The Economics of Process Transparency

(Forthcoming, *Production & Operations Management*)

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Agenda

Introduction

Digression: Belief-Based Utility

Model

Analysis

Conclusion

Process View of a Firm

Processes are ubiquitous.

- A collection of value-adding tasks, performed by resources, that transform inputs to outputs.
- Go-to example: Operations at a pizza store.

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Service firm whose operations are organized as a process.

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How should the service firm inform the consumer about the progress of their flow unit in the firm's process while they await completion.

- How transparent should the firm design its post-sales process?

A Popular Strategy: Process Tracker

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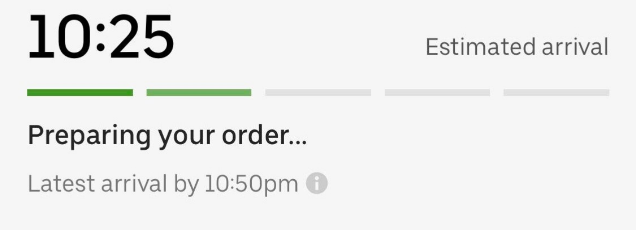
Domino's Pizza Tracker

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

A Popular Strategy: Process Tracker

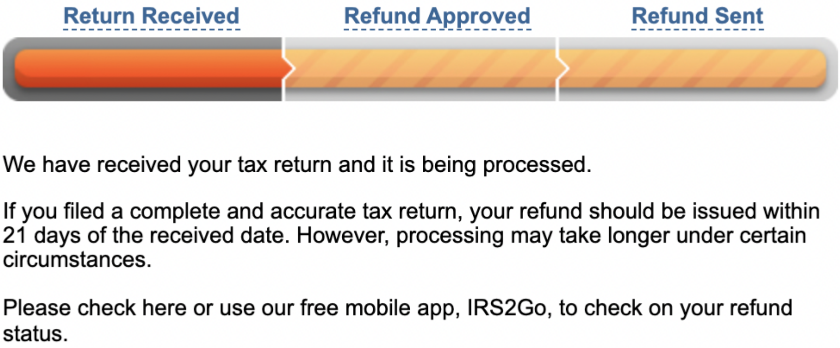
Uber Eats' Order Tracker



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

A Popular Strategy: Process Tracker

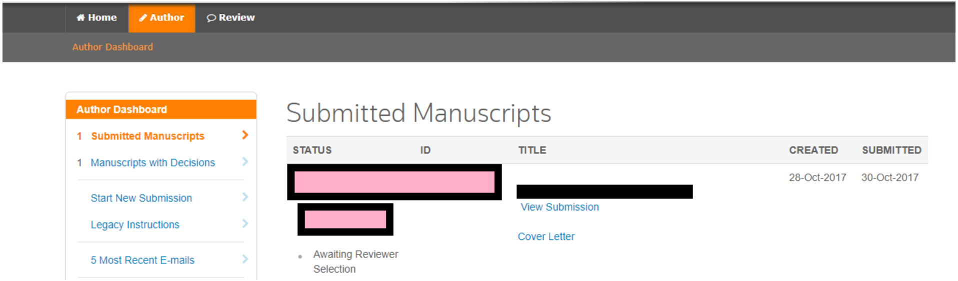
IRS' Refund Tracker



Process: Return received → Refund approved → Refund sent.

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: Sharing Progress Information (+)

Firms strive to provide as much information as possible.

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> *"After I order, it's a black hole until I get my food at my door".*
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> *— Uber Eats' customer before the launch of the in-app order progress bar.*

> *"In the case of food delivery, people intuitively understand the difficulties that arise when you're trying to get hot food from a restaurant in the real world and drive it from point* $\mathfrak{a}$ *to* $\mathfrak{b}$*. . . .*
>
> *By acknowledging some of that complexity, and being transparent about it, we can increase people's confidence a lot".*
>
> *— Andy Szybalski, Global Head of Product Design at Uber Eats.*

Post-Sales Process Transparency: Sharing Progress Information (-)

Sharing information $\Longrightarrow$ Expectations about anticipated delay $\Longrightarrow$ Hurt customer satisfaction if expectations are unmet.

> *"I was fine with the way pizza used to work, where they'd say it'd show up in 45 minutes, and it would take an hour."*
>
> *— Domino's pizza customer about the company's real-time pizza tracker (The Wall Street Journal, 2017).*

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- Information about delay $\Rightarrow$ Consumer's decision to participate in trade.

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Our work: Non-Instrumental Information.

- Information about delay $\Rightarrow$ Consumer's waiting experience after participation, but before completion of the process.

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How does non-instrumental information affect an agent?

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 (2020)*

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- Good news $\Rightarrow$ ☺. Bad news $\Rightarrow$ ☹.

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- Good news ⇒ ☺. Bad news ⇒ ☹.

Fully resolves uncertainty on the day of the vacation.

Material Utility vs. Belief-Based Utility

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- Depends on “which” state is realized.

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Belief-Based Utility ("News" Utility)

- Realized in the interim, $0 < t \leqslant T$.
- Depends on "how" uncertainty is resolved.

Our Work and the Economics Literature: Main Differences

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Strategies we analyze are commonly observed in real-world service processes.

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

$$D \sim f^{(n)}(\cdot), F^{(n)}(\cdot), \text{ with support } \mathcal{D}.$$

Consumer Model

Consumer is delay-sensitive.

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A progress disclosure strategy σ and the prior $f^{(n)}$ induces a stochastic path of beliefs on D.

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

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

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

Consumer Model

Consider $t < D$ and an interval $[t, t + dt)$ under strategy σ.

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

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Good/Bad news depends on decrease/increase in anticipated delay.

Consumer Model

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

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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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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 $0 < \rho_P < \rho_N$.

Consumer's Total Utility

Sum of Expected Material and Belief-Based Utiliy

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

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$$= \underbrace{v - n\bar{x}}_{\text{expected material payoff}} + \underbrace{\mathbb{E}\left[\int_0^D \mu\left(\overline{D}_t - \overline{D}_{t+dt}\right)\right]}_{\text{expected belief-based utility under } \boldsymbol{\sigma}} .$$

The expected material payoff is a constant $\Longrightarrow$ Suffices to compare the expected belief-based utility.

Firm's Strategy

Firm commits to one of two progress disclosure strategies to 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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Firm maximizes consumer's total expected utility.

$$\max_{\sigma \in \{OP, CTI\}} U^{\sigma}.$$

- No incentive misalignment between firm and consumer.

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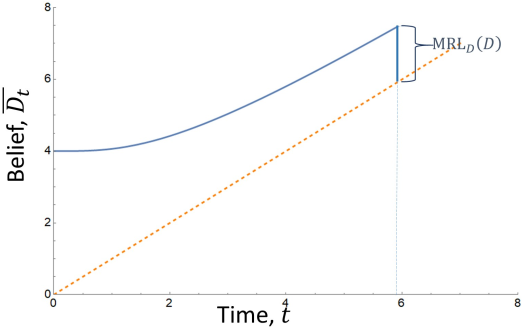
Continuous Distributions for Task Durations

Under OP:



(mean belief at t) $\overline{D}_t^{OP} = \mathbb{E}_{D \sim \pi_t^{OP}}[D] = \begin{cases} t + \mathrm{MRL}_D(t), & \text{if } t < D; \\ D, & \text{if } t = D. \end{cases}$

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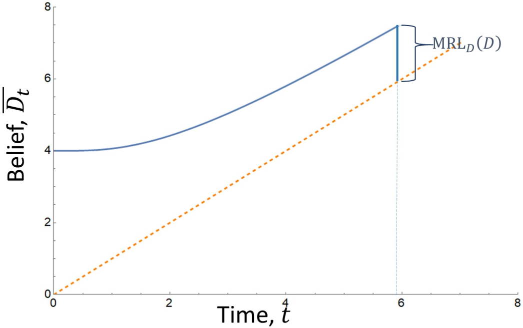

$$\Longrightarrow \underbrace{n\bar{x} - D}_{\text{total stock of news}} = \underbrace{\int_{t=0}^{D} -(1 + \mathrm{MRL}_D'(t))\,dt}_{\text{flow of bad news in } t \in [0, D)} + \underbrace{\mathrm{MRL}_D(D)}_{\text{lump-sum good news at } t = D} .$$

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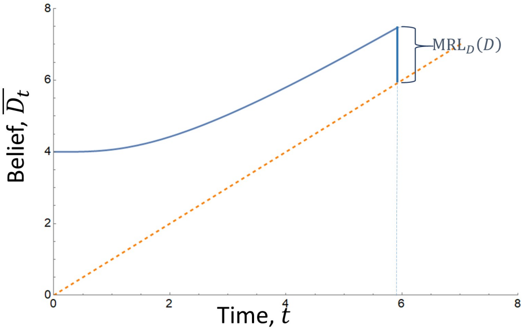
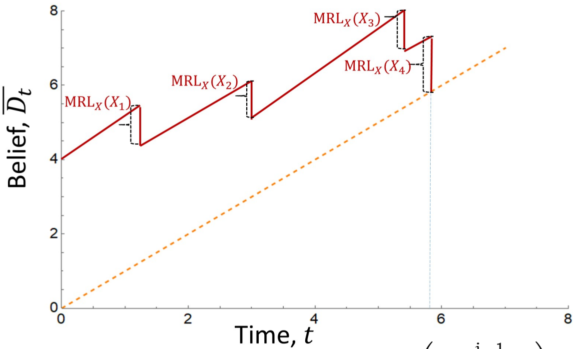


(expected cancelled news) $y_{(n)} = \mathbb{E}[\mathrm{MRL}_D(D)]$.

Continuous Distributions for Task Durations

Under CTI:



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

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

Continuous Distributions for Task Durations

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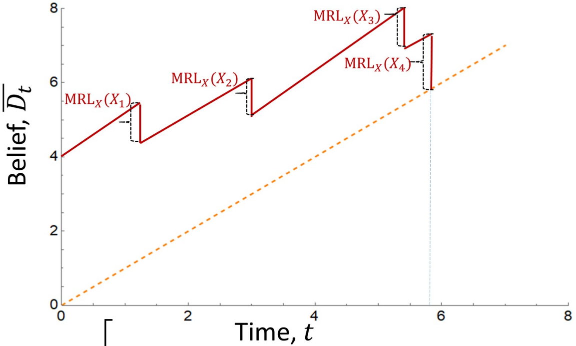

$$\underbrace{n\bar{x} - D}_{\text{total stock of news}} = \sum_{i=1}^{n}\left[\underbrace{\int_{t=\sum_{j=0}^{i-1}X_j}^{\sum_{j=0}^{i}X_j} -\left(1+\mathrm{MRL}_X\left(t-\sum_{j=0}^{i-1}X_j\right)\right)dt}_{\text{flow of bad news in } \sum_{j=0}^{i-1}X_j \leqslant t < \sum_{j=0}^{i}X_j} + \underbrace{\mathrm{MRL}_X(X_i)}_{\text{lump-sum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

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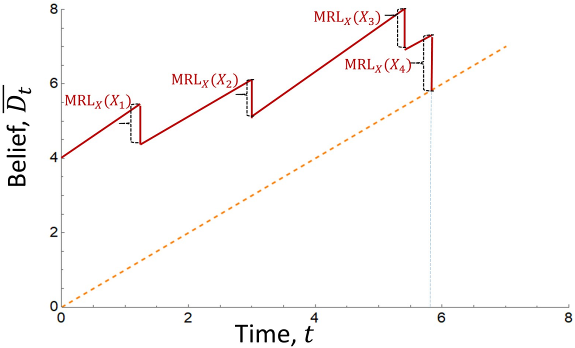

(expected cancelled news) $\quad ny_{(1)} \quad = \quad n\mathbb{E}\left[\mathrm{MRL}_X(X)\right]$

Comparison Under Loss Aversion

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

- Loss aversion = Belief fluctuation aversion.

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Theorem

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

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

Discrete Distributions

Two-point distribution for task-durations.

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

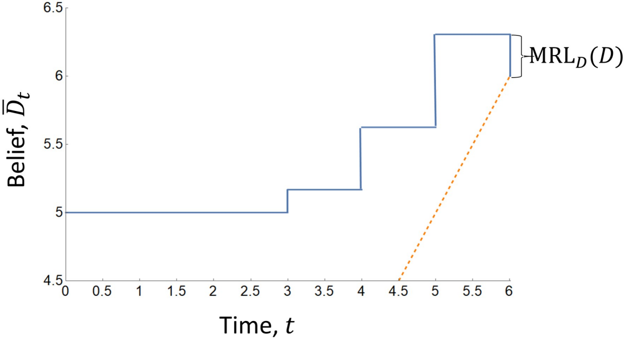
Delay distribution:

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

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

Discrete Distributions

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



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

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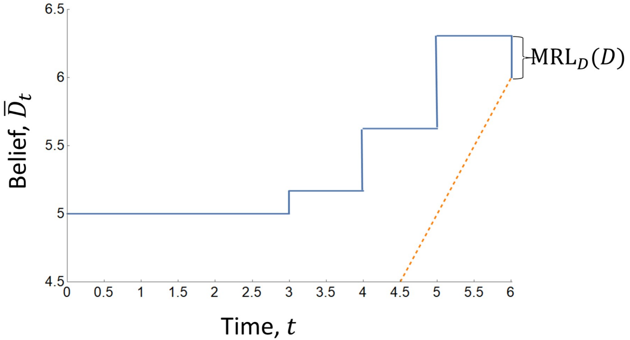

$$\underbrace{n\bar{x} - D}_{\text{stock of news}} = \underbrace{(n\bar{x} - \delta_0)}_{\text{bad news at } t_0} + \underbrace{(\delta_0 - \delta_1)}_{\text{bad news at } t_1} + \underbrace{\ldots}_{\text{bad news at } \ldots} + \underbrace{(\delta_{i^*-2} - \delta_{i^*-1})}_{\text{bad news at } t_{i^*-1}}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

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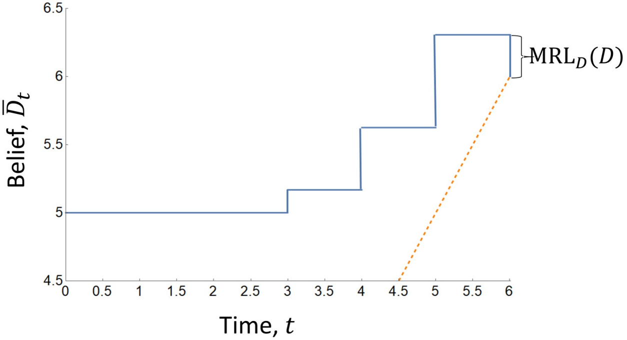

(cancelled news) $y_{(n)} = \mathbb{E}[MRL_D(D)]$.

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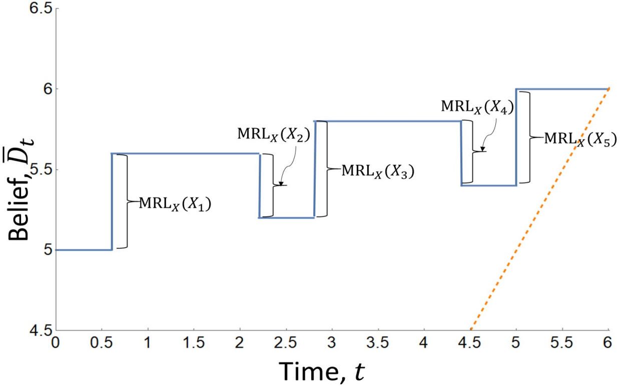
Under CTI: Information resolved at $t \in \{x_L, X_1 + x_L, \ldots, \sum_{i=1}^{n-1} X_i + x_L\}$.



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

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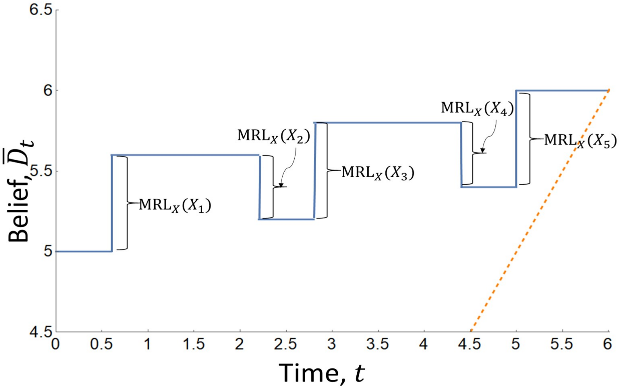

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Above condition satisfied for any two-point distribution for X_i.

Diminishing Sensitivity to News

Results thus far: Under many common distributions, OP $\succ$ CTI.

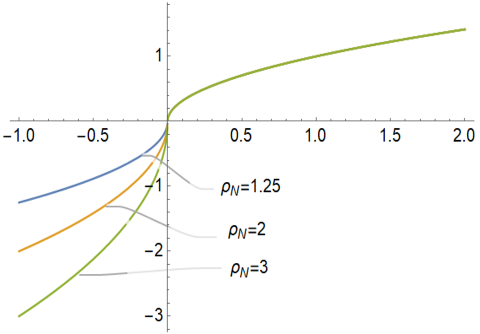
Diminishing sensitivity to news:

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

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



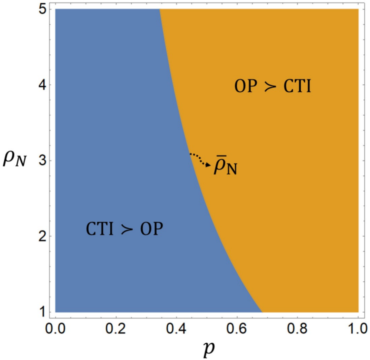
$$\mu(x) = \begin{cases} \sqrt[\alpha]{x}, & \text{if } x \geqslant 0\ ; \\ -\rho_N \sqrt[\alpha]{-x}, & \text{if } x < 0. \end{cases}$$

Interpretation: Greater psychological impact if a piece of news is shared via multiple congruent pieces.

Comparison: Two-task process, Two-point distribution for Task Duration, $\alpha = 2$

Theorem

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



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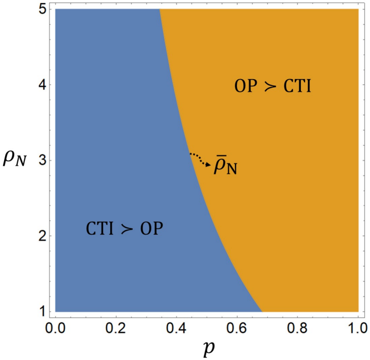
$$\bar{\rho}_N \downarrow \ \textit{in}\ p.$$



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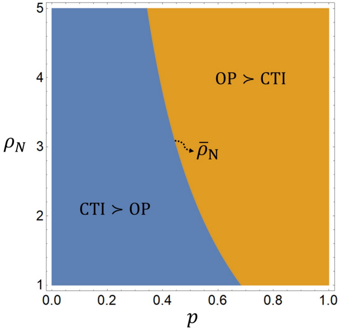
Comparison: Two-task process, Two-point distribution for Task Duration, $\alpha = 2$

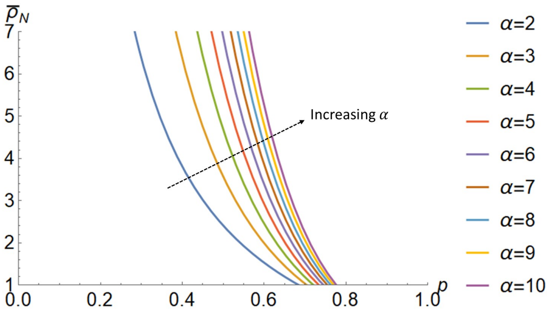
Intuition:

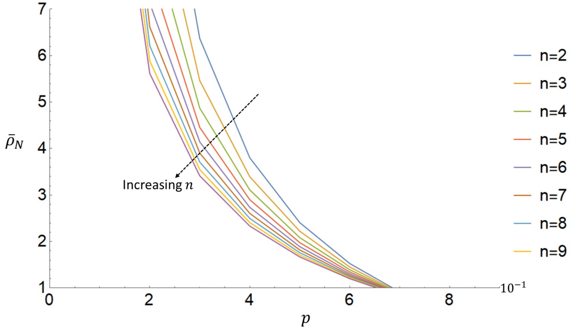
- p is high $\implies$ higher delay (bad news) is more likely $\implies$ better to not break bad news into multiple pieces $\implies$ CTI $\prec$ OP.
- p is low $\implies$ low delay (good news) is more likely $\implies$ better to break good news into multiple pieces $\implies$ CTI $\succ$ OP.



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

Implications

The likelihood of good/bad news depends on the skewness in the distributions of task durations.

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- Right-skewed distributions $\implies$ Good news is more likely $\implies$ CTI $\succ$ OP.
  - "Efficient" processes: Less prone to delay shocks.
- Left-skewed distributions $\implies$ Bad news is more likely $\implies$ OP $\succ$ CTI.
  - "Lousy" processes: Prone to frequent disruptions.

Exention: Independent, Non-Identical Distributions for Task Durations

Results extend in a straightforward manner to independent, non-identical distributions for task durations.

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Processes where managers have discretion over the sequence on which tasks are performed.

- The sequence of tasks does not affect the comparison of OP and CTI.

Agenda

Introduction

Digression: Belief-Based Utility

Model

Analysis

Conclusion

Concluding Remarks

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

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- Different predictions!

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Managing customers' post-sales waiting experience in service processes.

Belief-Based Utility: Closest Papers

- Suspense and Surprise (Ely et al., 2015).
- Dynamic Information Design with Diminishing Sensitivity over News (Duraj and He, 2019).
- Wait-Time Information Design (Debo et al., 2023).
- Operational Transparency: Showing When Work Gets Done (Bray, 2020).
- (Comment) The Renaissance of Belief-Based Utility in Economics (Loewenstein and Molnar, 2018).

Thank You.

Paper, Slides, and a Non-Technical Summary available at harishguda.me/research.

Bray, Robert L, "Operational transparency: Showing when work gets done," *Manufacturing & Service Operations Management*, 2020.

Debo, Laurens, Robert A Shumsky, Sina Ansari, Seyed Iravani, and Zhonghao Liu, "Wait Time Information Design," *Available at SSRN 4308999*, 2023.

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The Wall Street Journal, "Domino's tracking app tells you who made your pizza—Or does it?," `https://tinyurl.com/dominos-wsj` 2017.