The Economics of Process Transparency

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Summary

- Process View of a Firm.
  - Firm as a process: Transform inputs to output by resources performing value-adding tasks.
- How transparent should a service firm design its' post-sales process?
  - Share information about the progress of a flow unit in the firm's post-sales process to a consumer while they await completion?
- Belief-Based Utility in Economics.
  - Consumers realize utility from non-instrumental information .
- Sharing information about progress creates greater fluctuations in the consumer's beliefs and more optimistic references about delay.
  1. Hurts consumers who exhibit loss aversion to news.
  2. Can benefits consumers who exhibit loss aversion + diminishing sensitivity to news.

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Agenda

Introduction

Preliminaries

Model

Analysis

Conclusion

Process View of a Firm

- Processes are ubiquitous.
- Consider a service firm, whose operations are organized as a process (sequence of tasks).
- Firm shares information about the progress of a flow unit in the firm's process while the customer awaits completion.

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A Popular Strategy: Process Tracker

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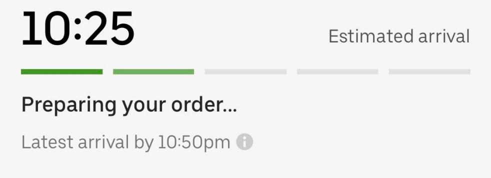
Uber Eats' Order Tracker



Process: Order received $\rightarrow$ Preparing your order $\rightarrow$ Worker Picking up Order $\rightarrow$ Worker on their way to deliver.

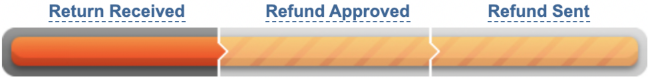
A Popular Strategy: Process Tracker

Domino's Pizza Tracker

Process: Order → Prep → Bake → Box → Deliver.

A Popular Strategy: Process Tracker

IRS' Refund Tracker



We have received your tax return and it is being processed.

If you filed a complete and accurate tax return, your refund should be issued within 21 days of the received date. However, processing may take longer under certain circumstances.

Please check here or use our free mobile app, IRS2Go, to check on your refund status.

Process: Return received $\rightarrow$ Refund approved $\rightarrow$ Refund sent.

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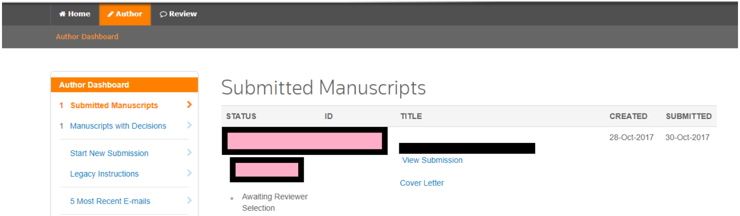
A Popular Strategy: Process Tracker

Journal's Manuscript Review Tracker



Process: Editorial check → Referees' assessment → AE's assessment → DE's decision.

Post-Sales Process Transparency

- Extant literature in service OM: Role of information about delay affects a consumer's decision to participate in trade.
  - Instrumental information.
- Our work: Role of information about delay affects consumer's waiting experience after participation, but before completion of the process.
  - Non-Instrumental information.

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Instrumental vs. Non-Instrumental Information

- Information is either instrumental or non-instrumental.
- Instrumental information: Enables an agent to make better decisions.
  - Example: Information about delay before participating in trade.
- Non-instrumental information: Does not affect an agent's decisions.
  - In fact, no contingent action awaits.
- Our work: First to study non-instrumental information sharing in service processes.

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Belief-Based Utility in Economics

> *intuitive and well-documented that beliefs about future consumption . . . directly affect [current] well-being.*

> *an individual may enjoy looking forward to an upcoming vacation and particularly so if the risk of severe weather conditions became very unlikely; on the other hand, the same individual may worry about a future medical procedure he determined to undertake.*

> *. . . There is also widespread evidence from other fields discussing how anticipation of pain produces psychological-stress reactions.*
>
> — *Dillenberger and Raymond (2018)*

Classic Example in Economics: Weather

- An individual has a vacation upcoming in T days.
- The weather on the day of vacation is random (payoff-relevant random variable).
- Individual checks the weather forecast everyday, uses Bayes' rule to update his prior.
- Individual enjoys looking forward to the vacation if good weather is more likely.
  - Good news $\Rightarrow$ ☺, bad news $\Rightarrow$ ☹.
- Fully resolves uncertainty on the day of the vacation.

Material payoff/utility: Realized on the day of the vacation, $t = T$.
Belief-based/News utility: Realized in the interim, $t \in [T]$.

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Our Work and the Economics Literature: Main Differences

- Payoff-relevant random variable: Delay (length of the horizon).
- Simple passage of time provides information to the consumer about the realized delay.
- Strategies we analyze are commonly observed in real-life service processes.

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Firm's Service Process

- Process comprises of n sequential tasks.
- Duration of each task is i.i.d. with IFR.

$$\begin{aligned} X_i &\sim f(\cdot), F(\cdot), \quad i \in [n] \\ \mathbb{E}[X_i] &= \bar{x}. \end{aligned}$$

- Total delay $D = \sum_{i \in [n]} X_i$.

$$D \sim f^{(n)}(\cdot), F^{(n)}(\cdot).$$

- Firm commits to one of two information disclosure strategies σ that inform the consumer about the progress of the flow unit.
  - Opaque, OP: Firm does not provide any update until the completion of the process.
  - Current Task Identity, CTI: Firm provides an update (truthfully) after the completion of each task.

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Consumer Model

- Consumer is delay-sensitive.

$$\text{Material Payoff/Utility:} \quad u_M = \underbrace{v}_{\text{Value from the process}} - \underbrace{D}_{\text{cost due to delay.}} .$$

- The consumer is a rational Bayesian.

- Any disclosure strategy σ of the firm induces a belief π_t^σ on the delay at any time $t \leqslant D$.

$$\begin{aligned} \pi_t^\sigma &\in \Delta(D), \quad t \in [0, D) \\ \pi_0^\sigma &= f^{(n)}, \quad \pi_D^\sigma = 1 \circ D. \end{aligned}$$

- Consumer's mean belief on D under σ at any time $t \leqslant D$:

$$\overline{D}_t = \mathbb{E}_{D \sim \pi_t^\sigma}[D].$$

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Consumer Model

- Consider $t < D$ and an interval $[t, t+dt)$.

$$\text{Belief-Based (News) Utility:} \quad U_B[t, t+dt) = \mu\left(\underbrace{U_M\Big|_{t+dt} - U_M\Big|_t}_{\text{change in anticipated material payoff}}\right)$$

$$= \mu\left(\underbrace{\overline{D}_t - \overline{D}_{t+dt}}_{\text{decrease in delay}}\right).$$

- Good/Bad news depends on decrease in delay.

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Consumer Model

- $\mu(\cdot)$: Reference-dependent universal gain-loss utility model (Kőszegi and Rabin, 2006).

- Assumptions:
  1. $\mu(\cdot)$ is continuous, strictly increasing, and twice differentiable (except, possibly, at 0).
  2. $\mu(0) = 0$.
  3. Loss aversion (to news): $-\mu(-x) > \mu(x) > 0$ for $x > 0$.
  4. Diminishing Sensitivity (to news): $\mu''(-x) > 0 > \mu''(x)$ for $x > 0$.

- Several papers model loss aversion, but not diminishing sensitivity.

$$\text{(Piecewise-linear model)} \quad \mu(x) = \begin{cases} \rho_P x, & \text{if } x \geqslant 0; \\ \rho_N x, & \text{if } x < 0. \end{cases}$$

where $0 < \rho_P < \rho_N$.

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$$\text{(Piecewise-linear model)} \quad \mu(x) = \begin{cases} \rho_P x, & \text{if } x \geqslant 0; \\ \rho_N x, & \text{if } x < 0. \end{cases}$$

where $0 < \rho_P < \rho_N$.

Consumer Model

- $\mu(\cdot)$: Reference-dependent universal gain-loss utility model (Kőszegi and Rabin, 2006).
- Assumptions:
  1. $\mu(\cdot)$ is continuous, strictly increasing, and twice differentiable (except, possibly, at 0).
  2. $\mu(0) = 0$.
  3. Loss aversion (to news): $-\mu(-x) > \mu(x) > 0$ for $x > 0$.
  4. Diminishing Sensitivity (to news): $\mu''(-x) > 0 > \mu''(x)$ for $x > 0$.
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where $0 < \rho_P < \rho_N$.

Consumer's Total Expected Utility

- Sum of Expected Material and Belief-Based Utiliy

$$U = U_M + U_B \quad = \quad \mathbb{E}_{D\sim\boldsymbol{\pi}_0^{\sigma}}\left[(v - D) + \int_{t=0}^{D} \mu\left(\overline{D}_t - \overline{D}_{t+dt}\right)\right]$$

$$= \quad \underbrace{v - n\bar{x}}_{\text{expected material payoff}} \quad + \underbrace{\mathbb{E}_{D\sim\boldsymbol{\pi}_0^{\sigma}}\left[\int_{0}^{D} \mu\left(\overline{D}_t - \overline{D}_{t+dt}\right)\right]}_{\text{expected belief-based utility under } \sigma}.$$

- The expected material payoff is a constant $\implies$ Suffices to compare the expected belief-based utility under OP and CTI.

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$$
\begin{aligned}
U = U_M + U_B &= \mathbb{E}_{D\sim\boldsymbol{\pi}_0^{\sigma}}\left[(\nu - D) + \int_{t=0}^{D} \mu\left(\overline{D}_t - \overline{D}_{t+dt}\right)\right] \\
&= \underbrace{\nu - n\bar{x}}_{\text{expected material payoff}} + \underbrace{\mathbb{E}_{D\sim\boldsymbol{\pi}_0^{\sigma}}\left[\left[\int_0^{D} \mu\left(\overline{D}_t - \overline{D}_{t+dt}\right)\right]\right]}_{\text{expected belief-based utility under } \boldsymbol{\sigma}}.
\end{aligned}
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- The expected material payoff is a constant $\implies$ Suffices to compare the expected belief-based utility under OP and CTI.

Agenda

Introduction

Preliminaries

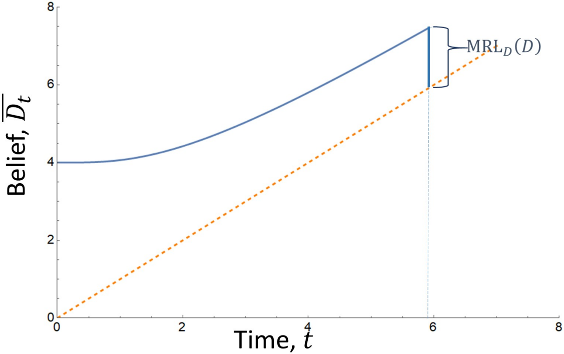
Model

Analysis

Conclusion

Continuous Distributions for Task Durations

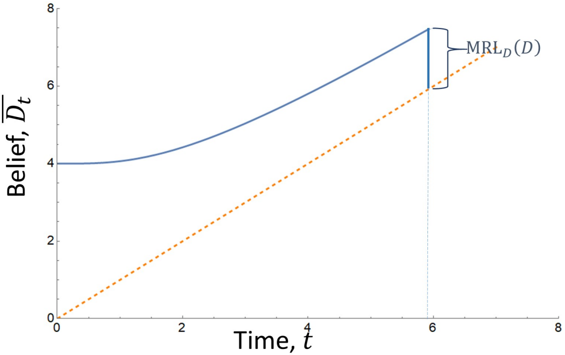
- Under OP:



(mean belief at t) $$\overline{\mathrm{D}}_{\mathrm{t}} = \mathbb{E}_{\mathrm{D}\sim\pi_{\mathrm{t}}^{\mathrm{OP}}} = \begin{cases} \mathrm{t} + \mathrm{MRL_D(t)}, & \text{if } \mathrm{t} < \mathrm{D}; \\ \mathrm{D}, & \text{if } \mathrm{t} = \mathrm{D}. \end{cases}$$

Continuous Distributions for Task Durations

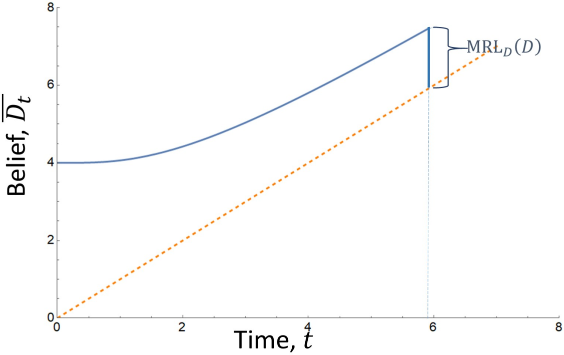
- Under OP:



$$\Longrightarrow \underbrace{n\bar{x} - D}_{\text{total stock of news}} = \underbrace{\int_{t=0}^{D} -(1 + \mathrm{MRL}_D'(t))\,dt}_{\text{flow of bad news in } t \in [0, D)} + \underbrace{\mathrm{MRL}_D(D)}_{\text{lump-sum good news at } t = D}.$$

Continuous Distributions for Task Durations

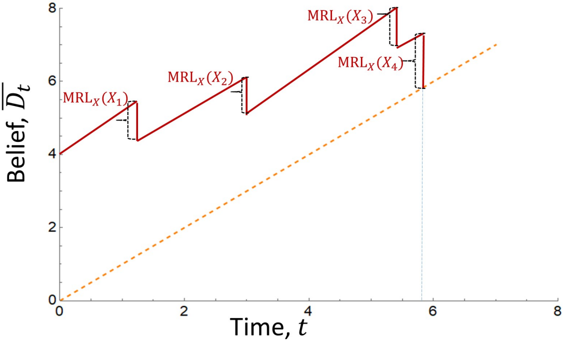
- Under OP:



(expected cancelled news) $y_{(n)} = \mathbb{E}[\mathrm{MRL}_D(D)]$.

Continuous Distributions for Task Durations

- Under CTI:

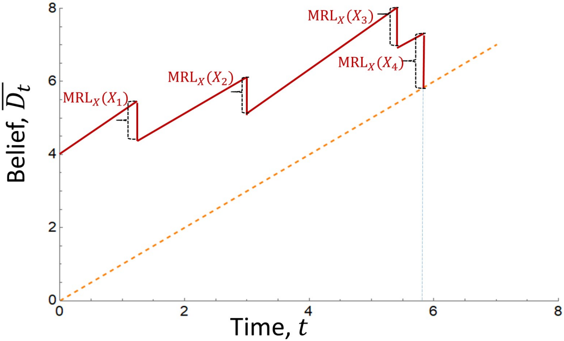


(mean belief at t) $$\overline{D}_t = \mathbb{E}_{D\sim\pi_t^{\mathsf{CTI}}}[D] = t + \mathsf{MRL}_X\left(t - \sum_{j=0}^{i-1} X_j\right) + (n-i)\mathbb{E}[X_i],$$

$$\text{where } \sum_{j=0}^{i-1} X_j \leqslant t < \sum_{j=0}^{i} X_j.$$

Continuous Distributions for Task Durations

- Under CTI:



$$\underbrace{n\bar{x} - D}_{\text{total stock of news}} = \sum_{i=1}^{n} \left[\underbrace{\int_{t=\sum_{j=0}^{i-1} X_j}^{\sum_{j=0}^{i} X_j} - \left(1 + \mathrm{MRL}_X\left(t - \sum_{j=0}^{i-1} X_j\right)\right) dt}_{\text{flow of bad news in } \sum_{j=0}^{i-1} X_j \leqslant t < \sum_{j=0}^{i} X_j} + \underbrace{\mathrm{MRL}_X(X_i)}_{\text{lump-sum good news at } t = X_i} \right].$$

Continuous Distributions for Task Durations

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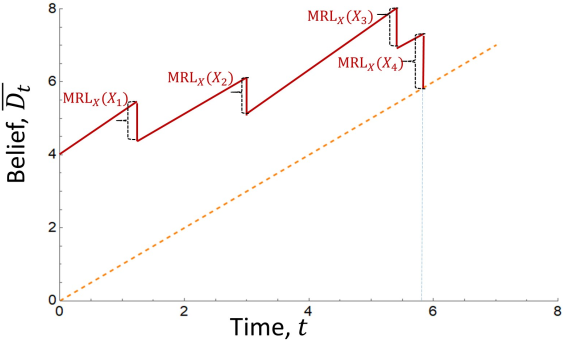

(expected cancelled news) $\quad ny_{(1)} \quad = \quad n\mathbb{E}\left[\mathrm{MRL}_X(X)\right]$

Comparison

- Under piecewise-linear model: U_B is linear in cancelled news.

Theorem

$$\mathrm{OP} \succ \mathrm{CTI} \Leftrightarrow \underbrace{y_{(n)}}_{\textit{cancelled news under } \mathrm{OP}} > \underbrace{n y_{(1)}}_{\textit{cancelled news under } \mathrm{CTI}}.$$

- Above condition is satisfied by many common distributions such as exponential, normal, uniform, etc.

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Discrete Distributions

- Two-point distribution for task-durations.

$$X_i \quad \sim \quad (1-p)\circ x_L + p\circ x_H, \quad 0 < x_L < x_H, 0 < p < 1.$$

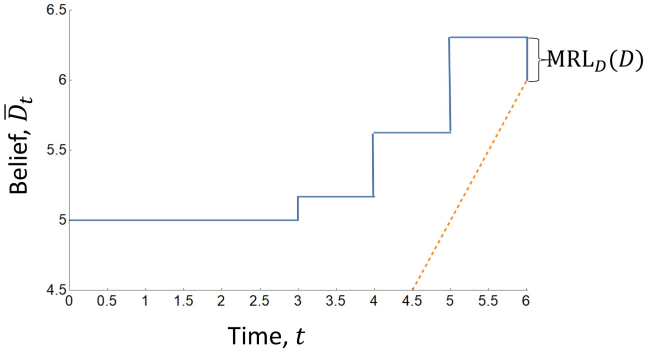
- Delay distribution:

$$D \quad \sim \quad \sum_{i=0}^{n} q_i \circ \left(\underbrace{i x_H + (n-i) x_L}_{=t_i} \right), \quad \text{where } q_i = \binom{n}{i} p^i (1-p)^{n-i}.$$

- $D \in \{t_0, t_1, \ldots, t_n\}$.

Discrete Distributions

- Under OP: Information resolved at $t \in \{t_0, t_1, \ldots, D\}$.



(mean belief at t) $\overline{D}_t = \mathbb{E}[D|D > t_i] = \delta_i = \sum_{j=i+1}^{n} \left(\frac{q_j}{\sum_{j'=i+1}^{n} q_{j'}} (jx_H + (n-j)x_L) \right).$

Discrete Distributions

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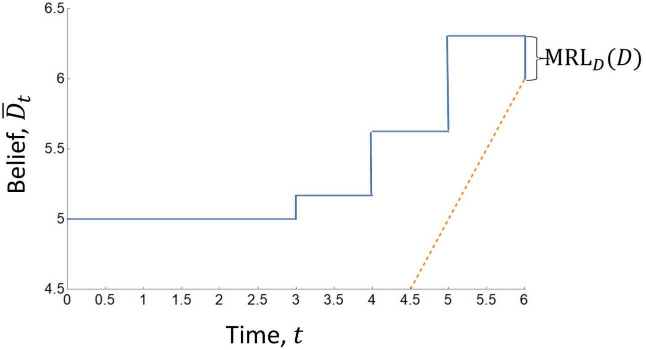

$$\underbrace{n\bar{x} - D}_{\text{stock of news}} = \underbrace{(n\bar{x} - \delta_0)}_{\text{bad news at } t_0} + \underbrace{(\delta_0 - \delta_1)}_{\text{bad news at } t_1} + \underbrace{\ldots}_{\text{bad news at } \ldots} + \underbrace{(\delta_{i^*-2} - \delta_{i^*-1})}_{\text{bad news at } t_{i^*-1}} + \underbrace{(\delta_{i^*-1} - D)}_{\text{good news at } t = D}.$$

Discrete Distributions

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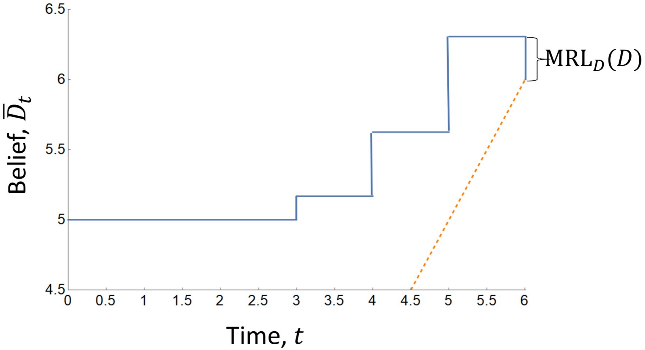
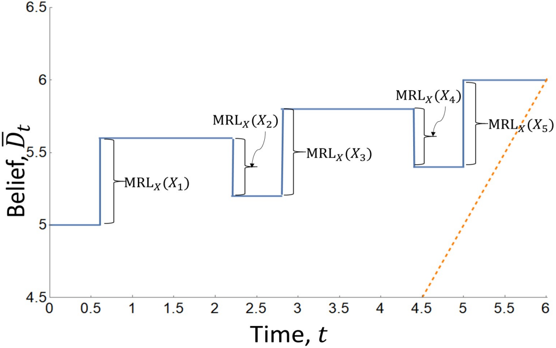


(cancelled news) $\quad y_{(n)} = \mathbb{E}[\mathrm{MRL}_D(D)].$

Discrete Distributions

- Under CTI: Information resolved at $t \in \{x_L, X_1 + x_L, \ldots, \sum_{i=1}^{n-1} X_i + x_L\}$.



$$\underbrace{n\bar{x} - D}_{\text{stock of news}} = \underbrace{(\bar{x} - X_1)}_{\text{news at } t = x_L} + \underbrace{(\bar{x} - X_2)}_{\text{news at } t = X_1 + x_L} + \ldots + \underbrace{(\bar{x} - X_n)}_{\text{news at } t = \sum_{i=1}^{n-1} X_i + x_L}.$$

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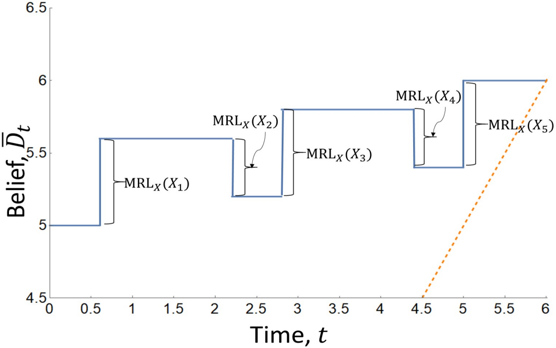

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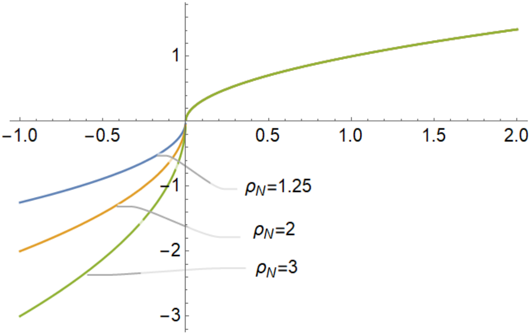
Diminishing Sensitivity to News

- Results thus far: Under many common distributions, OP $\succ$ CTI.
- Diminishing sensitivity to news:

$$\mu(x) = \begin{cases} \sqrt[\alpha]{x}, & \text{if } x \geqslant 0 ; \\ -\rho_N \sqrt[\alpha]{-x}, & \text{if } x < 0. \end{cases}$$

  where $\rho_N > 1$, $\alpha > 1$.
- ρ_N is degree of loss-aversion to news.
- α is degree of diminishing sensitivity to news.

Diminishing Sensitivity to News

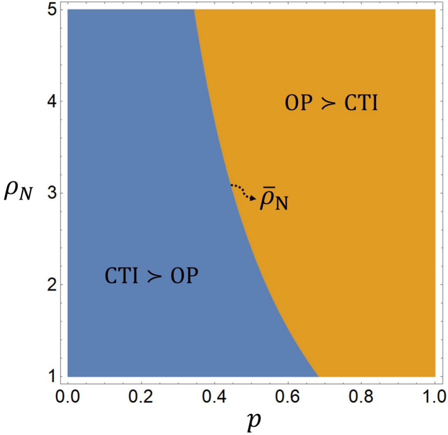


$$\mu(x) = \begin{cases} \sqrt[\alpha]{x}, & \text{if } x \geqslant 0 \text{ ;} \\ -\rho_N \sqrt[\alpha]{-x}, & \text{if } x < 0. \end{cases}$$

Comparison: Two-task process, $\alpha = 2$

Theorem

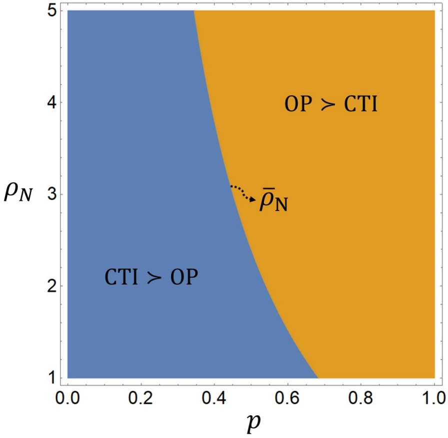
$$\text{CTI} \succ \text{OP} \quad \Leftrightarrow \quad \rho_N < \bar{\rho}_N.$$



Comparison: Two-task process, $\alpha = 2$

Theorem

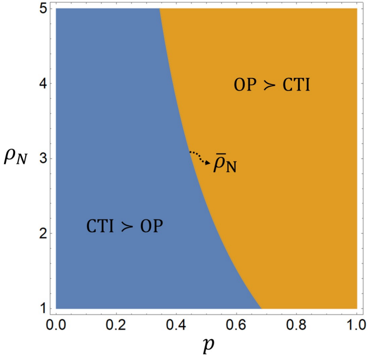
$$\overline{\rho}_N \downarrow \textit{ in } p.$$



Comparison: Two-task process, $\alpha = 2$

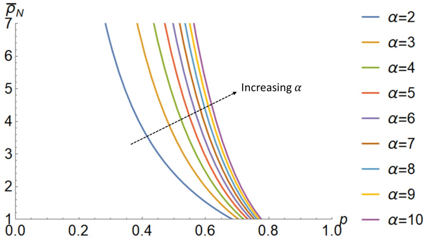
Intuition:

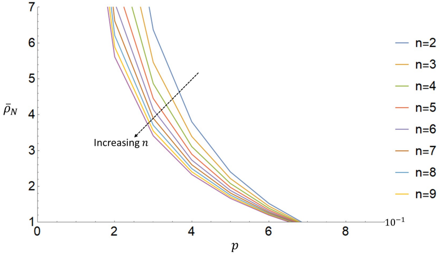
- p is high $\implies$ higher delay (bad news) is more likely $\implies$ better to not break bad news into multiple pieces $\implies$ CTI $\prec$ OP.
- p is low $\implies$ low delay (good news) is more likely $\implies$ better to break good news into multiple pieces $\implies$ CTI $\succ$ OP.



Robustness: Higher α, Higher n

$$\text{CTI} \succ \text{OP} \Leftrightarrow \rho_N < \overline{\rho}_N.$$





$\overline{\rho}_N \uparrow$ in α

Value of providing updates $\uparrow$ in α

$\overline{\rho}_N \downarrow$ in n

Value of providing updates $\downarrow$ in n

Agenda

Concluding Remarks

- Service firms often use process trackers to share information about progress of a consumer's flow unit while they await completion.

- Non-instrumental information affects consumer's waiting experience.

- Sharing progress updates (CTI) $\Longrightarrow$ greater fluctuations in the consumer's beliefs and more optimistic references about delay.

- Roles of loss aversion and diminishing sensitivity to news.
  - Different predictions!

- Our work sheds light on managing customers' post-sales waiting experience in service processes.

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Thank You.

New version of the paper will be posted on `harishguda.me/research` soon!

Dillenberger, David and Collin Raymond, "Additive-Belief-Based Preferences," 2018.

Kőszegi, Botond and Matthew Rabin, "A model of reference-dependent preferences," *The Quarterly Journal of Economics*, 2006, *121* (4), 1133–1165.