上海纽约大学
NYU SHANGHAI

CUHK
BUSINESS SCHOOL

The Impact of Social Nudges on User-Generated Content for Social Network Platforms

Renyu (Philip) Zhang

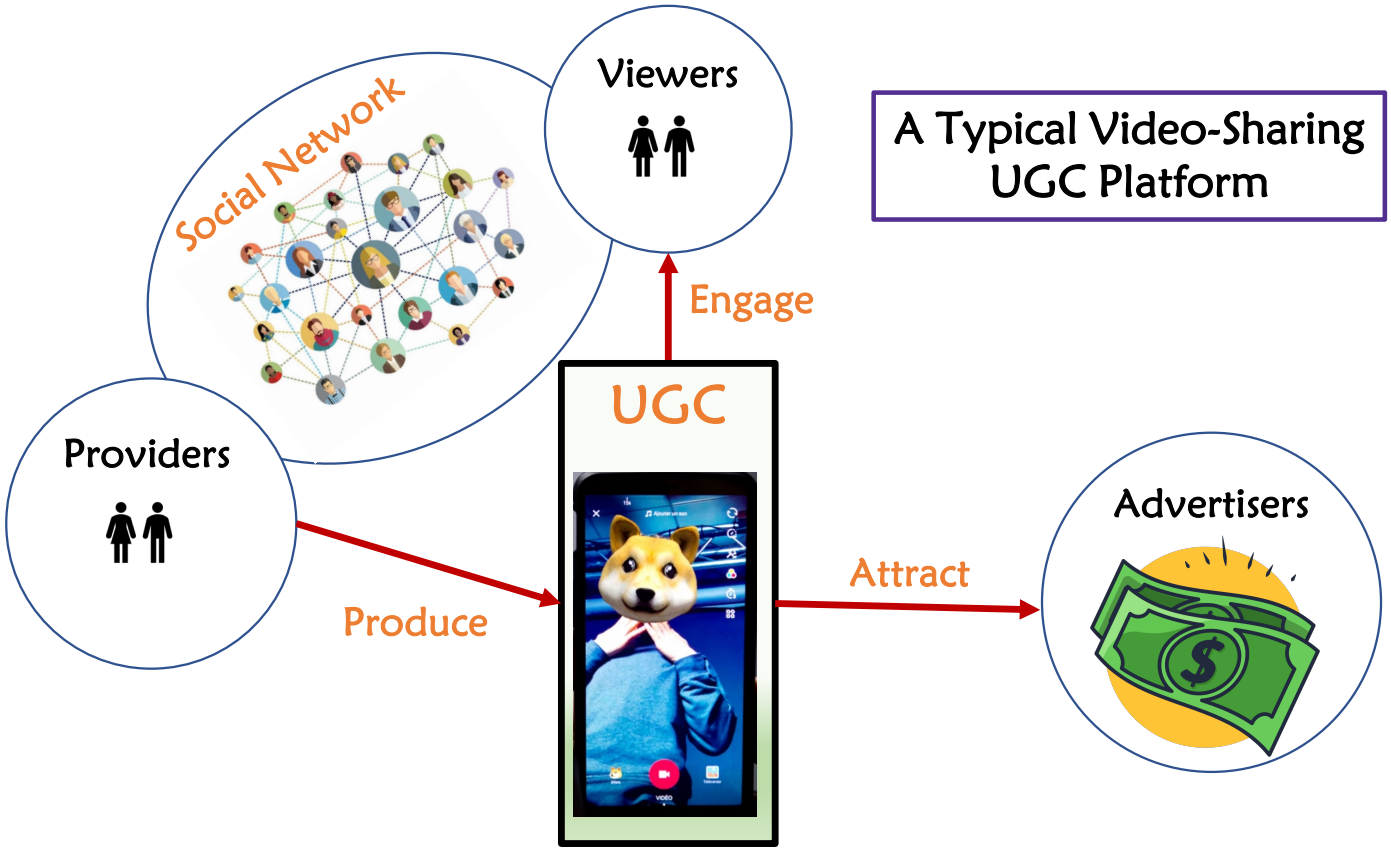
(Joint works with Zhiyu Zeng, Hengchen Dai, Dennis J. Zhang, Heng Zhang, Max Shen)

上海纽约大学
NYU SHANGHAI

CUHK
BUSINESS SCHOOL

- Introduction and Contributions
- Experiments and Empirics
- Social Network Model and Global Effect

Video-Sharing UGC Platforms



A Typical Video-Sharing UGC Platform

Boosting the production of UGC is crucial to the platform!

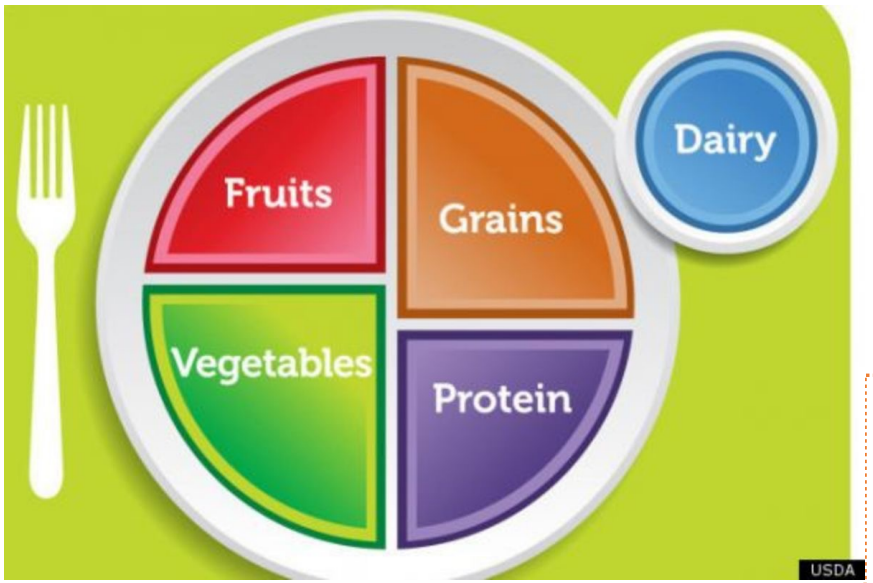
- The platform has little power over providers.
- Social interactions (e.g., likes and comments) not only engage viewers but also motivate providers to produce more.

How can a UGC platform leverage the embedded social network to motivate content production?

Nudge: Intervention without Money or Restriction

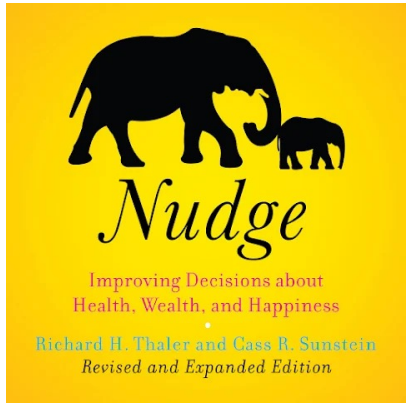
- Nudge: Intervention that intends to change individual behaviors without altering financial incentives or imposing restrictions (Thaler and Sunstein 2009).
- Nudge is a central concept in behavioral science and very widely applied in practice:

Photo credit: Xiaolong Li



Nudge for healthy food:
- + 18% fruit and +25% veg consumptions
- +15.3% healthier dietary or nutrition choices

Nudge for COVID-19 Vaccination:
- +84% appointment rate
- +26% vaccination rate



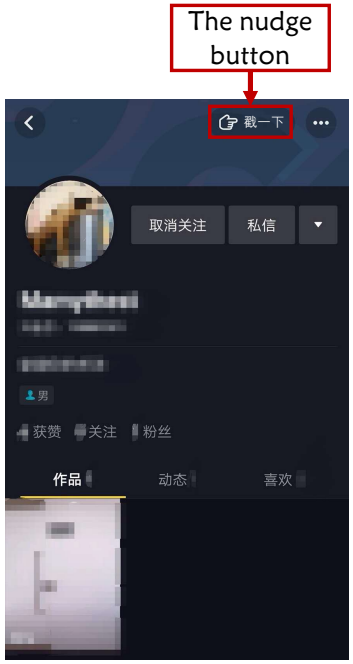
Can a UGC platform use nudge to motivate production?

Social Nudge

Social Nudge =

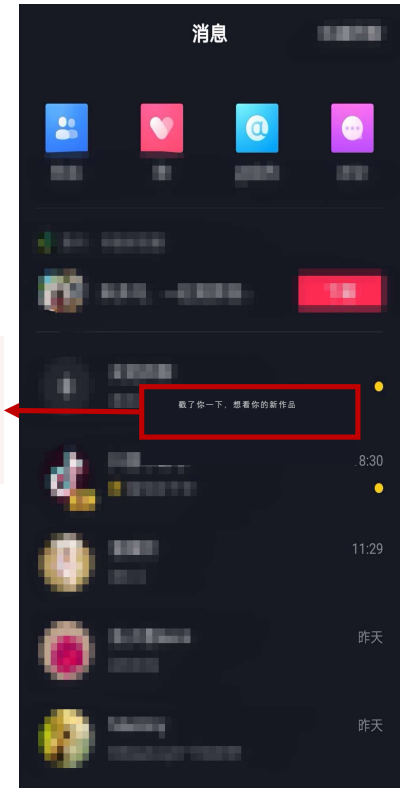
+ Nudge

- Social Nudge: A user encourages a provider s/he follows to produce more: Conveying subtle peer recognition.
- Literature: Peer recognition may not work; not clear how social network plays a role.
- Practice: A low-cost (less than 1 week of work for an SDE) and novel product function.
- Different from likes and comments.



Screen Shot of the Profile Page of the provider you follow.

Philip poked you and wanted to see your new posts!



Screen Shot of the Message Box of the nudge recipient.

Key Research (and Business) Questions

- How do social nudges affect the UGC production of the recipients?
  - Literature: Peer recognition NOT accompanied by financial incentives may backfire.
- How does the underlying social network impact social nudges?
- How to quantify the global effect of social nudges on the entire social network, considering nudge diffusion?

Combined Analytics Framework:
Field Experiment (A/B Testing) + Social Network Modeling

Related Literature

- Content production on UGC platforms: Peer recognition NOT accompanied by financial incentives may backfire.
  - Burtch et al. (2018), Huang et al. (2019), Restivo and Van de Rijt (2014), Gallus et al. (2020), etc.

- Peer effects on social networks: People's behaviors are largely influenced by those of their neighbors on the network.
  - Jackson (2010), Ballester et al. (2006), Candogan et al. (2012), Bimpkis et al. (2016), Zhou and Chen (2016), Gelper et al. (2021), etc.

- Information-based interventions: Offering the right information to the right people improves the customer engagement and service capacity.
  - Buell and Norton (2011), Buell et al. (2017), Parker et al. (2016), Cui et al. (2019), Xu et al. (2021), etc.

- Platform operations: Optimizing operational strategies for online platforms.
  - Banerjee et al. (2016), Cachon et al. (2017), Bai et al. (2019), Kabra et al. (2020), etc.

Highlight of Main Contributions

- **Social nudge: A Novel Intervention to Boost UGC Production**
  - Direct effect: Receiving social nudges boosts the production of the provider by +13.21%.
  - Low-cost, information-based and flexible approach leveraging the embedded social network to address a central platform operations problem: Increasing UGC production.

- **Impact of the Social Network on Social Nudges**
  - Indirect effect (diffusion): Nudge receivers send +15.57% more social nudges to providers.
  - Both direct and indirect effects of social nudges are stronger with a stronger tie and last for a few days.

- **Global Effect of Social Nudges under Interferences**
  - A social network model captures the direct and indirect effects of social nudges.
  - Bonacich Centrality for Edges helps quantify the global effect of social nudges (~+1% of total production).

上海纽约大学
NYU SHANGHAI

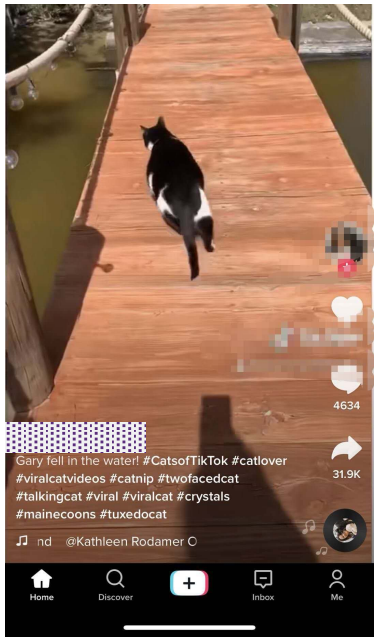
CUHK
BUSINESS SCHOOL

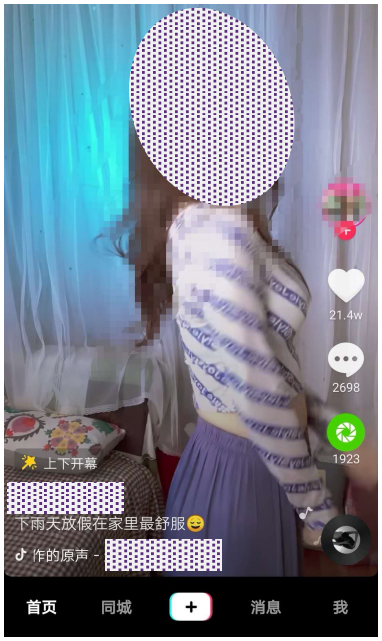
- Introduction and Contributions
- **Experiments and Empirics**
- Social Network Model and Global Effect

Field Setting

- A Chinese online short-video sharing social network platform (referred to as Platform O hereafter).
- 300 million of daily-active users (DAU), half-billion MAU, 20 million USD advertising revenue per day.
- Each user can have two roles: Content provider and content viewer.
- Each user can follow other users: An embedded social network on Platform O.

Typical User-Interfaces of a Short-Video Sharing Platform

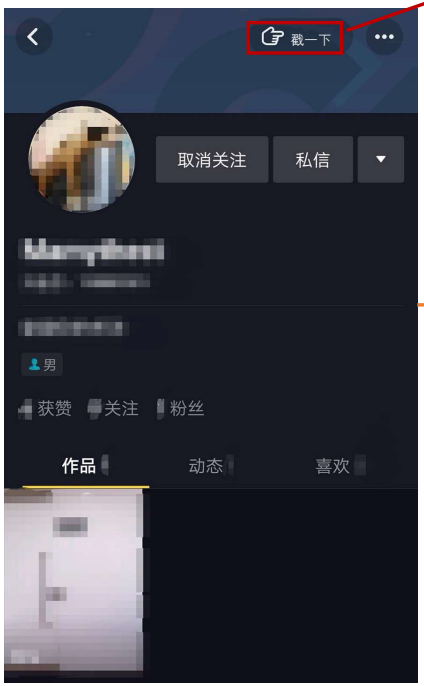




Experiment Design

Followers sent social nudges to providers

The nudge button



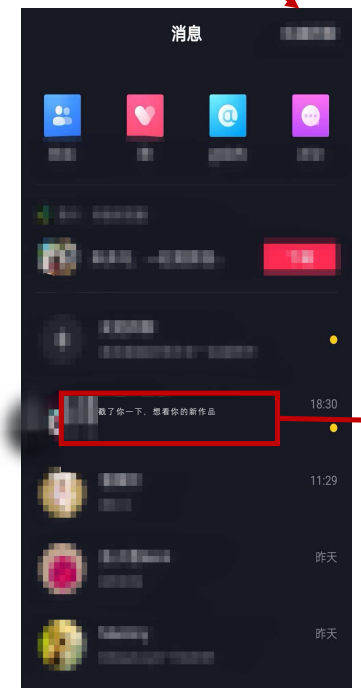
Sample of the Social Nudge Experiment

Providers were sent at least one nudge in the experiment

Treatment

Control

Could see nudges sent by their followers



Philip poked you and wanted to see your new posts!

Could NOT see nudges sent by their followers

Data

- Main experiment:
  - Sept. 12, 2018 ~ Sept. 14, 2018
  - Sample size: 993,676 providers (496,976 treatment and 496,700 control)
    - They had never received any social nudges before the experiment.
    - Most (94%) received only one social nudge during this experiment.

- Replication experiment (for robustness check):
  - Sept 14, 2018 ~ Sept. 20, 2018.
  - 655,001 providers non-overlapping with the main experiment.

- Data from both experiments pass the randomization checks, i.e., treatment and control providers are comparable.

- Outcome variables:
  - Number of videos uploaded.
  - Number of social nudges sent to other providers by the recipient.

Question: How do social nudges impact UGC production on a social network platform?

Social Nudges Boost UGC Production

- We focus on the day a provider was sent the first social nudge in the experiment (the first reception day).
- Model specifications (a two-way tie means the nudge receiver also follows the sender):

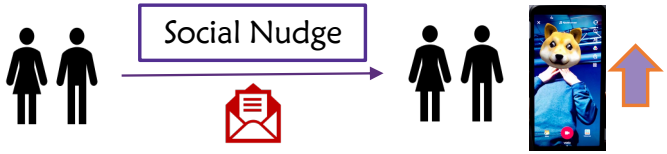
$$Number\ of\ Videos\ Uploaded_i = \beta_0 + \beta_1 Treatment_i + \epsilon_i$$

$$Number\ of\ Videos\ Uploaded_i = \beta_0 + \beta_1 Treatment_i + \beta_2 Two\_Way\_Tie_i + \alpha_3 Treatment_i * Two\_Way\_Tie_i + \epsilon_i$$

- Direct effect on production:

Treatment Effect	Average	2-way Tie	1-way Tie
Relative Effective Size	+13.21%***	+17.40%***	+9.35%***

Note: All p-values are smaller than 0.001.



- Social nudges boost UGC production.
- The direct effect of social nudges is stronger with a stronger tie.
- (i) Video views, likes, and comments ↑; (ii) video quality (like-rate and comment-rate) →; (iii) more effective than platform-initiated nudges; (iv) production boost not driven by the additional likes and comments.
- Literature: Peer recognition without financial incentives may backfire.

Social Nudges Diffuse

- How does the underlying social network impact the effect of social nudges?
- Model specifications:

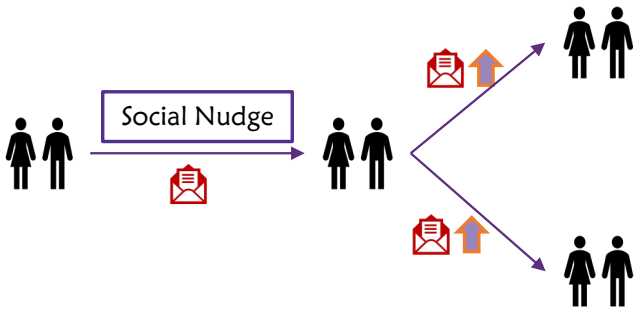
$$Number\ of\ Social\ Nudges\ Sent_i = \beta_0 + \beta_1 Treatment_i + \epsilon_i$$

$$Number\ of\ Social\ Nudges\ Sent_i = \beta_0 + \beta_1 Treatment_i + \beta_2 Two\_Way\_Tie_i + \alpha_3 Treatment_i * Two\_Way\_Tie_i + \epsilon_i$$

- Indirect effect of social nudges:

Treatment Effect	Average	2-way Tie	1-way Tie
Relative Effective Size	+15.57%***	+30.02%***	+2.87%*

Note: ***: p-value<0.001; *: p-value<0.05.

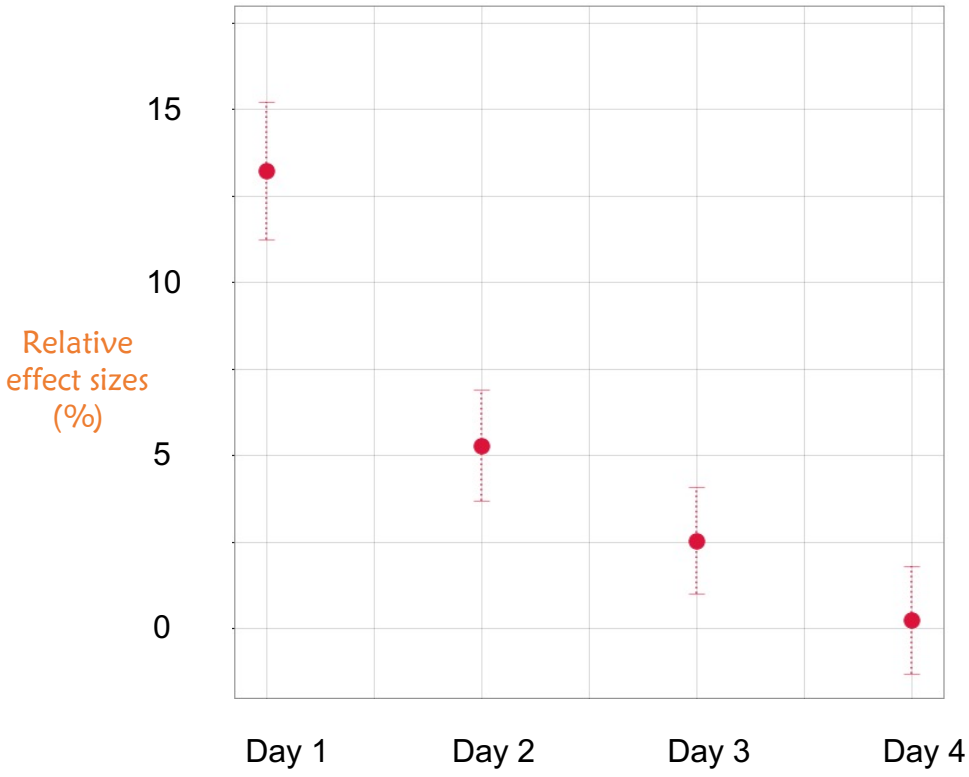


- Social nudges diffuse on the social network platform.
- The social nudge diffusion is stronger with a stronger tie.

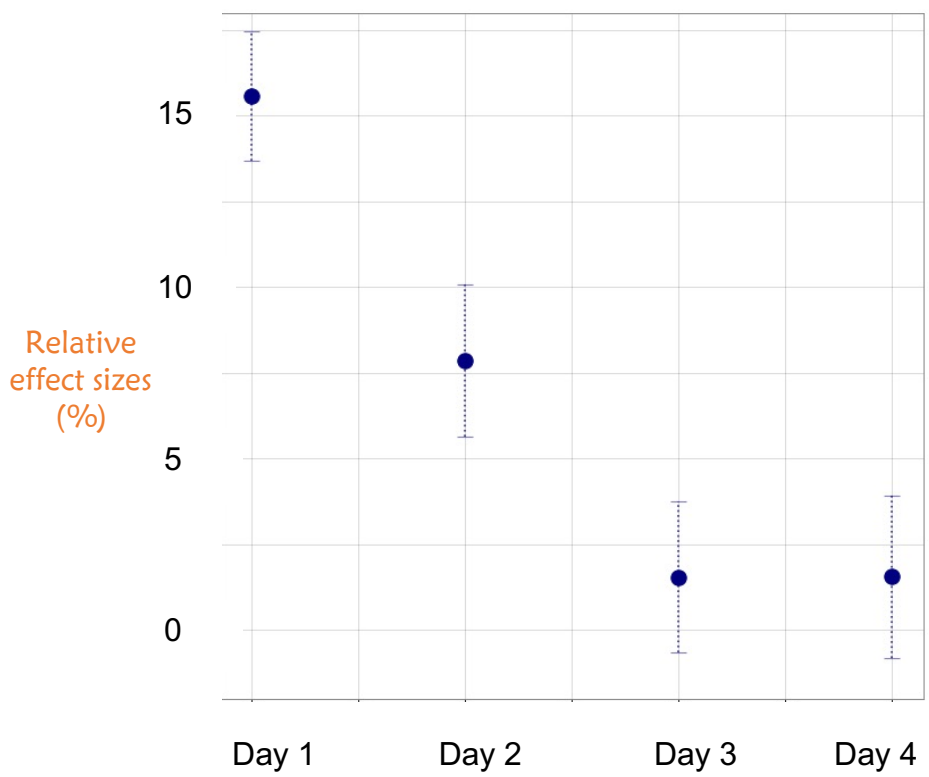
Over-Time Effects of Social Nudges

- How do the direct and indirect effects of social nudges evolve over time?

Direct effect
(DV = Number of Videos Uploaded)

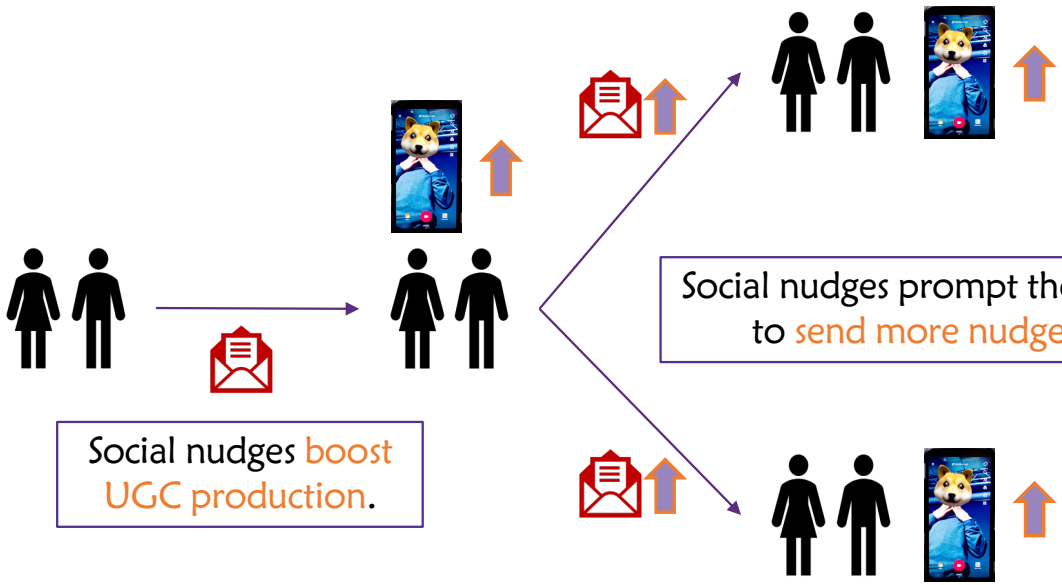


Indirect effect
(DV = Number of Social Nudges Sent)



Note: The error bars are the 95% confidence intervals.

Recap of the Social Nudge Experiment



Social nudges boost UGC production.

Social nudges prompt the recipient to send more nudges out.

Both the direct and the indirect effects are stronger with a stronger tie, and last for several days.

- How to evaluate the global effect of social nudges on the entire social network?
  - The global effect is NOT directly measurable by user-side randomized experiments due to the interference from nudge diffusion.

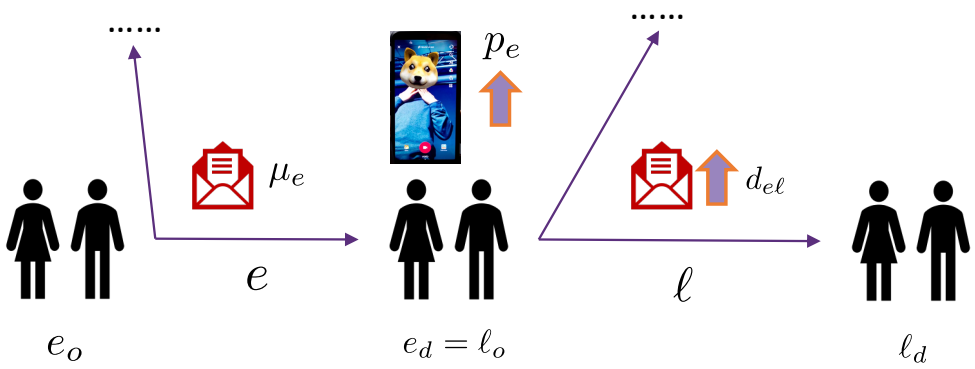
上海纽约大学
NYU SHANGHAI

CUHK
BUSINESS SCHOOL

- Introduction and Contributions
- Experiments and Empirics
- Social Network Model and Global Effect

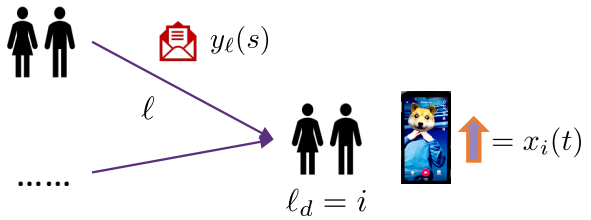
Social Network Model

- A social network $G = (V, E)$, where V is the set of users and E is the set of following relationships.
- Discrete time period: t=1,2,3,⋯ (t=1 is the day when the social nudge function was launched).
- μ_e: the number of social nudges e_o sends to e_d without receiving any nudge (called the organic nudges).
- p_e: the production boost of e_d after receiving a social nudge sent by e_o, i.e., the direct effect of social nudge.
- $d_{e\ell}$: the increase in the number of nudges sent on ℓ after e_d receives a nudge sent by e_o ($e_d = \ell_o$), i.e., the indirect effect.



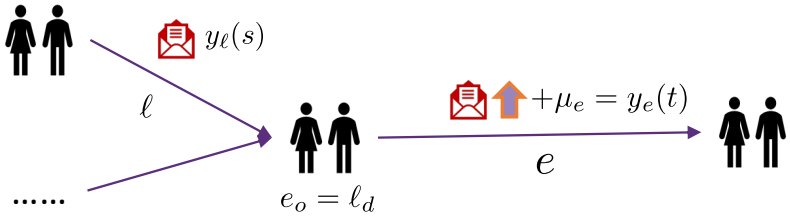
Direct and indirect effects decay to 0 exponentially as $p_e\alpha_p^{\Delta t}$ and $d_{e\ell}\alpha_d^{\Delta t}$.

$$\mathbf{D} := (d_{\ell e} : (\ell, e) \in E^2) \quad \mu := (\mu_e : e \in E) \quad \eta := (p_e/(1-\alpha_p) : e \in E)$$



- The production boost of user i in period t (direct effect):

$$x_i(t) = \sum_{s=1}^{t} \alpha_p^{t-s} \sum_{\ell_d = i} p_\ell y_\ell(s) + \epsilon_i^x(t)$$



- The number of social nudges on edge e in period t (indirect effect):

$$y_e(t) = \mu_e + \sum_{s=1}^{t} \alpha_d^{t-s} \sum_{\ell_d = e_o} d_{\ell e} y_\ell(s) + \epsilon_e^y(t)$$

Bonacich Centrality for Edges and the Equilibrium

- We care about the expected equilibrium/stationary state, i.e., t goes to infinity.
- Equilibrium nudge vector $\mathbf{y}^* := \lim_{t\uparrow+\infty} \mathbb{E}[\mathbf{y}(t)]$ and production boost $\mathbf{x}^* := \lim_{t\uparrow+\infty} \sum_{i\in V} \mathbb{E}[x_i(t)]$.

Theorem. The equilibrium nudge vector is $\mathbf{y}^* = \mathcal{BE}(\mathbf{D}, \mu)$ and the equilibrium production boost is $\mathbf{x}^* = \eta^T \mathbf{y}^*$.

- Bonacich Centrality for Edges (BCE) ($\mathbf{I}$ is the identity matrix, assuming the limit exists):

$$\mathcal{BE}(\mathbf{D}, \mu) = \left(\mathbf{I} - \frac{1}{1-\alpha_d}\mathbf{D}\right)^{-1} \mu = \left(\mathbf{I} + \sum_{k=1}^{+\infty} \frac{1}{(1-\alpha_d)^k}\mathbf{D}^k\right) \mu$$

Direct Effect

Indirect Effect

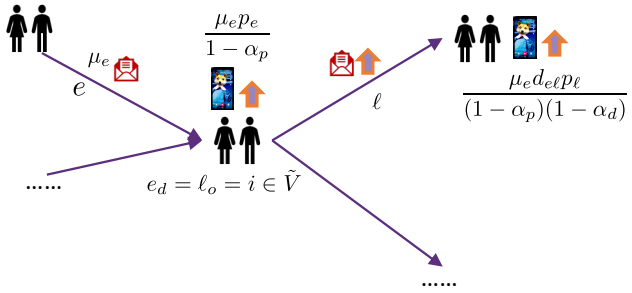
- The nudge vector of the k[th]-order diffusion: $\frac{1}{(1-\alpha_d)^k}\mathbf{D}^k\mu$; the production boost from k[th]-order diffusion: $\frac{1}{(1-\alpha_d)^k}\eta^T\mathbf{D}^k\mu$
- Core challenge: Dimension of the diffusion matrix **D** for Platform O is 10^{32}.

Approximation for the Global Effect

- Dimension of the diffusion matrix **D** for Platform O: 10^{32}.
  - First approximation: Consider the first-order diffusion only and ignore the higher-order diffusions (~ -0.72% gap for Platform O).

$$\tilde{\mathbf{y}}(1) = \widetilde{\mathcal{BE}}(\mathbf{D}, \mu, 1) = \left(\mathbf{I} + \underbrace{\frac{1}{1-\alpha_d}}_{\text{First-order Diffusion}}\mathbf{D}\right)\mu, \;\; \tilde{\mathbf{x}}(1) = \eta^T \tilde{\mathbf{y}}(1)$$

  - Second approximation: Randomly down-sample a subset of providers $\tilde{V}$, compute $\tilde{x}(1, \tilde{V}) := \sum_{i \in \tilde{V}} \left(\sum_{e \in E, e_d = i} \left(\underbrace{\frac{\mu_e p_e}{1-\alpha_p}}_{\text{Direct Effect}} + \underbrace{\sum_{\ell \in E, e_d = \ell_o = i} \frac{\mu_e d_{e\ell} p_\ell}{(1-\alpha_p)(1-\alpha_d)}}_{\text{First-order Diffusion}} \right) \right)$ and scale it to the entire social network by the inverse sampling rate.



Proposition. $\kappa \cdot \tilde{x}(1, \tilde{V})$ is an unbiased estimate of $\tilde{\mathbf{x}}(1)$, where $\kappa := |V|/|\tilde{V}|$ is the scaling factor.

Parameter Estimation with Experimental Data

- To quantify the global effect of social nudges, it suffices to estimate $(\mathbf{D}, \mathbf{p}, \mu, \alpha_p, \alpha_d)$ with data from the experiments.
- μ_e (the likelihood of sending organic nudges): Sampling edges in E whose origin was in the control group and cross-validate a logistic regression model.
- Jointly estimate (p_e, α_p) by minimize the mean-squared-error between the true over-time direct effect (from the experiment) and the one predicted by our social network model $p_e \alpha_p^t$ for t = 0,1,2.
- Jointly estimate $(d_{e\ell}, \alpha_d)$ by minimize the mean-squared-error between the true over-time indirect effect (from the experiment) and the one predicted by our social network model $d_{e\ell} \alpha_d^t$ for t = 0,1.
- The estimates can be replicated by the data from the second experiment (relative gap <10% for each parameter), suggesting the robustness and accuracy of our approach.

The estimated parameter values are the inputs of the social network model to evaluate the global effect of social nudges, $\kappa \cdot \tilde{x}(1, \tilde{V})$.

Estimation Results of the Global Effect

- Baseline estimation: Global Effect = +48.65 videos per day
  - Number of providers who received any social nudges per day multiplies the production boost of receiving social nudges (estimated from the experiment).

Estimation with Our Social Network Model Global Effect = +140.67 videos per day (~+1% of the total UGC production of Platform O)	
Accumulated Direct Effect = +130.08 videos per day 167% higher than the baseline estimation	Accumulated Indirect Effect (diffusion) = +10.59 videos per day Amounting to 22% of the baseline estimation and 8.14% of the direct effect

Note: The absolute global effect is scaled to protect sensitive data.

- The estimation of global effect is robust and accurate, which can be replicated by the second experiment.
  - The ratio between the indirect effect and the direct effect is 8.38%.

Insight: Our social network model helps de-bias the substantial underestimates of the natural baseline estimation approach.

Takeaways

- Develop the social nudge as a novel low-cost, information-based, and flexible intervention that leverages the embedded social network to increase content production on a large-scale UGC platform.
  - Social nudges boost UGC production and diffuse on the social network.

- Social network model: Evaluate the global effect of social nudges on a social network with the interferences from nudge diffusion.

- The combined framework of A/B testing and social network model has the potential to study other operations problems for large-scale social network platforms.

Link to the paper: https://rphilipzhang.github.io/rphilipzhang/Social_nudge_nonblinded.pdf

上海纽约大学
NYU SHANGHAI

CUHK
BUSINESS SCHOOL

Thank You!

Questions?

renyu.zhang@nyu.edu and philipzhang@cuhk.edu.hk

https://rphilipzhang.github.io/rphilipzhang/index.html