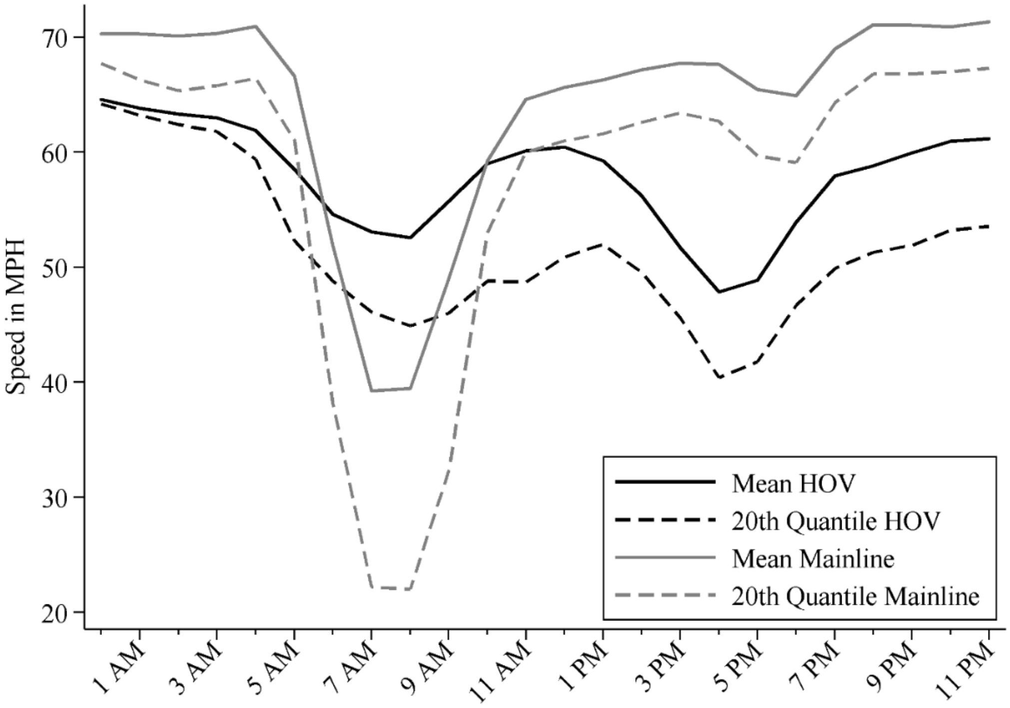


FIGURE B.2. MEAN AND 20TH QUANTILE OF SPEED BY HOUR

Notes: The figure displays the average hourly pre-policy mean and 20th quantile speed detected by PeMS from September 3rd, 2012 until February 22nd, 2013 in the indicated lane for each hour of the day on the I-10W in the HOV and mainline lanes. The graph indicates the travel time savings of the HOV lane during AM peak hours, whereas during off-peak times slower speeds in the HOV lanes reflect differential speed preferences between HOV and mainline drivers. Weekends, holidays and observations where any of the 30 second observations are missing are dropped.

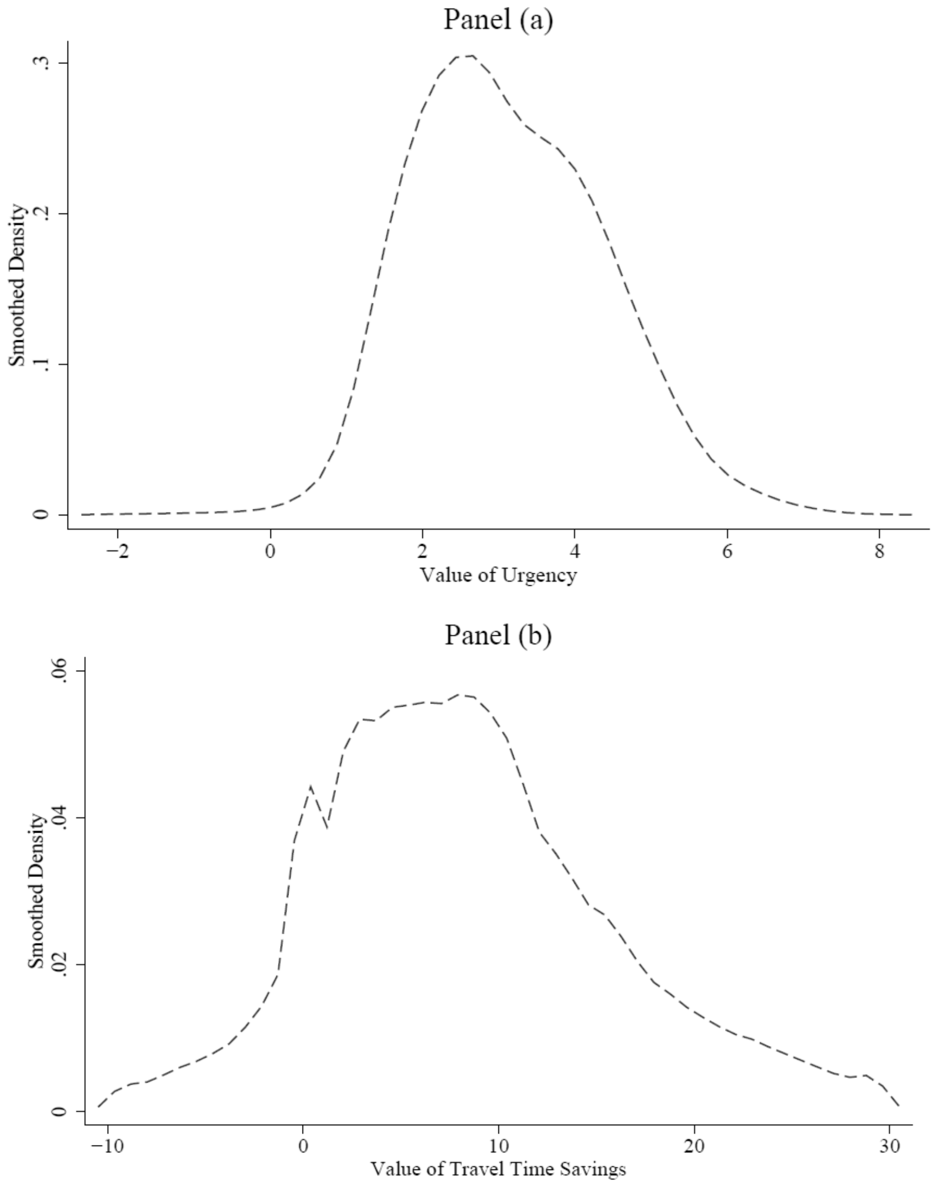


Figure B.3. ESTIMATED DISTRIBUTION OF VALUE OF TIME AND URGENCY

Notes: The figures depict smoothed kernel density estimates of the value of urgency and travel time savings from account-specific regressions of the total toll on the travel time saved and a constant and are consistent with the heterogeneous individual bid curve model. Time, measured in hours, is the time saved by taking the ExpressLanes compared with mainline lanes, from mainline line speeds reported by PeMS, for the chosen trip distance. Observations from morning peak hours are included with weekends and holidays removed.

Appendix C. Additional Tables

Table C.1. Trip-Level Willingness-to-Pay Estimates by Decile of Travel Time Savings
Table C.2. Most Common Vehicles by Decile of Travel Time Savings
Table C.3. Segment Frequency by Travel Time Savings Decile
Table C.4. Entry-Exit Frequency Matrix
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Table C.11. Regression of Total Toll on Time Differentials: Restricted Time Windows
Table C.12. Regression of Total Toll on Time Differentials: Reliability Robustness
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Table C.14. Regression of Distance on Exit Time
Table C.15. Regression of Total Toll on Time Differentials: Segment Robustness
Table C.16. Regression of Total Toll on Time Differentials: Gas Price and Weather Robustness
Table C.17. Regression of Total Toll on Time Differentials: Other Functional Form
Table C.18. Regression of Total Toll on Time Differentials: Other Corridors
Table C.19. Value of Registered Vehicle Relative to Urgency and Value of Time
Table C.20. Regression of Total Toll on Time Differentials: Models without Constant

TABLE C.1—TRIP-LEVEL WILLINGNESS-TO-PAY ESTIMATES BY DECILE OF TRAVEL TIME SAVINGS

I	II	III	IV	V	VI	VII	VIII
	Time Savings			Average WTP per Hour			
Decile of Time Savings	in Hours	in Minutes	Average Toll Paid	Full Time Period	February & March	June	September
1	0.01	0.39	$3.20	$1,977	$1,730	$1,910	$1,220
2	0.02	1.01	$3.10	$190	$147	$242	$134
3	0.03	1.66	$3.12	$115	$94	$158	$86
4	0.04	2.37	$3.17	$81	$72	$116	$66
5	0.05	3.11	$3.29	$64	$55	$85	$55
6	0.06	3.88	$3.57	$55	$45	$70	$48
7	0.08	4.69	$3.81	$49	$39	$62	$44
8	0.09	5.64	$4.15	$44	$34	$56	$41
9	0.12	6.95	$4.49	$39	$29	$46	$38
10	0.18	11.04	$4.95	$28	$25	$40	$28
Average	0.07	4.08	$3.69	$264	$227	$278	$176

Notes: The table calculates the implied WTP for travel time saved in a model without Urgency across various time periods. Unless otherwise indicated, all data cover work days for the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. "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. 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 are dropped. 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.

(i) TABLE C.2—MOST COMMON VEHICLES BY DECILE OF TRAVEL TIME SAVINGS

I	II	III	IV
Decile of Time Savings		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 top three vehicle models by decile of time saved. We report the vehicle make and model registered to accounts 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 during weekends and holidays are removed as well as those for vehicles linked to public sector, corporate or unknown accounts. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Each decile contains 62,570 trips.

Table C.3—Segment Frequency by Travel Time Savings Decile

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Decile of Time Savings	2	3	4	5	8	9	10	12	13	14	17
1	15.13%	16.00%	5.10%	18.68%	2.93%	0.93%	12.08%	0.13%	0.38%	7.31%	21.33%
2	17.54%	28.61%	5.82%	20.99%	4.30%	0.44%	8.14%	0.21%	0.11%	4.39%	9.44%
3	22.75%	24.51%	5.35%	25.58%	6.86%	0.30%	7.05%	0.19%	0.04%	2.05%	5.32%
4	31.27%	22.17%	3.60%	26.71%	5.73%	0.15%	6.50%	0.07%	0.02%	1.24%	2.54%
5	35.32%	24.85%	3.33%	26.48%	2.21%	0.11%	4.93%	0.04%	0.02%	0.81%	1.90%
6	33.44%	28.53%	2.92%	29.33%	0.73%	0.18%	3.03%	0.05%	0.02%	0.37%	1.39%
7	35.44%	27.92%	2.45%	30.70%	0.40%	0.05%	2.00%	0.02%	0.01%	0.29%	0.72%
8	26.87%	31.95%	2.24%	36.08%	0.25%	0.08%	1.75%	0.01%	0.01%	0.26%	0.50%
9	13.23%	39.18%	1.99%	42.34%	0.20%	0.05%	2.28%	0.00%	0.00%	0.35%	0.39%
10	8.04%	26.74%	2.66%	58.28%	0.05%	0.03%	3.79%	0.00%	0.00%	0.40%	0.01%

Notes: This table presents the share of trips in each decile of travel time savings that occur in each of the 11 ExpressLanes trip segments. Values represent the percentage of trips in each decile that were taken over the listed road segment. Data cover the morning peak (5-9 AM) for work days from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled and the 6.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. There are 46,624 trips per decile.

TABLE C.4—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 C.5—Lane Use Frequency by Hour

I	II	III	IV	V	VI
Panel A: First Month					
		Hour			
		5 AM	6 AM	7 AM	8 AM
Decile of Time Savings	Minutes Saved	Number of Observations by Decile			
1	0.4	1,108	519	850	784
2	1.2	988	1,077	643	553
3	1.8	319	1,534	853	555
4	2.5	118	1,768	822	553
5	3.2	30	1,692	843	696
6	3.9	5	1,024	1,285	947
7	4.8	—	625	1,399	1,237
8	5.7	—	209	1,748	1,304
9	6.9	—	126	1,618	1,517
10	10.1	—	4	1,632	1,624
Avg. Minutes Saved		0.8	2.8	4.6	5.3
Number of Observations		4,342	13,100	16,916	15,341
Panel B: Full Time Period					
		Hour			
		5 AM	6 AM	7 AM	8 AM
Decile of Time Savings	Minutes Saved	Number of Observations by Decile			
1	0.4	15,987	9,782	11,395	9,460
2	1.0	12,355	15,467	9,105	9,696
3	1.7	4,517	20,767	10,659	10,680
4	2.4	804	22,420	13,187	10,212
5	3.1	60	19,322	15,235	12,006
6	3.9	7	14,164	18,143	14,310
7	4.7	—	8,728	20,885	17,010
8	5.6	—	5,670	22,493	18,460
9	7.0	—	2,199	22,054	22,370
10	11.0	—	1,766	16,989	27,868
Avg. Minutes Saved		0.9	2.8	4.7	5.3
Number of Observations		33,730	120,285	160,145	152,072

Notes: This table presents trip information by hour and decile of travel time savings during work days. The frequency of trips by decile in each hour for the first month of the policy (February and March 2013) is given in Panel A and for the full dataset (February through December 2013) in Panel B. Average minutes saved by using the ExpressLanes compared with the mainline lanes, in minutes, is presented for each decile and each hour in the given time period. Trips with zero distance traveled and the 6.2% of observations with negative time saving, are removed. There are 46,624 trips per decile. Observations from PeMS where any of the 30 second observations are missing are also dropped.

TABLE C.6—MONTHLY FREQUENCY BY TRAVEL TIME SAVINGS DECILE

I	II	III	IV	V	VI	VII
Decile of Time Savings	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 by decile of travel time savings. First we categorize agents 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 work days 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. Observations from PeMS where any of the 30 second observations are missing are also dropped.

TABLE C.7—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: STANDARD ERROR CLUSTERING

	I	II	III	IV	V	VI
	I-10 W Morning Peak: Clustering					
	Robust	Day	Week	Month	Account	Week-Segment
Constant	2.94***	2.94***	2.94***	2.94***	2.94***	2.94***
	(0.00)	(0.04)	(0.06)	(0.08)	(0.01)	(0.50)
Travel Time in Hours	11.05***	11.05***	11.05***	11.05***	11.05***	11.05***
	(0.04)	(0.70)	(0.89)	(0.89)	(0.11)	(2.97)
R^2	0.15	0.15	0.15	0.15	0.15	0.15
Number of Observations	466,232	466,232	466,232	466,232	466,232	466,232
Log-Likelihood Function	-864,975	-864,975	-864,975	-864,975	-864,975	-864,975
AIC	1,655,287	1,655,287	1,655,287	1,655,287	1,655,287	1,655,287
BIC	1,655,310	1,655,310	1,655,310	1,655,310	1,655,310	1,655,310

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. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, 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 C.8—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: POTENTIAL MEASUREMENT ERRORS

	I	II	III	IV
Panel A. Measurement Error Models				
Constant	2.94***	2.97***	1.66***	0.36
	(0.50)	(0.50)	(0.47)	(0.67)
Travel Time in Hours	5.53***	9.70***	11.05***	11.05***
	(1.51)	(2.85)	(3.03)	(3.03)
R^2	0.15	0.13	0.15	0.15
Number of Observations	466,232	433,623	433,623	433,623
	Multiply time saved by 2	Each segment is 0.5 miles longer than measured	Add 7 minutes to ALL time savings	Add 14 minutes to ALL time savings
Panel B. Alternative Measurements of Travel Time Difference				
Constant	2.779***	2.384***	2.841***	2.387***
	(0.479)	(0.441)	(0.525)	(0.438)
Time in Hours (Max. 1)	11.836***			
	(3.216)			
Time in Hours (Max. 2)		13.495***		
		(2.643)		
Time in Hours (Max. 3)			11.385***	
			(1.402)	
Time in Hours (Max. 4)				12.235***
				(1.261)
R^2	0.180	0.284	0.255	0.366
Number of Observations	466,232	433,623	433,623	433,623
Avg. Travel Time Diff. in Min.	4.60	5.98	4.68	6.59

Notes: This table explores the robustness of our main results to variations in the construction of the travel time difference variable to understand how various types of measurement error would influence the estimates, reflecting alternative driver perceptions than those assumed in our main results. Values shown are the coefficients from 8 separate regressions of the total toll on the regressands. In Panel A, Column I doubles the travel time saved suggesting that underestimating the time saved inflates the value of time. Column II assumes that each segment is half a mile longer than recorded, possibly because of transition zones. Columns III and IV add 7 and 14 minutes of time saved to all trips suggesting that only by uniformly adding travel time will the constant go to zero. Panel B examines the robustness of the central specification to variation in the calculation of travel times in the parallel mainline segment. "Max. 1" compares the maximum speed in the ExpressLanes within a 5-minute interval that a transponder is recorded in the lane to the average speed recorded by PeMS detectors in the mainline lanes for a comparable segment at the same time. "Max. 2" compares the maximum speed in the ExpressLanes for the preceding month by hour and day of week to the average speed recorded by PeMS detectors in the mainline lanes for a comparable segment at the same time. "Max. 3" compares the travel time recorded by the transponder receiver for each vehicle to the minimum speed in the mainline lanes from PeMS detectors for the preceding month by hour and day of week. "Max 4" compares the maximum speed in the ExpressLanes for the preceding month by hour and day of week to the minimum speed in the mainline lanes from PeMS detectors for the preceding month by hour and day of week. These results also serve as a robustness check to recording errors with individual PeMS detectors in mainline lanes.

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

TABLE C.9—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: I-210W ML SPEEDS RELATIVE TO AVERAGE

	I	II	III	IV	V	VI
	Below Avg.	Below Avg.	Below Avg.	Above Avg.	Above Avg.	Above Avg.
Constant	3.042***	2.815***	2.940***	2.908***	2.566***	2.788***
	(0.531)	(0.501)	(0.515)	(0.470)	(0.404)	(0.428)
Travel Time in Hours	11.168***	7.644**	8.661**	9.182**	3.506	4.995
	(2.878)	(2.666)	(2.805)	(3.753)	(3.757)	(3.924)
ML Reliability		22.976***			39.846***	
		(4.851)			(6.402)	
Reliability Difference			19.984***			35.927***
			(4.871)			(6.195)
R^2	0.158	0.243	0.209	0.087	0.271	0.206
Number of Observations	243,680	237,839	237,839	222,552	195,784	195,784

Notes: The table examines the robustness of the result to times when speeds on a substitute route (I-210 W) are above and below average to assess the extent to which conditions on this substitute route influence the demand for ExpressLanes. Values shown are the coefficients of 6 separate regressions of the toll paid during the AM peak period (5 - 9 AM) on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Reliability is constructed from the 50th and 20th quantiles of travel time for the 55 minute window before and after each 5 minute observation. "ML Reliability" is the difference between 80th and 20th quantiles in the mainline lanes, while "Reliability Difference" is the difference between that measure in the mainline and in the HOV lanes, where negative values are set to zero. "Below Avg." are observations where the average hourly speed on the I-210W for the preceding hour is at or below the average for that hour-day of the week, and "Above Avg." is when it is above.

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

Table C.10—Regression of Total Toll on Time Differentials: Travel Time Difference Relative to I-210W ML

	I	II	III	IV	V	VI	VII	VIII
	AM Peak	AM Peak	Eve. Off-Peak	Eve. Off-Peak	PM Peak	PM Peak	Mid-day Off Peak	Mid-day Off Peak
Constant	2.923***	3.099***	1.320***	1.426***	2.123***	2.383***	1.144***	1.290***
	(0.544)	(0.571)	(0.155)	(0.177)	(0.286)	(0.316)	(0.184)	(0.207)
Travel Time in Hours (I-210W)	6.217***	7.991***	4.065***	6.254***	5.077***	7.234***	4.761***	5.344***
	(0.675)	(1.001)	(0.942)	(1.801)	(0.852)	(1.730)	(0.444)	(0.552)
ML Reliability	26.832***		58.008*		64.334***		29.365***	
	(3.870)		(27.165)		(14.566)		(2.023)	
Reliability Difference		21.818***		-10.901		48.161***		30.590***
		(2.854)		(21.850)		(9.418)		(2.018)
R^2	0.247	0.207	0.005	0.002	0.153	0.079	0.184	0.165
Number of Observations	433,623	433,623	3,186	3,180	35,301	35,301	130,239	130,239

Notes: The table examines the robustness of the result to the use of I-210W travel times to construct the travel time difference. Values shown are the coefficients of 8 separate regressions of the toll paid during the AM peak period (5 - 9 AM) on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Reliability is constructed from the 50th and 20th quantiles of travel time for the 55 minute window before and after each 5 minute observation. "ML Reliability" is the difference between 80th and 20th quantiles in the mainline lanes, while "Reliability Difference" is the difference between that measure in the mainline and in the HOV lanes, where negative values are set to zero.

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

TABLE C.11—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: RESTRICTED TIME WINDOWS

	I	II
Constant	2.28***	3.15***
	(0.27)	(0.32)
Travel Time in Hours	19.09*	-0.07
	(9.20)	(8.57)
Limit on Trip Differential	3-5 min	<3 min
Number of Observations	119,064	203,032

Notes: The table tests the robustness of the central specification to restrictions on the trip time saved that enter the regression. Values shown are the coefficients from 2 regressions of the toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, 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 C.12—Regression of Total Toll on Time Differentials: Reliability Robustness

	I	II	III	IV	V	VI	VII	VIII	IX
	AM Peak	AM Peak	AM Peak	Eve. Off-Peak	Eve. Off-Peak	PM Peak	PM Peak	Mid-day Off Peak	Mid-day Off Peak
Constant	2.769***	2.505***	2.677***	1.023***	1.177***	1.842***	2.078***	0.992***	1.110***
	(0.507)	(0.462)	(0.487)	(0.116)	(0.151)	(0.223)	(0.249)	(0.141)	(0.157)
Travel Time in Hours	12.951***	8.008**	9.455***	7.885	17.795**	11.604**	19.785**	4.929***	5.631***
	(3.028)	(2.691)	(2.921)	(4.596)	(7.902)	(5.210)	(7.706)	(1.531)	(1.637)
ML Reliability		30.271***		116.649**		76.649***		28.356***	
		(5.235)		(45.975)		(16.074)		(3.073)	
Reliability Difference			26.521***		-8.996		55.364***		29.980***
			(5.537)		(16.749)		(11.769)		(3.538)
R^2	0.190	0.321	0.267	0.018	0.005	0.205	0.105	0.214	0.195
Number of Observations	574,175	538,329	538,329	5,536	5,521	51,379	51,379	175,567	175,567

Notes: The table examines the robustness of the central specification to the inclusion of reliability measures. Values shown are the coefficients of 9 separate regressions of the toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9AM), evening off-peak (8PM-5AM), afternoon peak (4 -8PM) and mid-day off-peak (9AM - 4PM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Reliability is constructed from the 50th and 20th quantiles of travel time for the 55 minute window before and after each 5 minute observation. "ML Reliability" is the difference between 80th and 20th quantiles in the mainline lanes, while "Reliability Difference" is the difference between that measure in the mainline and in the HOV lanes, where negative values are set to zero.

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

TABLE C.13—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: INCLUDING NEGATIVE TRAVEL TIME DIFFERENCE IN RELIABILITY

	I	II	III	IV
	AM Peak	Eve. Off-Peak	PM Peak	Mid-day Off Peak
Constant	2.704***	0.859***	2.115***	1.171***
	(0.490)	(0.067)	(0.257)	(0.168)
Travel Time in Hours	9.713***	10.372***	23.185**	6.332***
	(2.981)	(3.338)	(8.950)	(1.782)
Reliability Difference	24.244***	-99.303***	2.067	24.265***
	(5.229)	(23.199)	(5.950)	(3.206)
R^2	0.259	0.037	0.082	0.179
Number of Observations	538,329	5,521	51,379	175,567

Notes: The table examines the robustness of the central specification to the addition of 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. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9AM), evening off-peak (8PM-5AM), afternoon peak (4-8PM) and mid-day off-peak (9AM - 4PM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. Reliability is constructed from the 50th and 20th quantiles of travel time for the 55 minute window before and after each 5 minute observation. "Reliability Difference" is the difference between that measure in the mainline and in the HOV lanes, where negative values are set to zero.

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

TABLE C.14—REGRESSION OF DISTANCE ON EXIT TIME

	I	II	III	IV	V
Exit time in Hours from Average	0.27***	0.27***	0.27***	0.26***	0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exit time squared				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	0.6589	0.6745	0.1031	0.1983
Number of Observations	334,127	334,127	334,127	334,127	232,053

Notes: The table provides additional evidence of the main effect measured in the paper by considering how drivers' consumption of distance along the ExpressLanes responds to variation in average exit time during the AM Peak (5-9AM). Values shown are the coefficients of a 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 transponder account. Standard errors, clustered by road segment, are in parentheses. Observations from morning peak hours are included with weekends and holidays removed.

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

Table C.15—Regression of Total Toll on Time Differentials: Segment Robustness

	I	II	III	IV	V	VI
Segment 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)
Travel Time in Hours	7.57***	6.83***	12.95***	9.51***	—	11.09***
	(0.60)	(0.57)	(1.28)	(1.07)	—	(1.25)
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

Segment 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)
Travel Time in Hours	4.23*	3.02**	8.82***	-0.33	5.42**	3.19*
	(1.82)	(0.71)	(1.67)	(2.39)	(1.52)	(1.28)
R^2	0.03	0.04	0.15	0.00	0.04	0.00
Number of 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 12 separate regressions of total toll on the regressands for the indicated road segment. Standard errors, clustered by month, are in parentheses. Data cover work days during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, 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 C.16—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: GAS PRICE AND WEATHER ROBUSTNESS

	I	II	III	IV
	Gas Price <$4	Gas Price >$4	Dry	Rainy
Constant	3.085***	2.815***	2.928***	3.053***
	(0.538)	(0.460)	(0.505)	(0.453)
Travel Time in Hours	10.733***	10.541**	11.090***	10.285**
	(2.783)	(3.574)	(2.995)	(4.569)
R^2	0.150	0.120	0.152	0.085
Number of Observations	253,671	212,561	439,896	26,336

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. Values shown are the coefficients of 4 separate regressions of the toll paid during the AM peak period (5 - 9 AM) on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, are removed. Observations from PeMS where any of the 30 second observations are missing are also dropped. 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).

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

TABLE C.17—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: OTHER FUNCTIONAL FORM

	I	II	III	IV	V	VI
	Higher Order Terms			$\beta_0 + \beta_1(Travel\ Time)^{\beta_2}$	Non-Linear Power Model	
Constant	2.89***	3.09***	3.29***	β_0	2.85***	
	(0.32)	(0.31)	(0.31)		(0.36)	
Travel Time in Hours	11.13	-2.37	-20.03			
	(14.93)	(16.91)	(13.87)			
Travel Time in Hours^2	15.78	210.57	578.06***	β_1	9.59	5.95***
	(87.27)	(139.57)	(140.05)		(5.80)	(1.81)
Travel Time in Hours^3	-65.29	-955.68*	-3734.09***	β_2	0.90	0.16**
	(134.37)	(435.23)	(724.12)		(0.58)	(0.06)
Travel Time in Hours^4		1202.68**	9533.69***			
		(452.76)	(1696.70)			
Travel Time in Hours^5			-8399.45***			
			(1434.41)			
Number of Observations	466,232	466,232	466,232		466,232	466,232
AIC	1,652,865	1,649,554	1,646,926		1,654,945	1,676,121
BIC	1,652,909	1,649,609	1,646,992		1,654,978	1,676,144

Notes: The table examines the robustness of models with urgency to functional form assumptions. Values shown are the coefficients of five regressions of the toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, 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 C.18—Regression of Total Toll on Time Differentials: Other Corridors

	I	II	III	IV	V	VI
	I-10 East		I-110 North		I-110 South	
	Morning Peak	Afternoon Peak	Morning Peak	Afternoon Peak	Morning Peak	Afternoon Peak
Constant	1.98**	2.26***	3.58***	2.42***	2.18***	2.38***
	(0.66)	(0.53)	(0.34)	(0.24)	(0.26)	(0.25)
Time in hours	6.25	23.42	21.16***	6.10**	10.62*	11.23**
	(5.31)	(15.91)	(3.47)	(2.37)	(5.58)	(4.87)
R^2	0.08	0.02	0.10	0.04	0.07	0.05
Number of Observations	20,213	320,666	474,762	259,110	234,671	646,562
LL function	-28,801	-520,991	-963,518	-331,190	-294,116	-1,072,068
AIC	55,899	1,035,479	1,876,820	651,574	571,318	2,112,752
BIC	55,915	1,035,500	1,876,843	651,595	571,339	2,112,774
Average Toll	$2.35	$2.43	$4.45	$2.57	$2.42	$2.79
Ratio of Urgency to Total Toll	0.84	0.93	0.80	0.94	0.90	0.85
Average Time Savings (Hrs.)	0.060	0.007	0.041	0.025	0.022	0.037
Average Time Savings (Min.)	3.612	0.436	2.476	1.525	1.345	2.196

Notes: The table examines the central specification using trips from the other direction of the I-10 and trips on the I-110. Values shown are the coefficients of a 6 separate regressions of the total toll paid on the regressands. 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. Standard errors, clustered by road segment, are in parentheses. Observations from morning peak hours are included with weekends and holidays removed.

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

TABLE C.19—VALUE OF REGISTERED VEHICLE RELATIVE TO URGENCY AND VALUE OF TIME

	I	II
	Urgency ($)	Value of Time ($/hr.)
Vehicle Price in 2013 Dollars	-0.011***	0.051***
(MSRP)	(0.001)	(0.005)
Constant	2.139***	7.352***
	(0.009)	(0.079)
R^2	0.019	0.006
Observations	17,168	17,168

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 2 regressions of account-level estimated urgency or value of time on the regressands. Vehicles are matched to Wards Auto Database MSRPs by vehicle make, model and year. Standard errors are in parentheses. Columns report cumulative sample restrictions. Vehicle prices are depreciated by an annual rate of 20%. Regressions are weighted by inverse of account-level regression standard error of dependent variable.

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

TABLE C.20—REGRESSION OF TOTAL TOLL ON TIME DIFFERENTIALS: MODELS WITHOUT CONSTANT

	I	II	III	IV	V
Travel Time in Hours	37.59*** (3.94)	62.27*** (9.12)	88.15*** (13.11)	117.72*** (17.05)	152.25*** (20.14)
Travel Time in Hours^2		-158.39*** (18.82)	-489.36*** (66.34)	-1073.32*** (166.42)	-2060.11*** (356.07)
Travel Time in Hours^3			795.29*** (127.18)	3841.06*** (735.75)	12384.09*** (2835.57)
Travel Time in Hours^4				-4416.15*** (1010.85)	-31963.92*** (8751.05)
Travel Time in Hours^5					29022.69*** (8925.67)
Number of Observations	466,232	466,232	466,232	466,232	466,232
AIC	2,106,127	1,951,494	1,881,085	1,839,839	1,810,528
BIC	2,106,138	1,951,516	1,881,118	1,839,883	1,810,583

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. 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. Standard errors, clustered by road segment, are in parentheses. Data cover work days during the morning peak (5-9 AM) from February 25th, 2013 until December 30th, 2013. Trips with zero distance traveled, with willingness-to-pay values greater than $2,000 and the 7.22% of observations with negative time saving, 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.