The Value of Time: Evidence from Auctioned Cab Rides

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Decentralization of Ridehail Platforms

California bill passes to classify Lyft, Uber drivers as employees

The legislation could transform the so-called "gig economy," which is made up of independent contractors.

Sean Szymkowski September 11, 2019 9:28 AM PDT

Drivers have argued for employee benefits in recent years. This week, they won.
James Martin/CNET

12,234 views | Sep 11, 2019, 02:54pm

Despite Sweeping California Gig Worker Law, Uber Says It Won't Treat Drivers As Employees

Robert W. Wood Contributor
Taxes
I focus on taxes and litigation.

***UPDATE**: On September 11, 2019, Uber's top lawyer announced in a news conference that Uber will not treat its drivers, who are independent contractors, as employees under the newly passed California bill. Tony West, Uber chief legal officer, pledged that its drivers will remain independent contractors. Mr. West said Uber's business is not providing rides but "serving as a technology platform for several different types of digital marketplaces." He added that the company was "no stranger to legal battles."*

California's Senate has passed a bill—Assembly Bill 5—that could require Uber, Lyft and gig companies to treat workers as employees. A similar bill was already passed by California's Assembly, so the assumption is that soon the bill will become law. What happens then is anyone's guess. Under the new law, workers in California could generally only be considered

Questions to be answered:

1. **Market Design Questions**
   - What if Uber switched to competition between drivers over rides?
   - What if it de-coupled prices on both sides? Procured rides for c and sold them to passengers for p.
   - Benefits and costs of centralized vs decentralized ride hail markets (e.g., destination based pricing, price discrimination)
2. **How to estimate the Value of Time?**
   - How does it relate to time use and geography?
   - How to map ride choices to location-time-specific opportunity cost of time?
   - How much can the platform gain by engaging in 2nd or 3rd degree price discrimination?

$\Rightarrow$ All of this using Auction Data!

Our Setting: Data from a large European ridehail firm

Taxis

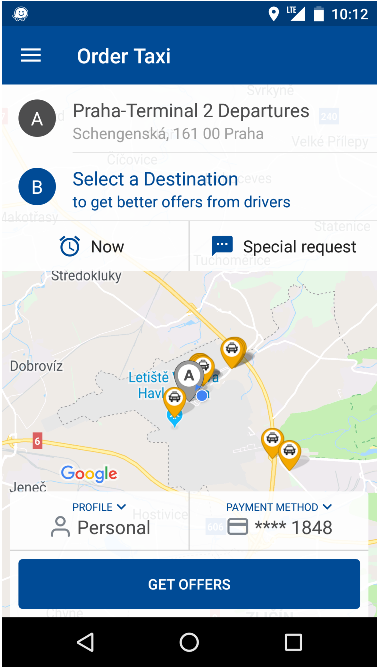
- Typically operate on a fixed price schedule.
- Trips allocated on the basis of waiting/searching.

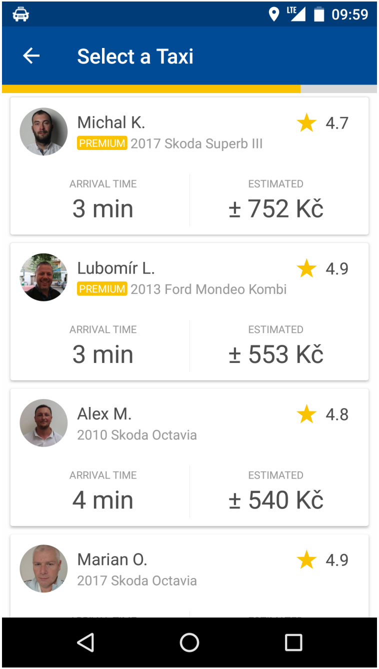
Uber/Lyft

- Employ “surge prices” to equilibrate supply and demand.
- Waiting times relatively stable.

Here: A hybrid between Ridehailing and Taxi

- App-based hailing and matching.
- **Rides auctioned off:** *drivers bid for rides* $\rightarrow$ choice set.
- Choice set $\rightarrow$ consumers select according to time & price preferences.
- Market clears on both <u>waiting time</u> and <u>prices</u>.


10:12
Order Taxi
A
Praha-Terminal 2 Departures
Schengenská, 161 00 Praha
B
Select a Destination
to get better offers from drivers
Now
Special request
Středokluky
Dobrovíz
Letiště
A
Google
Jeneč
PROFILE
Personal
PAYMENT METHOD
**** 1848
GET OFFERS


09:59
Select a Taxi
Michal K.
4.7
PREMIUM
2017 Skoda Superb III
ARRIVAL TIME
3 min
ESTIMATED
± 752 Kč
Lubomír L.
4.9
PREMIUM
2013 Ford Mondeo Kombi
ARRIVAL TIME
3 min
ESTIMATED
± 553 Kč
Alex M.
4.8
2010 Skoda Octavia
ARRIVAL TIME
4 min
ESTIMATED
± 540 Kč
Marian O.
4.9
2017 Skoda Octavia

Data

The universe of trip requests in Prague:

— Everything the platform observes from 9/2016-10/2018.

— 5.6 million bids on 1 million requests and 700k rides.

— prices, waiting times, ratings, car types

— trip time and distance, origin and destination GPS

— **Panel dimension:** Passenger and driver IDs

Auxiliary data:

— Detailed pub. transit/walk alternatives from Google Maps

— Hourly weather

— Prague GIS real estate prices, land use

— Data-linked rider survey (demographics, transport usage patterns etc).

Literature

Value of Time / Transportation

- McFadden 1974; Domencich and McFadden 1975; Small 2012; Duranton and Turner 2011; Heblich et al. 2018; Allen and Arkolakis 2019; Bento et al. 2020; Kreindler 2020; Goldszmidt et al. 2020; Castillo 2021.

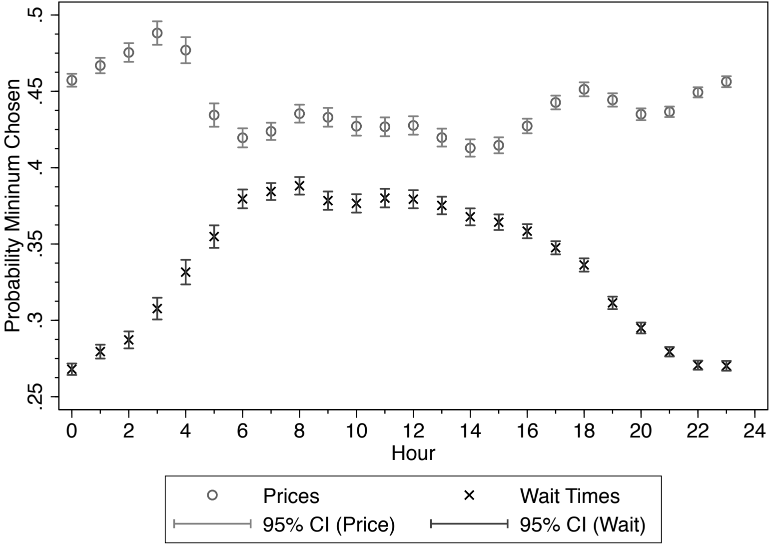
Trade off between market goods and time / flexibility

- Becker 1965; Aguiar and Hurst 2007; Aguiar et al. 2012; Nevo and Wong 2019; Mas and Pallais 2017; Chen at al. 2017.

High Resolution Spatial Data

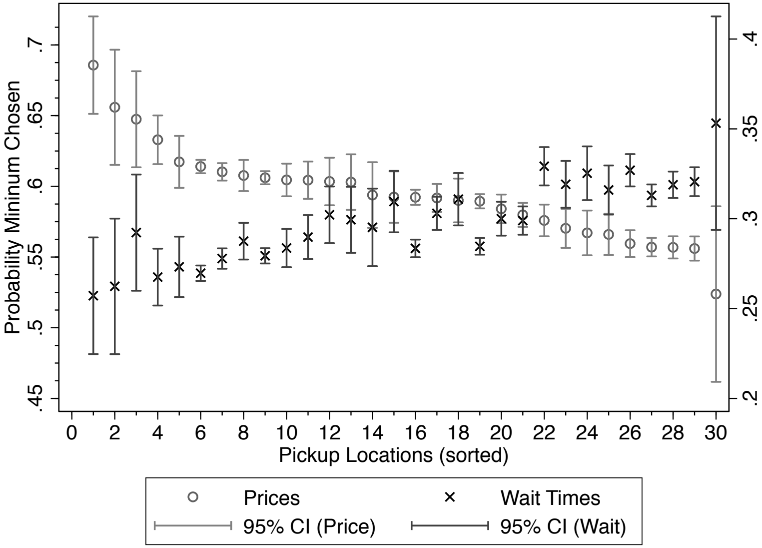
- Athey et al., 2019; Davis et al., 2017; Couture et al., 2019; Kreindler and Miyauchi, 2021; Almagro and Dominguez-Iino 2019; Nakajima, Miyauchi and Redding 2021.

Trade-off Over Time: Choices by Hour

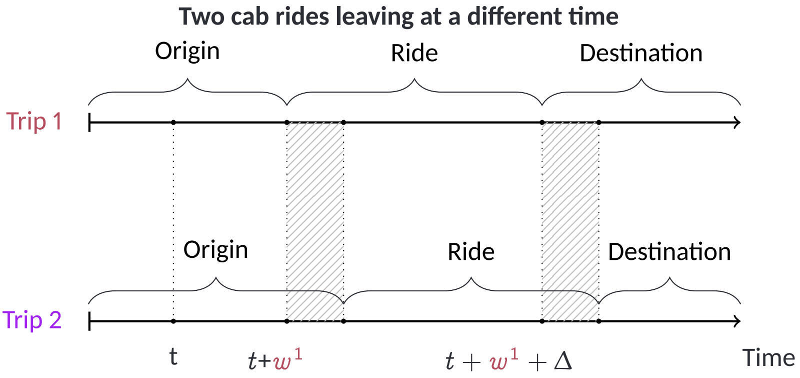


Trade-off Over Space

Figure: Tradeoffs and Choices by Location



Conceptual Framework



- **Trip from O to D** with constant travel time Δ
- Longer wait w^i does not imply *less time* overall, but more at D instead of O

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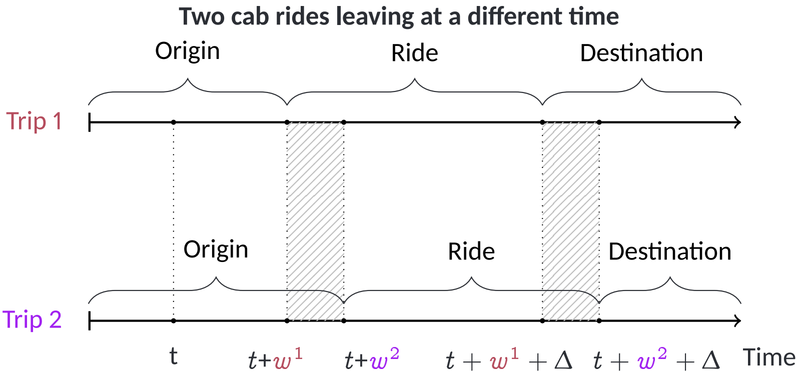

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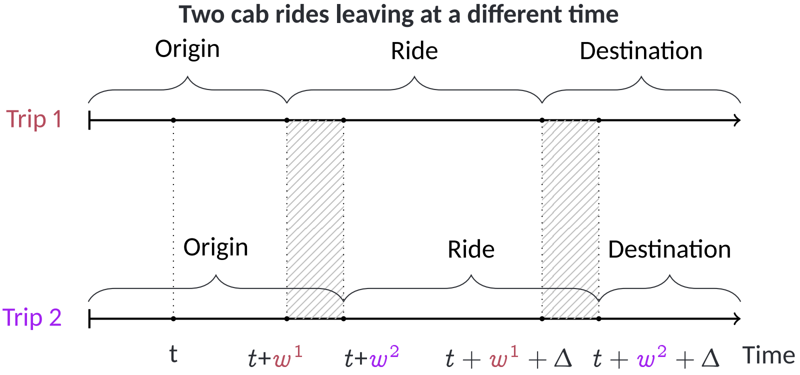
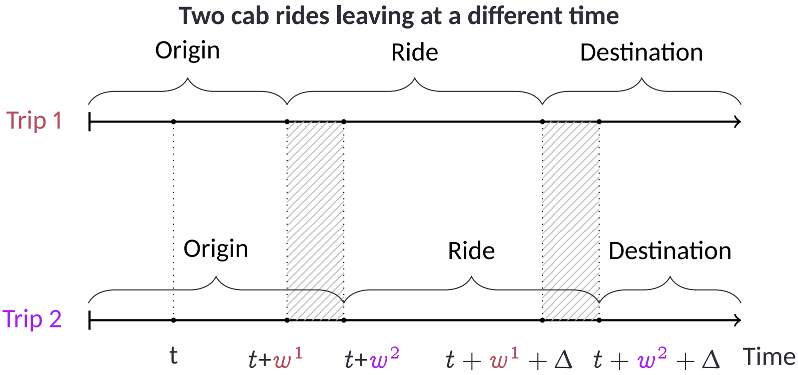


Utility

- Consumers have a value of time in each area of the city, vot
  - Each area has different available activities which generate value
- Utility of spending time t at either the origin, O, or the destination, D

Conceptual Framework



Choices

- In choosing Trip 1, spend $w_2 - w_1$ less at origin, $w_2 - w_1$ more at destination
- i.e., lose $vot^o \cdot (w_2 - w_1)$ and gain $vot^d \cdot (w_2 - w_1)$
- Define *net value of time* as **WTP for one-unit reduction in waiting**

Conceptual Framework: NVOT and VOT

Define the *net value of time*
as **WTP for one-unit reduction in waiting**

$$nvot_{o \to d} = vot^{d} - vot^{o}$$

Values Illustration

Rewrite in terms of destination value

- Note that each location can serve as both origin and destination
- Index locations by $a \in 1, ..., A$

Empirical Strategy:

1. From choices to NVOT

- We observe complete choice sets
- Use variation induced by drivers' locations and bids
- Estimate preferences for time vs. price to recover $nvot_{i,h_t,a,\hat{a}}$ (by person, time-of-day, origin, and destination), exploiting panel structure

2. From NVOT to VOT

- Decompose $nvot_{i,h_t,a,\hat{a}} = vot_{i,h_t,\hat{a}} - \delta_{i,h_t,a} \cdot vot_{i,h_t,a}$
- Can use this relationship to recover the full set of $vot_{i,h_t,a}$

Demand Model and Estimation Strategy

Discrete choice logit (consumer i, choice j, time period t, hours h_t)

$$\max_j u_{i,j,t} = \beta^{w}_{i,h_t,a,\hat{a}} \cdot w_{j,t} + \beta^{p}_{i,h_t} \cdot p_{j,t} + \beta^{\mathbf{x}}_{h_t} \cdot \mathbf{x}_{i,j,t} + \xi_{a,\hat{a},t} + \epsilon_{i,j,t}$$

- $\mathbf{x}$ includes bid-specific factors: car type, rating and common variables: weather, public transit access, place of order (inside/outside), place and time-of-day controls.

Unobservable Trip Attributes:

- $\xi_{a,\hat{a},t}$ captures unobserved shocks to the outside option
- Control function approach: use variation in driver-specific prices
- $nvot_{i,h_t,a,\hat{a}} = \beta^{w}_{i,h_t,a,\hat{a}} / \beta^{p}_{i,h_t}$

Demand Model: Estimation

Exploit panel structure

- Include individual-specific heterogeneity

$$\beta^{w}_{i,h_t,a,\hat{a}} = \beta^{w}_{h_t,a,\hat{a}} + \nu^{w}_{i,h_t}$$
$$\beta^{p}_{i,h_t,a,\hat{a}} = \beta^{p}_{h_t,a,\hat{a}} + \nu^{p}_{i,h_t}$$

- $h_t \in \{work, non-work\}$, i.e., the random coefficients are allowed to vary across day (6a-6p)/night and by route $(a, \hat{a})$.

Estimate via MCMC

- Hierarchical Bayes mixed-logit model
- We recover individual-specific estimates of $\beta^{w}_{i,\text{work}}$, $\beta^{w}_{i,\text{non-work}}$,$\beta^{p}_{i,\text{work}}$, $\beta^{p}_{i,\text{non-work}}$ from stationary Markov chain.

Results: Elasticities

Time of Day	Individual Type	Order-Level Elasticities Price	Order-Level Elasticities Wait Time
Daytime 6am-6pm	Overall	-3.9	-0.89
	H Price, H Wait Sensitivity	-7.36	-1.53
	H Price, L Wait Sensitivity	-2.8	-0.76
	L Price, H Wait Sensitivity	-4.47	-0.96
	L Price, L Wait Sensitivity	-2.06	-0.51
Evening 6pm-6am	Overall	-4.9	-0.49
	H Price, H Wait Sensitivity	-7.48	-0.75
	H Price, L Wait Sensitivity	-3.43	-0.37
	L Price, H Wait Sensitivity	-5.39	-0.52
	L Price, L Wait Sensitivity	-2.63	-0.24

— Consumers are much more **price** than **waiting time** elastic.

— Variation among individual groups: prices 2-4x, waiting 2-3x

— Evening hours: slightly more price elastic, less waiting-time elastic

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Demand Model and Estimation Strategy

1. NVOT

$$nvot_{i,h_t,a,\hat{a}} = \beta^{w}_{i,h_t,a,\hat{a}} / \beta^{p}_{i,h_t}$$

2. From NVOT to VOT

$$nvot_{i,h_t,a,\hat{a}} = vot_{i,h_t,\hat{a}} - \delta_{i,h_t,a} \cdot vot_{i,h_t,a}$$

Identification

— Require **(1)** # locations $\geqslant 3$, **(2)** a single normalization

Estimation

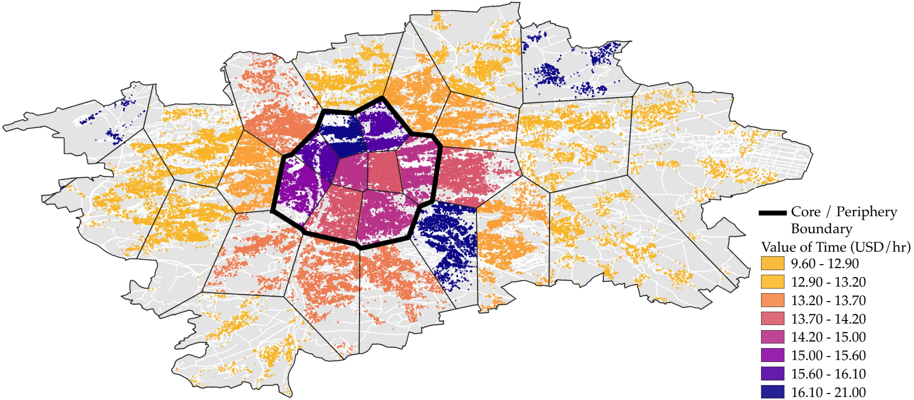
— Linear programming problem, estimate numerically

— Constrain vot to be non-negative

— Normalize $\delta_{i,h_t,a} = 0$ for location 1

VOT Estimation Results

Figure: Map of vot Estimates in Prague



VOT Estimation Results (2)

VOT by Work/Non-Work and Individual Types

	Work Time (USD)		**Non Work Time** (USD)		**Non Work Time** vot /
	Mean	STD	Mean	STD	**Work Time** vot (%)
Location Values (vot_{i,a,h_t})					
All	17.15	10.29	14.02	10.39	0.82
H Price, H Wait Sensitivity	19.18	7.0	15.95	7.05	0.83
H Price, L Wait Sensitivity	9.79	4.82	7.25	6.24	0.74
L Price, H Wait Sensitivity	27.05	12.43	23.45	12.73	0.87
L Price, L Wait Sensitivity	12.66	4.64	9.83	5.85	0.78

- Again we estimate rich heterogeneity in VOT
- 3x difference in VOT among most/least sensitive groups.
- Non-work time valued around 20% less than work time

VOT Estimation Results (3)

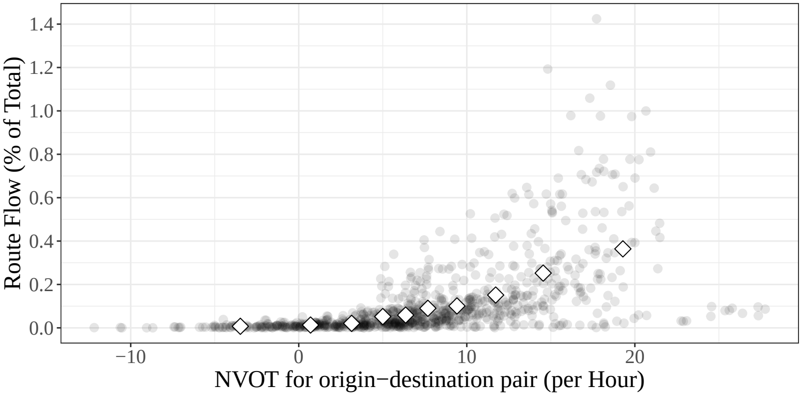
Variance Decomposition

— We perform a decomposition akin to Abowd, Kramerz, Margolis (1999)

— Decompose vot variation into person-, place-, and time-of-day-specific heterogeneity

— 78% of variance due to VOT differences among individuals

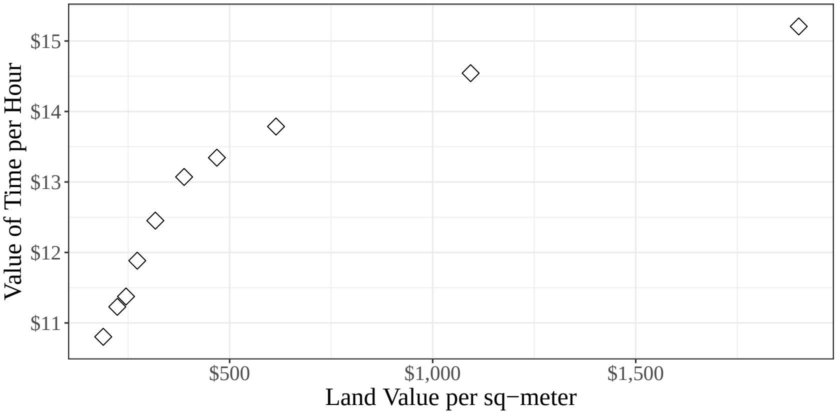
Validation (1): Travel Flows as measure of nvot



- Athey et al., 2019; Kreindler and Miyauchi (2019); Miyauchi et al. (2020)
- This graph shows the scatter (transparent round dots) and binscatter (white diamonds) relationship between the NVOT for an origin-destination pair and the respective traffic shares.

Validation (2): Land Values Values as measure of vot

Figure: vot by Group and Time



Supply Model

Supply Model: Key Ingredients

- **Need to model:**
  - Dynamic decisions by drivers
  - Optimal bidding
- **Main trade-off:**
  - Bidding aggressively for a ride (and hence possibly moving somewhere) versus passing on a passenger and collecting a continuation value instead

Supply Model: Dynamic Problem

Value of being in location a in time t with outside payoff ω:

$$\mathcal{S}^t(a_t, \omega) = \delta(a_t) \cdot \underbrace{\mathbb{E}_{\hat{a},\hat{\tau}}[\mathcal{H}^t(a_t, \hat{a}_{t+\hat{\tau}}, \omega) | a_t]}_{\text{Exp value of getting a ping}} + (1 - \delta(a_t)) \cdot \underbrace{\left[\omega + \mathbb{E}_{\hat{\omega},\hat{a},\hat{\tau}}[\beta^{\hat{\tau}} \cdot \mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega}) | a_t]\right]}_{\text{Collecting continuation value}}$$

Notation:

- $a \in \mathcal{A}$: locations.
- $\delta(a_t)$: probability of receiving a platform request.
- $\omega \sim \mathcal{F}(.|a_t)$: unobserved per-period earnings opportunities.
- τ: time it takes to travel from a to a'.
- Expectations are wrt variables with “hats.”
- $\mathcal{H}^t\left(a_t, a'_{t+\tau}, \omega\right)$: Value of holding a “ping” for a ride to $a'_{t+\tau}$ while also holding outside payoff ω

Supply Model: Dynamic Problem

Value of holding a "ping" for a ride to $a'_{t+\tau}$ while also holding outside payoff ω

$$\begin{aligned}\mathcal{H}^{t}\left(a_t, a'_{t+\tau}, \omega\right) = \max_{b} \Big\{ & p(b|a_t) \cdot \left(b - f + \beta^{\tau} \cdot \mathbb{E}_{\hat{\omega}}\left[\mathcal{S}^{t+\tau}\left(a'_{t+\tau}, \hat{\omega}|a_t\right)\right]\right) \\ & + (1 - p(b|a_t)) \cdot \left(\omega + \mathbb{E}_{\hat{\omega},\hat{a},\hat{\tau}}\left[\beta^{\hat{\tau}} \cdot \mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega})|a_t\right]\right) \Big\}\end{aligned}$$

Notation:

- $p(b|a_t)$: probability that passenger accepts bid b.
- f: fee collected by platform.

Supply Model: Bidding Problem

Let's zoom in on the driver's optimal decision problem:

$$\begin{aligned}\mathcal{H}^t(a_t, a'_{t+\tau}, \omega) = \\ \max_b p(b|a_t) \cdot \Big(b - f + \beta^\tau \cdot \mathbb{E}_{\hat{\omega}}\left[\mathcal{S}^{t+\tau}(a'_{t+\tau}, \hat{\omega})|a_t\right] - \mathbb{E}\left[\beta^{\hat{\tau}} \cdot \mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega})|a_t\right] - \omega\Big) \\ + \omega + \mathbb{E}\left[\beta^{\hat{\tau}} \cdot \mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega})|a_t\right]\end{aligned}$$

Define the opportunity cost as:

$$c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right) \equiv \omega + \mathbb{E}\left[\beta^{\hat{\tau}}\mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega})|a_t\right] - \beta^\tau \cdot \mathbb{E}\left[\mathcal{S}^{t+\tau}(a'_{t+\tau}, \hat{\omega})|a_t\right]$$

Rewrite the bidder's problem as:

$$\max_b p(b) \cdot \left(b - f - c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right)\right)$$

Supply Model

$$\max_{b} p(b) \cdot \left(b - f - c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right)\right)$$

This formulation illustrates that:

— The problem of estimating the value function can be informed by inverting bids in a first price sealed bid procurement auction!

Supply Model

$$\max_b p(b) \cdot \left(b - f - c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right)\right).$$

Proceed in two steps:

1. For identification of $c(\cdot)$ we can appeal to GPV (Guerre, Perrigne, and Vuong (2000)): equilibrium trade-off between $\Pr(win|b)$ and surplus $b - c$. Roughly:

$$c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right) = b - f - \frac{G(b|a_t, a'_{t+\tau}, \omega, t, \tau)}{(N-1)g(b|a_t, a'_{t+\tau}, \omega, t, \tau)}$$

2. The individual pieces of c can be recovered by a projection on a bunch of FE (plus the residual), coupled with the definition of the value functions to identify $\mathbb{E}(\omega|a_t)$ separately.

$$c\left(a_t, a'_{t+\tau}, \omega, t, \tau\right) \equiv \omega + \mathbb{E}\left[\beta^{\hat{\tau}} \mathcal{S}^{t+\hat{\tau}}(\hat{a}_{t+\hat{\tau}}, \hat{\omega})|a_t\right] - \beta^{\tau} \cdot \mathbb{E}\left[\mathcal{S}^{t+\tau}(a'_{t+\tau}, \hat{\omega})|a_t\right]$$

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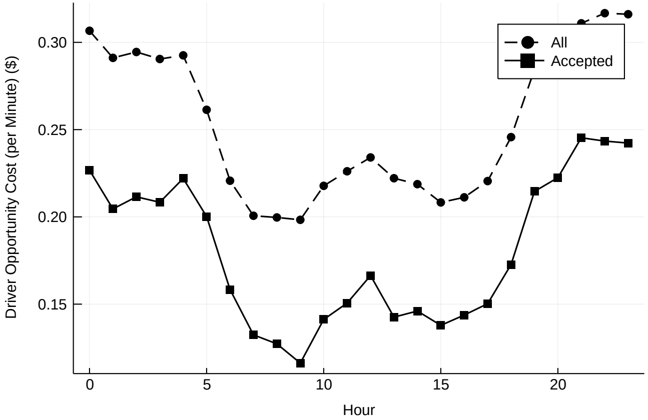
Supply Side Results

Driver Opportunity Cost



- Implies hourly (mean) opportunity cost in [$12,$20] - with lots of time- and place-specific heterogeneity.
- Opportunity cost of “winners” in [$6,$15].

Application: Price Discrimination and Pricing De-coupling

- Now we are ready to split platform's pricing:
  1. Charge prices that are potentially independently set on supply and demand side.
  2. Optimize against the passengers' demand curve leveraging the knowledge of the distribution of the heterogeneity (2nd degree PD).
  3. Procure the drivers in most efficient manner.
- To begin: Shut down spatial re-allocation of drivers due to pricing change.
  - Hold drivers' continuation values the same.
  - Drivers reveal their opportunity cost through the auction as done now.
  - Platform decides which driver to procur and pays him "as if" under the original regime (90% of quoted fare).

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Application: Price Discrimination and Pricing De-coupling

Table: Pricing Counterfactuals

Counterfactual Prices and Revenues (in $)							
Regime	Tariff	Menu	Surcharge	Tot rev/order	Net rev/order	% Inside Good	Mean VOT
Data	-	-	-	5.45	0.55	65.4	13.20
Data	Minimum Bid	-	-	5.14	0.51	62.6	12.85
Regulated	1.84 + 1.29/km	-	-	3.08	0.65	36.3	14.11
Regulated	1.84 + 1.29/km	Fast/Cheap	0.66	3.72	0.82	41.0	15.53/13.27
Monopoly	4.12 + 0.91/km	-	-	3.58	0.79	34.9	13.67
Monopoly	4.12 + 0.96/km	25th/75th	0.51	3.85	0.927	36.3	16.25/10.90
Monopoly	4.12 + 0.95/km	Fast/Cheap	0.48	4.07	0.954	38.9	15.11/12.90

- Menu: Choose closest (subject to surcharge) vs cheapest before seeing the choice set (subject to some “corner” caveats)

Conclusions

Transportation market behavior encodes time values

- New evidence of price and waiting elasticities, WTP for time savings
- Framework to decompose trip demand into spatial-, time-, person-vot, correlated with other spatial economic measures

Value of time is a key input for urban policy

- Can adapt our approach to new and broad settings (Uber, etc.) to guide transportation and infrastructure planning

Significant profits from 2nd degree price discrimination

Application: Time incentives in highway procurement

Time Incentives

- Cities often use time-incentives in road procurement (Bajari and Lewis, 2011)
- Contractors earn higher payments for faster completion (or fines on delays)
  - Each bid specifies project price and time
  - City conducts scoring auction to determine winner
- Scoring auction requires VOT as input

How much does VOT heterogeneity matter?

- We model a hypothetical road closure:
  - Adds three minutes (e.g., 20mph drop for five miles)
- Determine total time costs on each route, different times of day
  - Compare with a uniform average VOT

Application: Time incentives in highway procurement

Cost of a delay

- Costs are a weighted average of expected and unexpected congestion
  - Costs of **expected** congestion: origin vot (or $\delta_{i,h_t,a} \cdot vot_{i,h_t,a}$)
  - Costs of **unexpected** congestion: destination vot
- Assume half of congestion is expected (same as commuter fraction)

Extrapolation from our estimates to Prague drivers

- Take advantage of survey linking rider wages to 9am vot
- Provides scaling factor:
  - Mean Prague wages are $9.15, Mean wage in survey sample is $15.44
- Also scale by average car occupancy rates (1.3)
- Final scaling factor $0.59 \cdot 1.3 = 0.767$.

Application: Time incentives in highway procurement

Estimated Per-Trip Closure Costs by Time of Day

	Time-of-Day							
	3:00am	**6:00am**	**9:00am**	**12:00pm**	**3:00pm**	**6:00pm**	**9:00pm**	**12:00am**
A. Uniform Cost Baseline								
Uniform Price	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30
B. All Routes with Time Variation								
All Routes	$0.31	$0.29	$0.36	$0.36	$0.37	$0.34	$0.27	$0.24
% change	0.02	-0.05	0.17	0.19	0.21	0.12	-0.1	-0.2
All, Volume Weighted	$0.05	$0.06	$0.51	$0.52	$0.54	$0.56	$0.33	$0.12
% change	-0.83	-0.8	0.68	0.71	0.77	0.85	0.08	-0.6
C. Routes by Destination and Time								
Highest-VOT Destination	$0.26	$0.31	$0.42	$0.35	$0.35	$0.39	$0.36	$0.26
% change	-0.13	0.01	0.38	0.16	0.15	0.28	0.19	-0.14
Median-VOT Destination	$0.20	$0.20	$0.26	$0.27	$0.30	$0.32	$0.27	$0.24
% change	-0.35	-0.35	-0.13	-0.12	-0.0	0.07	-0.1	-0.2
Lowest-VOT Destination	$0.07	$0.02	$0.11	$0.08	$0.13	$0.11	$0.13	$0.12
% change	-0.78	-0.93	-0.65	-0.73	-0.58	-0.62	-0.58	-0.59

- Estimate of average cost per-trip of any delay
- Equivalent to $6 per hour (2/3 of mean Prague wage)

Application: Time incentives in highway procurement

Estimated Per-Trip Closure Costs by Time of Day

	Time-of-Day							
	3:00am	**6:00am**	**9:00am**	**12:00pm**	**3:00pm**	**6:00pm**	**9:00pm**	**12:00am**
A. Uniform Cost Baseline								
Uniform Price	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30
B. All Routes with Time Variation								
All Routes	$0.31	$0.29	$0.36	$0.36	$0.37	$0.34	$0.27	$0.24
% change	0.02	-0.05	0.17	0.19	0.21	0.12	-0.1	-0.2
All, Volume Weighted	$0.05	$0.06	$0.51	$0.52	$0.54	$0.56	$0.33	$0.12
% change	-0.83	-0.8	0.68	0.71	0.77	0.85	0.08	-0.6
C. Routes by Destination and Time								
Highest-VOT Destination	$0.26	$0.31	$0.42	$0.35	$0.35	$0.39	$0.36	$0.26
% change	-0.13	0.01	0.38	0.16	0.15	0.28	0.19	-0.14
Median-VOT Destination	$0.20	$0.20	$0.26	$0.27	$0.30	$0.32	$0.27	$0.24
% change	-0.35	-0.35	-0.13	-0.12	-0.0	0.07	-0.1	-0.2
Lowest-VOT Destination	$0.07	$0.02	$0.11	$0.08	$0.13	$0.11	$0.13	$0.12
% change	-0.78	-0.93	-0.65	-0.73	-0.58	-0.62	-0.58	-0.59

- Adds time variation to average VOT
- Pricing errors due to time +/- 20%

Application: Time incentives in highway procurement

Estimated Per-Trip Closure Costs by Time of Day

	Time-of-Day							
	3:00am	**6:00am**	**9:00am**	**12:00pm**	**3:00pm**	**6:00pm**	**9:00pm**	**12:00am**
A. Uniform Cost Baseline								
Uniform Price	\$0.30	\$0.30	\$0.30	\$0.30	\$0.30	\$0.30	\$0.30	\$0.30
B. All Routes with Time Variation								
All Routes	\$0.31	\$0.29	\$0.36	\$0.36	\$0.37	\$0.34	\$0.27	\$0.24
% change	0.02	-0.05	0.17	0.19	0.21	0.12	-0.1	-0.2
All, Volume Weighted	\$0.05	\$0.06	\$0.51	\$0.52	\$0.54	\$0.56	\$0.33	\$0.12
% change	-0.83	-0.8	0.68	0.71	0.77	0.85	0.08	-0.6
C. Routes by Destination and Time								
Highest-VOT Destination	\$0.26	\$0.31	\$0.42	\$0.35	\$0.35	\$0.39	\$0.36	\$0.26
% change	-0.13	0.01	0.38	0.16	0.15	0.28	0.19	-0.14
Median-VOT Destination	\$0.20	\$0.20	\$0.26	\$0.27	\$0.30	\$0.32	\$0.27	\$0.24
% change	-0.35	-0.35	-0.13	-0.12	-0.0	0.07	-0.1	-0.2
Lowest-VOT Destination	\$0.07	\$0.02	\$0.11	\$0.08	\$0.13	\$0.11	\$0.13	\$0.12
% change	-0.78	-0.93	-0.65	-0.73	-0.58	-0.62	-0.58	-0.59

- Adds route/time variation to average VOT
- Pricing errors +40 to -90%

Application: Time incentives in highway procurement

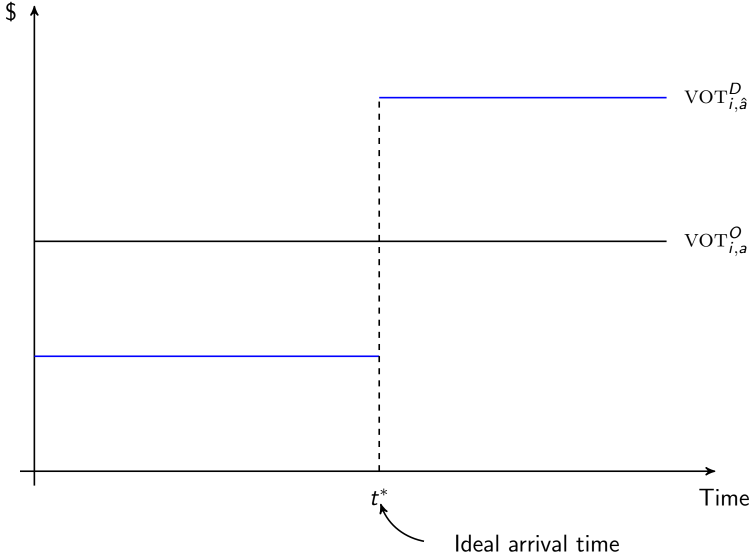
Example: Zlichovsky Tunnel

- 84,000 cars per day (both directions)
- Total delay costs per day: $31,600 to $35,500
- Uniform ($0.30/trip) price: $25,200 per day (-30%)

Example 2: Brusnicky Tunnel

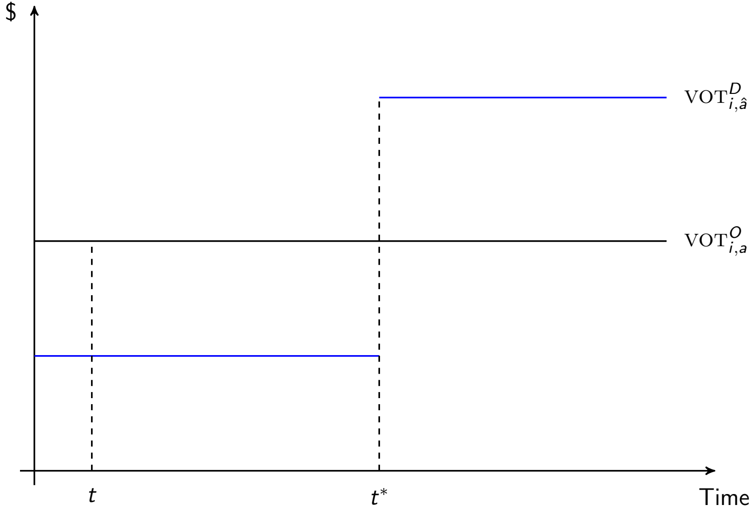
- 77,000 cars per day (both directions)
- Total delay costs per day: $29,600 to $31,800
- Uniform ($0.30/trip) price: $23,100 per day (-27%)

Valuation and WTP Illustration



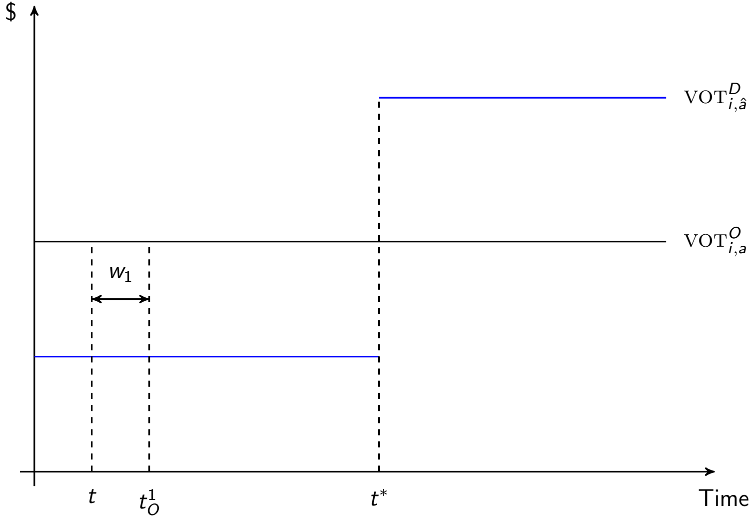
Link to Conceptual Framework

Valuation and WTP Illustration



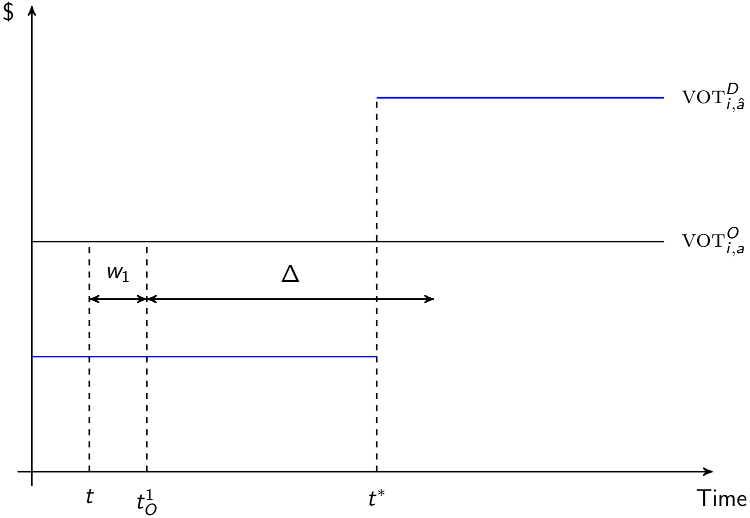
Link to Conceptual Framework

Valuation and WTP Illustration

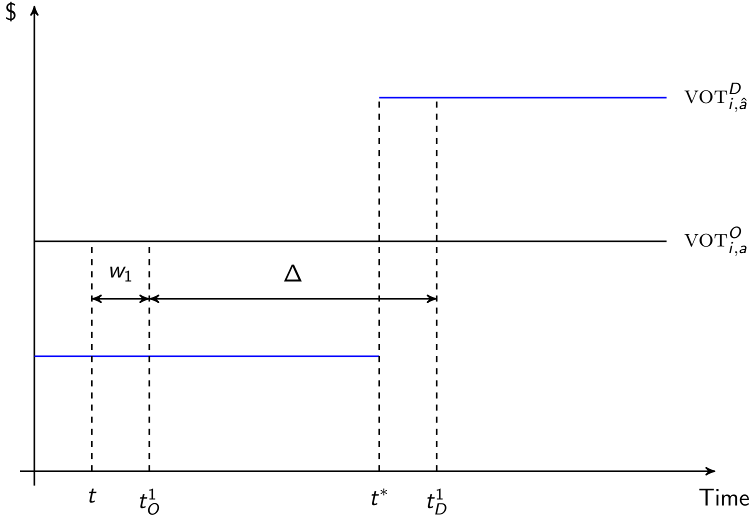


Link to Conceptual Framework

Valuation and WTP Illustration



Valuation and WTP Illustration



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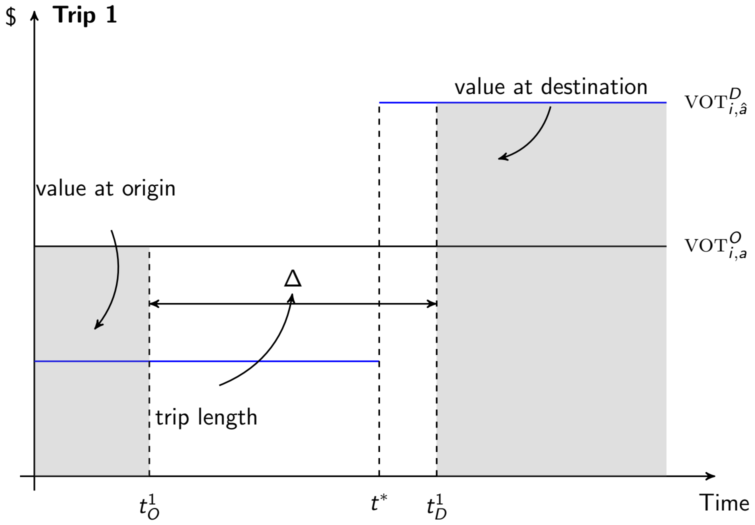

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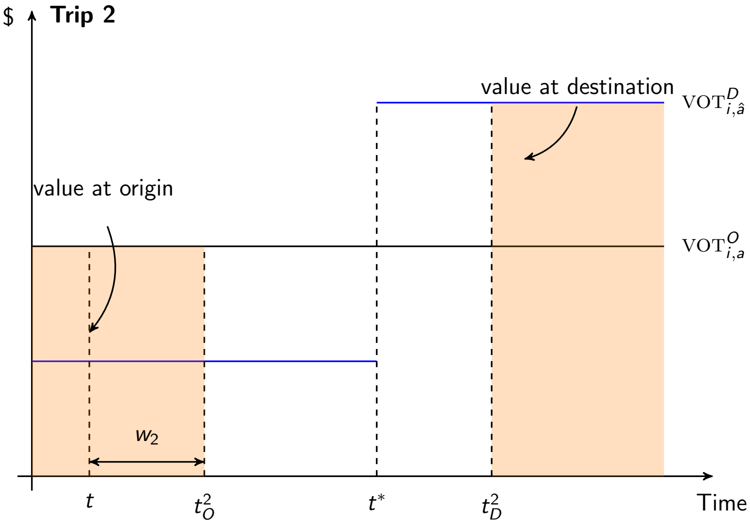

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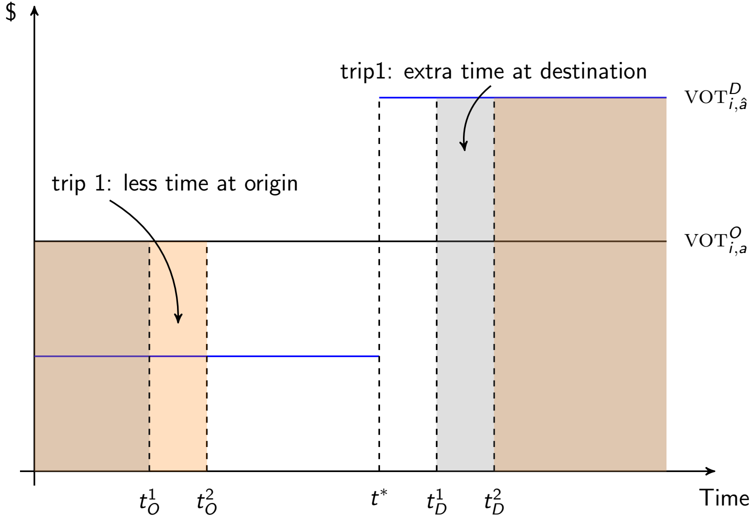
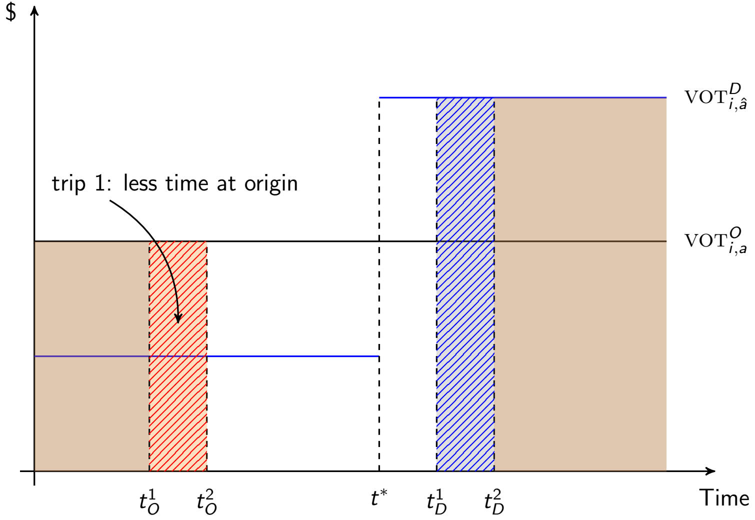


Link to Conceptual Framework

Valuation and WTP Illustration



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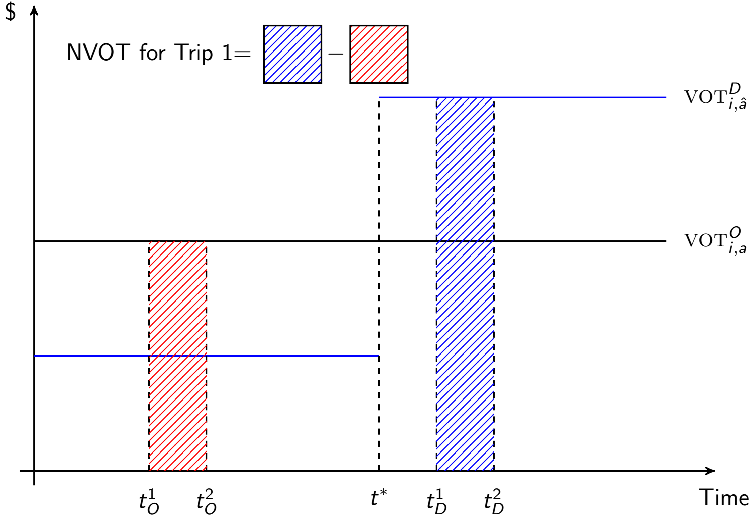

Valuation and WTP Illustration