

**Online Web Based Supplemental Material of**

**VALUE OF TIME:  
SPEEDING BEHAVIOR AND GASOLINE PRICES**

Hendrik Wolff  
*University of Washington*

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This Online Appendix consists of the following subsections:

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## 1. Data Appendix

**Speed data:** WSDOT records the total number of vehicles passing over the loop detectors per highway direction and quantifies speeds in  $j = \{0,2,\dots,14\}$  bins per hour  $h$ , the first bin  $b_0$  representing the total number of vehicles traveling below 35 mph and then in five mile per hour (mph) increments from 35 to 100 mph. The final bin  $b_{14}$  quantifies the number of vehicles with any speed above 100 mph. In order to calculate the average speed per hour, we assume that the speed per bin is the average within-bin speed and we set  $S(b_0)$  and  $S(b_{14})$  as 32.5 and 102.5 mph respectively, such that

$$speed_h = \sum_j \{ (S(b_0) + 5j) b_{jh} \} / \sum_j b_{jh}.$$

**Precipitation:** In the NOAA dataset precipitation is provided by hour in inches of rain. In 42% of all hours with rain, however, precipitation is defined nonnumerically as “Trace” which is precipitation of an unknown quantity below 0.01 inches per hour. In our weekly regressions, the sum over the hours with trace do not contribute to the overall weekly total precipitation measured in inches.

**Data frequency and timing:** The WSDOT speed dataset is provided by hour  $h$  and site  $s$  in clock time. Each year one hour is missing in the dataset, which is the clock time when Daylight Saving Time transfers to Standard Time (where in fact this clock hour should appear twice). In contrast the weather NOAA files have their own time variable which represents the exact time in minutes the weather reading was taken (which varies over time and locations). We changed the weather time to round to the closest clock hour time.

**Holidays:** We define a day as a holiday by following the typical state employee holiday calendar. Holidays are Martin Luther King, Presidents Day, Memorial Day, 4th of July, Labor Day, Veterans Day, Thanksgiving, the day after Thanksgiving, Christmas Eve, Christmas and New Years. If a holiday falls on a Saturday, we use the Friday before as the holiday. If the holiday falls on a Sunday, we use the Monday after. If Christmas Eve and New Years Eve fall on midweek, these days are not coded as Holidays. The exact list of Holidays is: 17 jan 2005, 21 feb 2005, 30 may 2005, 04 jul 2005, 05 sep 2005, 11 nov 2005, 24 nov 2005, 25 nov 2005, 26 dec 2005, 02 jan 2006, 16 jan 2006, 20 feb 2006, 29 may 2006, 03 jul 2006, 04 jul 2006, 04 sep 2006, 10 nov

2006, 23 nov 2006, 24 nov 2006, 25 dec 2006, 01 jan 2007, 15 jan 2007, 19 feb 2007, 28 may 2007, 04 jul 2007, 03 sep 2007, 12 nov 2007, 22 nov 2007, 23 nov 2007, 24 dec 2007, 25 dec 2007, 31dec 2007, 01 jan 2008, 21 jan 2008, 18 feb 2008, 26 may 2008, 04 jul 2008, 01 sep 2008, 10 nov 2008, 11 nov 2008, 27 nov 2008, 28 nov 2008, 25 dec 2008, 26 dec 2008.

### **Vehicle Occupancy Rate:**

While we were unable to find specific estimates of the vehicle occupancy rate for speed measuring sites in our dataset, by reviewing the literature we find that at highways with similar characteristics on workdays at the PM period the vehicle occupancy rate is ranging from 1.1 to 1.3 persons per vehicle. We draw these estimates from Heidtman *et al.* (1997) and Area Plan Commission (2003, 2010). For this study we assume a vehicle occupancy rate of 1.2.

## **2. Additional Robustness Tests**

### **2.1 Dropping all Individual Vehicles Driving Below/Above Speed Thresholds:**

The dependent variable in our main regressions of Table 6 is measured as the average hourly speed. Theoretically, changes in the “average speed” could occur because of a change in the tail of the speed distribution for drivers that have very different fuel economy benefits, invalidating our approach to calculate VOT through the range considered in  $g(S)$ . In order to check this, Table A0 presents robustness checks of sequentially dropping the speed bins in the tail(s) of the speed distribution.<sup>1</sup> As a reference case, our preferred regression of column (3) of Table 6 is displayed in the first row of Table A0 below, indicated as the ‘reference case’ (producing the gas price point estimate of -0.27). In the rows below, dropping individual vehicles in the tails of the speed distribution, does not lead to qualitative changes in the estimated coefficients—neither when dropping the very fast drivers, or dropping slow drivers. Only when cutting the sample considerably in the “middle” of the distribution, produces point estimates that are different and partially insignificant—see rows of Table A0 when cutting the sample at 65 to 75. These estimates are shaded in grey.

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<sup>1</sup> The original dependent variable of the hourly “average speed” is hence replaced by the conditional average speed, conditional on all individual vehicles driving below (or above) the speed threshold as indicated in column (2) of Table R2.

TABLE A0: ROBUSTNESS TEST: DROPPING ALL INDIVIDUAL VEHICLES DRIVING BELOW/ABOVE INDICATED SPEED THRESHOLD

| Regression Specification              | Speed Threshold | Gas price coefficient | Std. Error of gas price coefficient |
|---------------------------------------|-----------------|-----------------------|-------------------------------------|
| (1)                                   | (2)             | (3)                   | (4)                                 |
| Reference Case: Column (3) of Table 6 |                 | -.2701                | .0483                               |
| dropping all vehicles <b>below</b>    | 50              | -.2758                | .0483                               |
| dropping all vehicles <b>below</b>    | 55              | -.2704                | .0477                               |
| dropping all vehicles <b>below</b>    | 60              | -.2472                | .0438                               |
| dropping all vehicles <b>below</b>    | 65              | 1.2037                | .1878                               |
| dropping all vehicles <b>above</b>    | 70              | -.0627                | .0195                               |
| dropping all vehicles <b>above</b>    | 75              | -.1586                | .0275                               |
| dropping all vehicles <b>above</b>    | 80              | -.2412                | .0415                               |
| dropping all vehicles <b>above</b>    | 85              | -.2682                | .0468                               |
| dropping all vehicles <b>above</b>    | 90              | -.2662                | .0477                               |
| dropping all vehicles <b>above</b>    | 95              | -.2688                | .0480                               |
| dropping all vehicles <b>above</b>    | 100             | -.2696                | .0481                               |

*Notes:* The original dependent variable of the hourly “average speed” in the first row (reference case) is replaced in the subsequent rows by the conditional average speed, conditional on dropping all individual vehicles driving below (or above) the speed threshold as indicated in column (2).

## 2.2. Alternative Gasoline Consumption as a Function of Traveling Speeds

A crucial input for the calculation of the VOT parameter is the construction of the gasoline consumption function  $g(S)$ . To investigate the robustness on our  $g(S)$  assumption, in this paper we

- (a) use the commonly utilized West *et al.* (1999) data and
- (b) as a robustness we contrast our results with a more recent study by Davis *et al.* (2010) that uses newer data on  $g(S)$ .

Ad (a): For cost benefit analysis, U.S. governmental agencies rely on the West *et al.* (1999) data, as summarized by Davis (2001) which is based on nine vehicles sampled from a mix of automobiles and light trucks of model years 1988–1997. The average of the vehicle gas consumption data are displayed in Table A1, column (2). By piece-wise linearly interpolating between the data points we estimate that the derivative  $\delta g^{West99}/\delta S = 0.06018$  in the relevant interval of  $S \in [70,75]$ .

Ad (b): Davis *et al.* (2010) provide estimates of vehicle gasoline consumption for different vehicle classes based on newer vehicle models. Based on the Davis *et al.* (2010) data we calculate

the average miles per gallon for large, medium and small SUVs as displayed in Table A1, column (2) and obtain  $\delta g^{Davis2010} / \delta S = 0.06101$  in the relevant interval of  $S \in [70, 75]$ .

TABLE A1: GASOLINE CONSUMPTION SPEED RELATIONSHIP BASED ON TWO STUDIES

|       | from West <i>et al.</i> (1999) as summarized by Davis (2001) based on nine vehicles of model years 1988–97 sampled from automobiles and light trucks |                             |                       | average of small, medium and large SUVs, from Davis, Diegel and Boundy (2010): Table 4.26 |                             |                       |
|-------|--|-----------------------------|-----------------------|---|-----------------------------|-----------------------|
|       | (1)  |                             |                       | (2)   |                             |                       |
| Speed | miles per gallon   | gallon / (100 miles) $g(S)$ | $\delta g / \delta S$ | miles per gallon  | gallon / (100 miles) $g(S)$ | $\delta g / \delta S$ |
| 65    | 29.2   | 3.4247                      | 0.061337              | 29.67   | 3.37                        | 0.0522349             |
| 70    | 26.8   | 3.7313                      | 0.060183              | 27.53   | 3.63                        | 0.0610093             |
| 75    | 24.8   | 4.0323                      | n/a                   | 25.40   | 3.94                        |                       |

Notes: The entries of the derivative  $\delta g / \delta S$  refer to the speed range from the same row to the speed row below. Hence in case of West *et al.* (1999), for speeds between 65 and 70 the derivative of  $g^{West99}(S)$  with respect to 100 miles driven is  $\delta g \delta S(S \in [65, 70]) = 0.061337$ .

### 3. Calculation of the Standard Error of the Value of Time Coefficient:

Summarizing all parameters in (2) as  $\theta$ , and after simplifying we obtain

$$VOT = P^2 \delta g / \delta S / [1/S(P^2|\theta) - 1/S(P^1|\theta)]$$

Because VOT is a nonlinear function of  $\theta$ , the standard error of the VOT coefficient is derived via the delta method as

$$\text{std.err}(VOT) = \text{Sqrt}\{\delta VOT / \delta \theta^T \text{Cov}(\theta) \delta VOT / \delta \theta\}.$$

While  $\theta$  is estimated via least squares, the estimate of the covariance matrix  $\text{Cov}(\theta)$  relies on the covariance structure of the disturbance  $\varepsilon_{ih} = \text{Speed}_{ih} - f(z_{ih})$ , with  $z_{ih}$ . We allow  $\varepsilon_{ih}$  to be both heteroskedastic and clustered on a weekly level  $w$ , such that the expectations

$$E(\varepsilon_{iwh} \varepsilon_{iwh} | \mathbf{z}) = \sigma_{iwh}^2, E(\varepsilon_{wj} \varepsilon_{wk} | \mathbf{z}) = \rho_{wj} \forall j \neq k, \text{ and } E(\varepsilon_w \varepsilon_w^T | \mathbf{z}) = \mathbf{0} \forall w \neq w'.$$

The motivation for selecting this block-diagonal structure is that it accounts for autocorrelation as well as for common shocks that affect multiple sites contemporaneously. The clustered sample covariance matrix estimator is therefore used for  $\theta$  (Bertrand *et al.* 2004).

#### 4. The Disamenity Function:

##### 4.1 Calculation of Benefits from Reducing Speed due to Reduced Fines from Speeding Tickets

In order to calculate the monetary benefit from reducing speed in terms of the reduced probability to obtain a speeding ticket,  $\Delta d^T$ , we collect data from the following three sources.

- (a) The average annual total number of speeding tickets issued on rural highways in Washington state from 2005-2008 are collected through a public records request to the Washington State Patrol (2011).
- (b) Data on average annual total vehicle miles traveled from 2005 to 2008 on rural highways in Washington State are obtained from the Washington State Department of Transportation (2011)<sup>2</sup>.
- (c) The schedule of speeding ticket fines as a function of the vehicle speed is collected from the Washington Courts (2011) which expresses the fines  $T(k)$  to be traveling at speeds  $k$  to  $k+5$ , given a speed limit of 70 mph.  $k \in \mathbb{K} = \{70, 75, \dots, 100\}$ .

The hourly difference in costs due to a change in speed from  $S|P^1$  to  $S|P^2$  is

$$\Delta d^T = \frac{\sum_{k \in \{\mathbb{K}\}} T(k) \int_k^{k+5} f^1(S) - f^2(S) dS}{\int_{k_{min}}^{\infty} f^1(S) dS} p(T)$$

where  $k$  represents the minimum speed in each 5 mph interval in set  $\mathbb{K}$ ,  $f^i(S)$  is a probability density function of  $S$  given the gasoline price  $P^i$ ,  $i = 1, 2$ , and  $p(T)$  is the probability of receiving a ticket. The numerator, representing the weighted average of fines, is divided by the proportion of drivers eligible to receive speeding tickets.

To calculate  $\Delta d^T$  numerically, we match the average PM time period speed bin data from our speed measuring sites to the schedule of fines  $T(k)$ , creating a weighted average of fines. We initially fit our PM speed histogram to a normal distribution  $f^1(S)$  because we only have speeds in

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<sup>2</sup> Rural highway VMT from 2005-2008 can be found on pp. 48 in 2010 WSDOT Annual Traffic Report (WSDOT 2011).

discrete 5 mph bins. (For robustness we also fit the data assuming a uniform distribution within each speed bin. The different distributional assumption leads to qualitatively similar results and are available from the authors upon request). To calculate the expected number of drivers potentially obtaining a speeding ticket at  $S|P^1 = 70.82$ , we match the area under the normal density  $f^1$  to the appropriate 5 mph fine interval and integrate over the sum over the bins of fines. Secondly we recalculate a new normal distribution  $f^2(S)$  for the lower speeds  $S|P^2 = 70.55$  subtracting 0.27 mph from the normal density mean and calculate the corresponding new weighted average of speeding fines. Finally, to estimate the probability of receiving a speeding ticket per mile traveled  $p(T)$ , we divide the average annual speeding tickets by the average annual vehicle miles traveled.

Finally, an assumption on which drivers receive speeding tickets affects the set  $\mathbb{K}$ . Since the ticketing data provided by WSP are not disaggregated by the 5 mph speed brackets, (neither do the data include total revenues from speeding tickets) we need to make an assumption about which vehicles actually receive tickets. In Table A2, in Scenario 1, we first assume that all drivers going above 70 mph receive tickets, with  $\mathbb{K} = \{70, 75, \dots, 100\}$ . Next we calculate the benefits under the assumption that  $\mathbb{K} = \{75, 80, \dots, 100\}$  hence that only vehicles going above 75 mph will be ticketed. Lastly, in Scenario 3 we assume that  $\mathbb{K} = \{80, 85, \dots, 100\}$ , hence that only vehicles driving above 80 mph obtain speeding tickets. Since the number of tickets is fixed, increasing the speeds at which tickets are issued also increases the weighted average of fines, as displayed in Table A2.

The columns of Tables A2 display the estimates of the weighted average of fines, speeding costs per hour, the differentials for reduced speed, and the contribution to VOT. The rows display the costs based on the original and new distribution of speeds evaluated at  $S|P^1$  and  $S|P^2$ .

TABLE A2. BENEFITS FROM REDUCING SPEEDING TICKET COSTS

|   | Weighted<br>Average of<br>Fines | Cost per Hour<br>from Speeding<br>Tickets | Change in Costs<br>from Reduced<br>Speed | Change in VOT<br>from Reduced<br>Speed |
|---|---------------------------------|---|--|--|
| <u>Scenario 1: Cars Ticketed above 70 mph</u> |                                 |   |  |  |
| High Speed                                    | \$111.22                        | \$0.101                                   |  |  |
| Low Speed                                     | \$108.08                        | \$0.098                                   | \$0.003                                  | \$0.62                                 |
| <u>Scenario 2: Cars Ticketed above 75 mph</u> |                                 |   |  |  |
| High Speed                                    | \$126.39                        | \$0.115                                   |  |  |
| Low Speed                                     | \$120.47                        | \$0.109                                   | \$0.005                                  | \$1.17                                 |
| <u>Scenario 3: Cars Ticketed above 80 mph</u> |                                 |   |  |  |
| High Speed                                    | \$151.29                        | \$0.137                                   |  |  |
| Low Speed                                     | \$140.69                        | \$0.128                                   | \$0.010                                  | \$2.10                                 |

Notes: Cost per hour is the expected cost  $d^T$  based on the probability of obtaining a ticket. Change in VOT expresses the bias to the VOT estimate if the change in the disamenity  $\Delta d^T$  were omitted. ‘High Speed’ and ‘Low Speed’ refer to the speeds of  $S|P^1 = 70.82$  and  $S|P^2 = 70.55$  mph, respectively.

#### 4.2 Calculation of Benefits from Reducing Speed due to Reduced Accidents:

This section describes the data and methodology to calculate  $\Delta d^A = \Delta d^{A,PD} + n (\Delta d^{A,H} + \Delta d^{A,F})$  which monetizes the benefits associated with the decreased risk of accidents at the speed decrease from  $S|P^1=70.82$  to  $S|P^2=70.55$ . To calculate the change in accident rates (accidents per vehicle miles traveled) as a function of speed, the formulas by Cameron and Elvik (2010) and Ashenfelter and Greenstone (2004) require that we first determine a ‘baseline’ accident rate which represents the conditions at our highway sites. All baseline numbers will be superscripted by B.

The benefits from decreased fatalities are calculated by

$$\Delta d^{A,F} = 70.82 \left( \frac{\hat{F}^B(S|P^1) - \hat{F}^{CE}(S|P^2)}{VMT^B} \right) Cost^F \quad (A1)$$

- (a)  $\hat{F}^B(S|P^1)$  is our estimate of the baseline number of fatalities, which we calculate as the average annual number of fatal vehicle crashes under ideal conditions on all U.S. rural highways from 4:00-6:00 PM for the years 2005 to 2008. The data are obtained from the National Highway Traffic Safety Administration’s Fatality Analysis Reporting System

(FARS) (2005-2008)<sup>3</sup>. In our calculations we use the U.S. national fatalities because there are too few fatalities in Washington State alone to obtain a reliable state level estimate of the fatality rate.

- (b)  $\widehat{VMT}^B$  is the estimated number of vehicle miles traveled under the same restrictions used to calculate  $\widehat{F}^B(S|P^1)$ . We calculate  $\widehat{VMT}^B$  as

$$\widehat{VMT}^B = VMT^{R,US} * \Sigma total^{AD,PM} / total$$

whereby (i)  $VMT^{R,US}$  is the average annual vehicle-miles travelled for all rural highways in the U.S. from 2005-2008, which we obtained from the Federal Highway Administration (2005-2008) and (ii)  $\Sigma total^{AD,PM} / total = 0.068$  is the proportion of vehicles passing the double loop detectors under ideal driving conditions as calculated by our conditions A. to D. in the PM timeperiod as a percentage of to the total vehicles passing the loop detectors at any condition from 2005 to 2008.<sup>4</sup>

- (c)  $\widehat{F}^{CE}(S|P^2)$  is the predicted number of accidents conditional on  $S|P^2$ .  $\widehat{F}^{CE}(S|P^2)$  is calculated using the formula in Cameron and Elvik (2010)  $\widehat{F}^{CE}(S|P^2) = \widehat{F}^B(S|P^1) * \left(\frac{S|P^2}{S|P^1}\right)^{\beta^F}$  where  $\beta^F$  is the power parameter for rural highway fatal collisions obtained from column one of Table 8 on p. 1913 of Cameron and Elvik (2010).

- (d)  $\Delta d^{A,H}$  and  $\Delta d^{A,PD}$  are calculated in principle the same way as  $\Delta d^{A,F}$  substituting the appropriate power parameter,  $\beta^H$  and  $\beta^{PD}$  respectively, again using the first column of Table 8 in Cameron and Elvik (2010). The following additional adjustments are necessary. Since we were not able to directly collect  $\widehat{H}^B(S|P^1)$  and  $\widehat{PD}^B(S|P^1)$  we estimate these as,

<sup>3</sup> In the FARS dataset using the crash outcomes from 2005 to 2008 we control for the outcomes (displayed in parenthesis) of the following variables: Atmospheric Conditions (no rain, clear visibility), Construction Zone (no), Crash Hour (4pm-6pm), Day of Week (Monday to Friday), Holiday (no), Number of Travel Lanes (2 and higher), Relation to Junction (non- junction present), Roadway Alignment (Straight), Roadway Function Class (Rural-Principal Arterial-Interstate, Rural-Principal Arterial-Other, Rural-Other), Roadway Profile (Level), Roadway Surface Condition (dry), Route Signing (Interstate, U.S. Highway, State Highway), Speed Limit (60 to 95), and Trafficway Flow (Divided Highway, Median Strip(With Traffic Barrier, One Way Trafficway ). Furthermore, for all variables we also include the outcomes: “blank”, “unknown”, “Other”.

<sup>4</sup> The unconditional aggregate fatality rate  $F^{R,WA} / VMT^{R,WA}$  for Washington State (WA) for all rural (R) highways can be obtained from the 2009 Washington State Collision Data Summary, p.25 produced by Washington State Department of Transportation (2010). Using this published fatality rate is not appropriate however for our baseline fatality rate because our study controls for the most ideal driving conditions analyzing ‘safe’ sites under the best possible weather and driving conditions.

$$\frac{\widehat{H}^B(S|P^1)}{\widehat{VMT}^B} = \frac{H^{R,WA}}{VMT^{R,WA}} * \left( \frac{\widehat{F}^B(S|P^1)}{\frac{VMT^B}{F^{R,WA}}} \right)$$

where  $\frac{H^{R,WA}}{VMT^{R,WA}}$ , and  $\frac{F^{R,WA}}{VMT^{R,WA}}$  are the average annual accident rates of injuries and fatalities on Washington State's rural highways obtained from the Washington State Department of Transportation (2010). The final term,  $\left( \frac{\widehat{F}^B(S|P^1)}{\frac{VMT^B}{F^{R,WA}}} \right)$ , is the proportion of the ideal rural interstate PM fatality rate to the aggregate Washington rural interstate rate. To calculate the baseline property damage rate  $\frac{\widehat{PD}^B(S|P^1)}{\widehat{VMT}^B}$ , we simply replace  $\frac{H^{R,WA}}{VMT^{R,WA}}$  with  $\frac{PD^{R,WA}}{VMT^{R,WA}}$ , also obtained from Washington State Department of Transportation (2010).

- (e)  $Cost^j$  represent the monetary costs per accident type  $j = F, H, PD$ , which we obtain from AASHTO (2010)<sup>5</sup>.
- (f) Finally, the pre-factor of 70.82 of equation (A1) translates the benefits from reduced accidents per mile into the benefits from driving per hour at the baseline speed of 70.82 mph.

Since the  $\Delta d^{A,F}$  is a high proportion of the total cost of  $\Delta d^A$ , for robustness we also use the study by Ashenfelter and Greenstone (2004) to estimate the predicted fatalities at the lower speed as,

$$\widehat{F}^{AG}(S|P^2) = \widehat{F}^B(S|P^1)(1 + .14(S|P^2 - S|P^1))$$

where .14 is the increase in fatalities for every mph increase in speed as determined in Ashenfelter and Greenstone (2004).

As an additional robustness check we employ different estimates for  $Cost^F$ , commonly referred to as Value of Statistical life, from the Department of Transportation (DOT 2009) and Ashenfelter and Greenstone (2004). Throughout all the specifications for VSL the non-fatality costs,  $Cost^{PD}$  and  $Cost^H$ , remain constant as determined by AASHTO (2010).

<sup>5</sup> Estimates for  $Cost^{PD}$ ,  $Cost^H$ , and  $Cost^F$  can be found on pp. 190 in column 3 of table 5-17 of AASHTO (2010).

TABLE A3: TRAFFIC ACCIDENT BENEFITS

*Panel (a) Per Hour Traffic Accident Benefits from Reducing Speed by .27 mph*

|  |                             | Value of Statistical Life Estimate by |         |         |
|--|-----------------------------|---------------------------------------|---------|---------|
|  |                             | DOT                                   | AASHTO  | A&G     |
| Speed-Fatality<br>Parameter<br>Estimate by | Cameron &<br>Elvic          | \$0.007                               | \$0.006 | \$0.004 |
|  | Ashenfelter &<br>Greenstone | \$0.013                               | \$0.011 | \$0.006 |

*Panel (b): Contribution to the VOT in Dollars from Reducing Speed by .27 mph*

|  |                             | Value of Statistical Life Estimate by |        |        |
|--|-----------------------------|---------------------------------------|--------|--------|
|  |                             | DOT                                   | AASHTO | A&G    |
| Speed-Fatality<br>Parameter<br>Estimate by | Cameron &<br>Elvic          | \$1.72                                | \$1.50 | \$1.00 |
|  | Ashenfelter &<br>Greenstone | \$3.33                                | \$2.79 | \$1.58 |

Notes: Panel (a) displays  $\Delta d^A$  in dollars and Panel (b)  $\Delta d^A / [t(S|P^2) - t(S|P^1)]$  in dollars based on various scenarios. In the rows we display the sources of studies we draw the speed-fatality coefficients from and in the columns the sources of the different assumptions on the VSL. The property and injury benefits are derived from AASHTO (2010) and Cameron and Elvik (2010) for all fields. Benefits are calculated as the difference in accident damages over a 70.82 mile trip when an individual drivers speed is reduced from 70.82 mph to 70.55 mph. In 2008 dollars, the VSL is \$5,800,000, \$4,655,771.01 and \$2,065.835.64 for the DOT (2009), AASHTO (2010) and the Ashenfelter and Greenstone (2004) VSL study, respectively.

Table A3 shows the full range of benefits for  $\Delta d^A$  for a 0.27 mph decrease in speed per hour. The columns of Table A3 display how safety benefits change depending on the estimate of the VSL used by the Department of Transportation (DOT 2009), AASHTO (2010) and the VSL estimate by Ashenfelter and Greenstone (2004) (abbreviated by A&G). The rows represent the study from which we obtain the predicted number of fatalities,  $\hat{F}(S|P^2)$ .

#### 4.3 Bias from Omitting the Second Order Effects $d(S)$ in a Dichotomous Choice Setting:

In order to explore the potential bias from omitted elements of  $d(S)$  in discrete choice settings, we set up a simple dichotomous traffic choice model where drivers can circumvent a typically congested main lane by paying a toll on the HOT lane. To fill our example with data, we use the setting of Small *et al.* (2005), where for a 44.8 mile long highway commute on the toll lane of the

California SR-91 in Los Angeles the traffic fee amounts \$3.85<sup>6</sup>. For details we refer to the ‘Brooking revealed preference’ setup in Small *et al.* (2005). We assume VOT to be 50% of the 2008 LA gross wage rate of \$22.88, obtained from the Bureau of Labor Statistics (2008). Because we do not have the individual data on time savings in the Brooking setting, we calculate speed differentials from Bento *et al.* (2011). This study analyzes traffic on HOV and main lanes for different time periods from 2004-2007 on the I-10 in California. Since Small *et al.* (2005) study the morning commute, we get an estimate of the morning rush hour minute per miles by Bento *et al.* (2011, Table 1), which translates into speeds of 46.11 mph and 36.54 mph for the HOV lane and main lane respectively. This translates into time savings of 15.27 minutes for the 44.8 mile long highway commute. In this setting, the procedure for calculating  $\Delta d^A$  is in principle the same as explained earlier in this paper, predicting new fatalities using  $\hat{F}^{CE}(S|P^2)$  and utilizing the VSL from the AASHTO (2010). To calculate the appropriate baseline rate  $\hat{F}^B(S|P^1)$  we query the FARS system for highway crashes in California from 2004-2007 (National Highway Traffic Safety Administration, 2004-2007) and estimate  $\widehat{VMT}^B$  through collecting the annual highway VMT from the California State Department of Transportation Public Road Data reports (2004-2007)<sup>7</sup>. The gas expenditure saving,  $P\Delta g$ , is calculated by using the data of  $g^{West}(S)$  approximated by a quadratic functional form. To calculate the psychological costs of being in a traffic jam,  $\Delta d^{Jam}$ , we assume that  $\Delta d^A(S) = -\Delta d^A(Var(S))$ , so the increased accident cost due to higher speeds in the HOT lane perfectly offset the decrease in accident cost due to reduced congestion. This allows us to back out the bias of  $\Delta d^{Jam}$  as

$$\frac{\Delta d^{Jam}}{t(S|main\ lane) - t(S|toll\ lane)} = VOT - \frac{Toll + P\Delta g}{t(S|main\ lane) - t(S|toll\ lane)}.$$

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<sup>6</sup> The schedule of toll fees is collected from Orange County Transportation Authority (2011). We calculate the average toll of \$3.85 by matching the hourly toll schedule from 4:00am to 9:00am on weekdays to the proportion of drivers in the sample in Small *et al.* (2005) that travel at each hourly interval.

<sup>7</sup> These VMT can be found in Table 1 in all editions of the report under the category State Highway Annual Vehicle Miles Traveled on pp. 4 – 8 depending on the year (California State Department of Transportation 2004-2007).

## 5. References Cited in the Appendix:

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