Agent reflexivity in computational models: the case of diffusion of innovations

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About me

- César García-Díaz

- PhD from the University of Groningen (Netherlands)
- Associate Professor, School of Economics & Business, PUJ
- Computational analysis of social and organizational systems
- Interested in the link between micro-level rules, structural interdependence and macro-level outcomes in a variety of settings (e.g., organizational dynamics, industry evolution, competitive spatial location).

1o. Motivation and background

- Social systems, unlike natural systems, are **artificial structures designed and transformed by human action**.

- Such systems are collectives characterized by **heterogeneous**, **purposeful** individuals who are nested through a set of relationships or **interconnections** embedded in a structure, so that, consequently, the systems display **complex behaviors**.

1o. Motivation and background

- **Statistical physics** approaches maintain a visible influence on how complex systems theories are applied to study **social systems** (cf. Castellano et al., 2009; Galam, 2012).

- **Emergence** is a fundamental concept in complex systems. However, no proper distinction has been drawn between emergence in **natural** and **social systems** (Goldspink and Kay, 2007). Thus, emergent phenomena can have very different drivers in natural complex systems (**non-reflexive**) vs. social complex systems (**reflexive**) (Goldspink and Kay, 2007).

1o. Motivation and background

- Alike natural systems, humans can recognize patterns (i.e., societies, institutions, organizations) and set their behavior according to such patterns. This has been named "**second-order emergence**" (Gilbert, 2002).

- Need to differentiate between **epistemic** (representation of a reality rendered intelligible to an observer) and **ontic** (reality itself) sides in simulation modeling (Hauhs and Trancon y Widemann, 2012).

- Despite acknowledged importance by some few researchers, remains an ethereal concept of no scientific value due to its self-referential, paradoxical nature (Lynch, 2000). Nonetheless, Umpleby (2007) highlights the importance of developing knowledge that chooses "**scope**" over "**form**" (Umpleby, 2007: 515).

2o. Perspectives on reflexivity

- Umpleby (2007) speaks of reflexivity as “**the relation that exists between the entity and itself**” (Umpleby, 2007: 515):
  - **Heins von Foerster**’s second-order cybernetics (or the inclusion of the observer in the system under study)
  - **George Soros**’ conception of economic and political actors as both actors and observers

- Special issue of the *Journal of Economic Methodology*, Volume 20, Issue 4 (2013)
  - Reflexivity and Economics: George Soros's Theory of Reflexivity and the Methodology of Economic Science

2o. Perspectives on reflexivity

- Lynch (2000) reviews a number of interpretations of the concept, among which we highlight the following:
  - **Mechanistic reflexivity** (recursive processes that involve feedback).
  - **Substantive reflexivity** (an essential feature of human communication and interaction).

2o. Perspectives on reflexivity

- **Self-fulfilling prophecies** (Ferraro et al., 2005): Social science researchers can affect the system they study by shaping practices they try to understand through the diffusion of new language / jargon.

2o. Perspectives on reflexivity

- Reflexivity as **second-order behavior** (Goldspink, 2000:2.6): An agent is a "*natural or artificial entity with sufficient behavioural plasticity to persist in its medium by responding to recurrent perturbation within that medium so as to maintain its organisation*"

3o. Adding reflexivity to diffusion processes: Diffusion as classification (Etzion, 2014)

- Alternative process: Consideration of "**awareness**" (Etzion, 2014) : the moment at which an agent is capable of distinguishing between adopters and non-adopters
- Population of agents endowed with a perception capability:

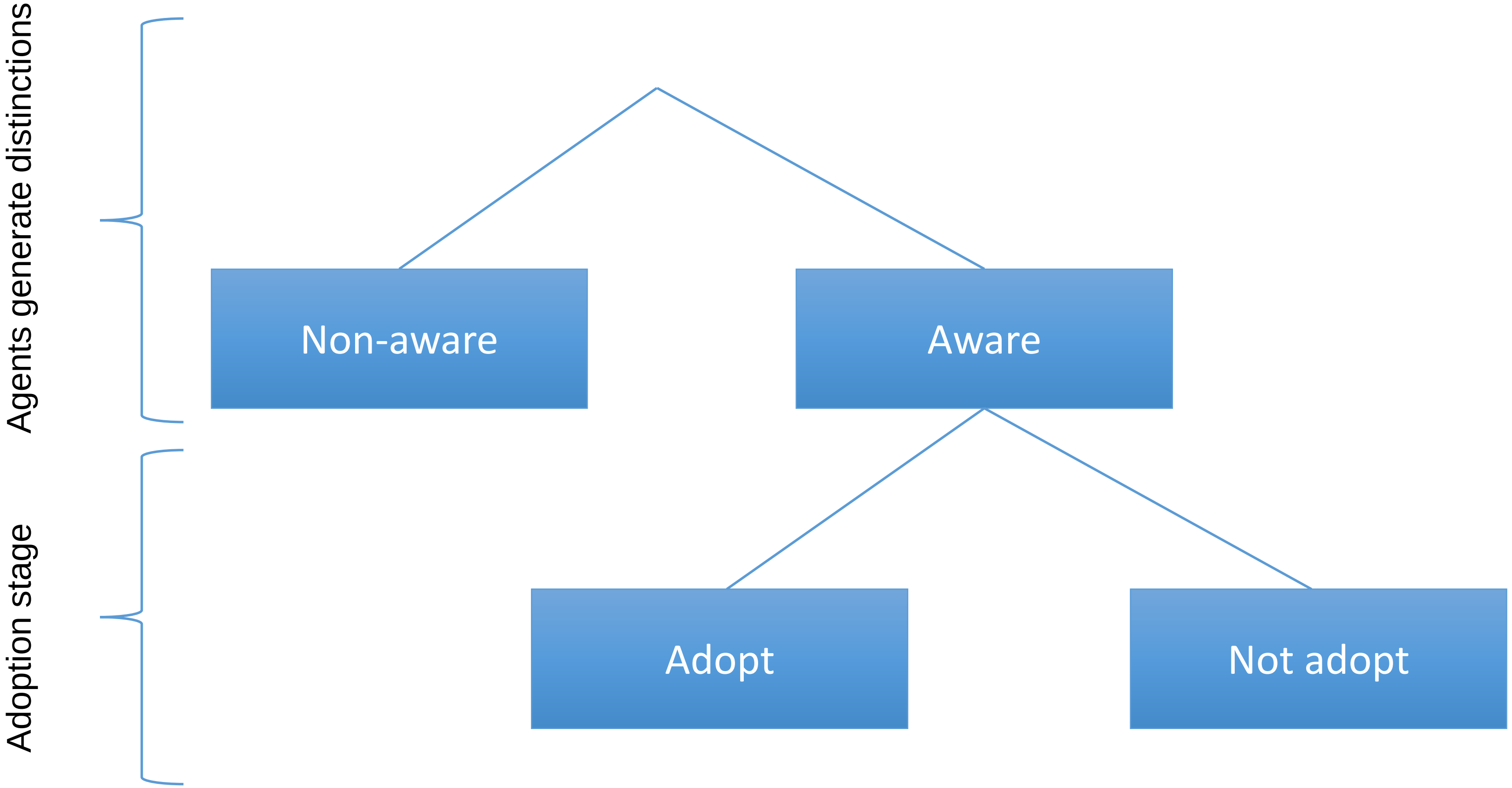
$$p_i \sim N(\overline{p_i}, \sigma^2)$$

- Awareness is defined as follows (Etzion, 2014):

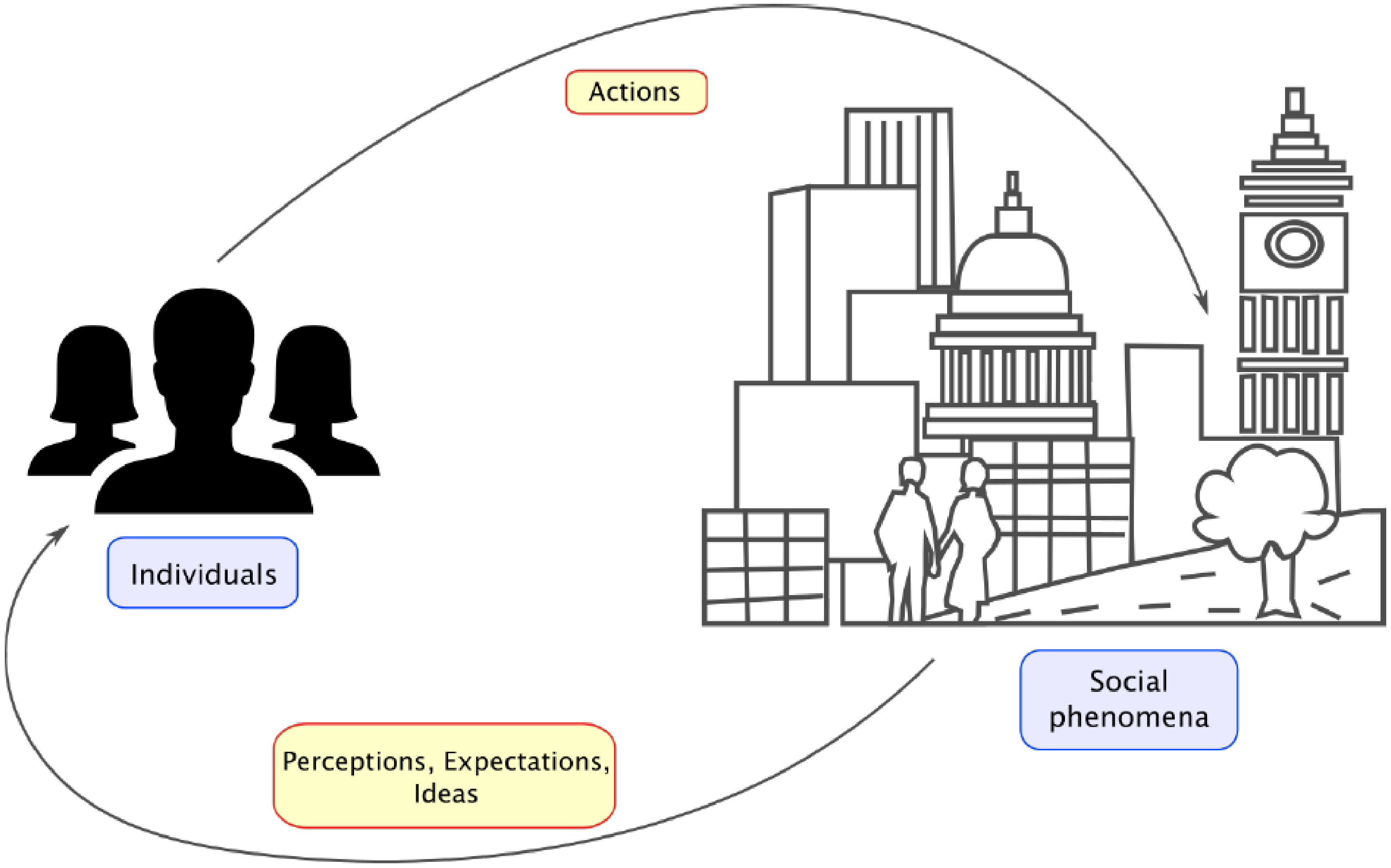
$$a_{i,t} = \begin{cases} 1 & \text{if } p_i + n_{t-1} \geq H \\ 0 & \text{if } p_i + n_{t-1} < H \end{cases}$$

- H corresponds to a threshold, while n_t represents the population of adopters at time t.

3o. Adding reflexivity to diffusion processes: Diffusion as classification (Etzion, 2014)



3o. Adding reflexivity to diffusion processes: Córdoba and García-Díaz (2020)



Córdoba, C., & Garcia-Diaz, C. (2020). Reflexivity in a Diffusion of Innovations Model. *Journal of Artificial Societies and Social Simulation*, *23*(3), 1-9.

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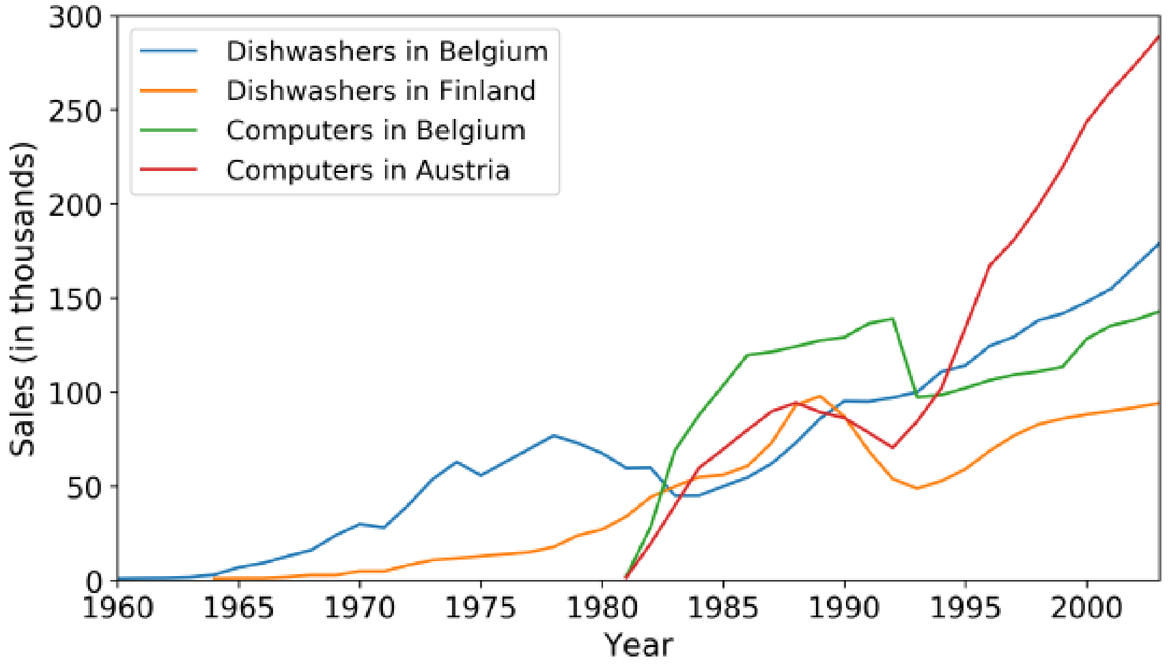
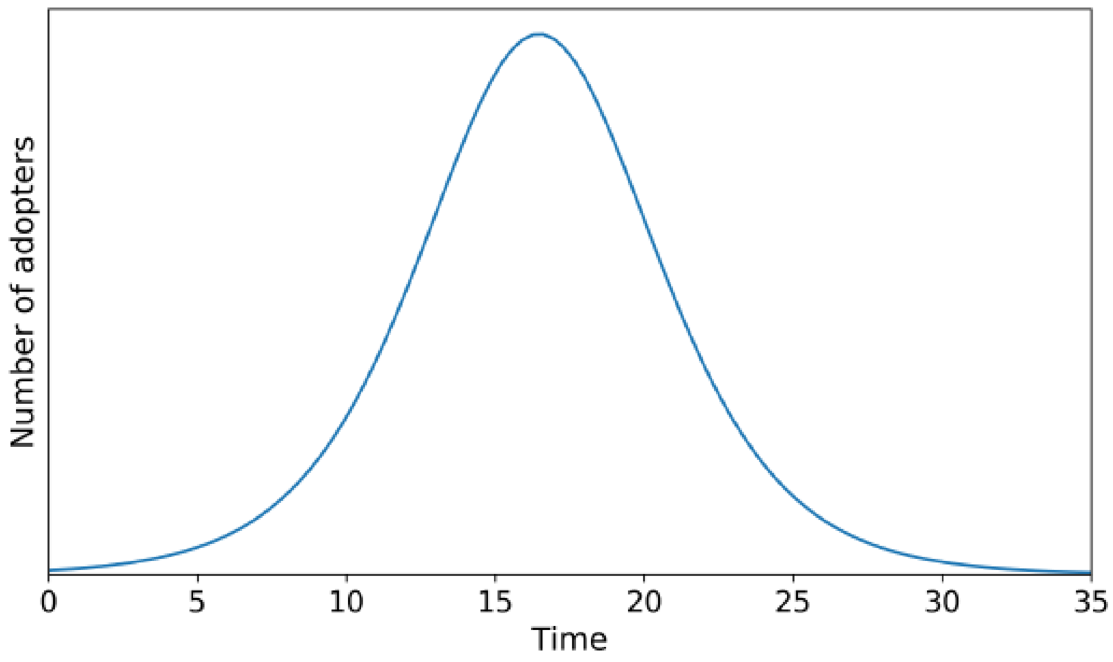


(a)



(b)

Córdoba, C., & Garcia-Diaz, C. (2020). Reflexivity in a Diffusion of Innovations Model. *Journal of Artificial Societies and Social Simulation*, *23*(3), 1-9.

4o. Model

- Agents placed in a social network (e.g., scale-free, small world, random)
- A given number of agents (δ) are initialized as adopters
- Adoption decisions: D_i

$$D_i = \begin{cases} 1, & U_i \geq U_{i,\min} \text{ or } \lambda > s_i \\ 0, & \text{otherwise} \end{cases}$$

- U_i is agent *i's* utility; $U_{i,\min}$ is a utility threshold for adoption; λ is the marketing effort, and s_i is agent *i's* marketing susceptibility to adoption
- $U_{i,\min} \sim U(0,1), s_i \sim U(0,1)$

4o. Model

- U_i has two components: a local factor (U_{Li}) and a global social influence (U_G)

$$U_{Li} = \beta \cdot x_i + (1 - \beta) \cdot y_i$$

$$x_i = \begin{cases} 1, & A_i \geq h_i \\ 0, & \text{otherwise} \end{cases}$$

$$y_i = \begin{cases} 1, & p_i \leq q \\ 0, & \text{otherwise} \end{cases}$$

- β is the ***social influence*** parameter; A_i is the fraction of adopters in neighborhood; h_i is a threshold value; p_i is the ***individual preference***; and q is ***product quality*** parameter. $p_i, h_i \sim U(0,1)$, $\beta, q \in (0,1)$

4o. Model

- We also incorporate a ***global influence*** effect, which leads agents to consider a ***category distinction*** between adopter and non-adopters
- This is a function on the average size of connected components in the subgraph of adopters

$$U_G = \frac{\overline{C}}{N}$$

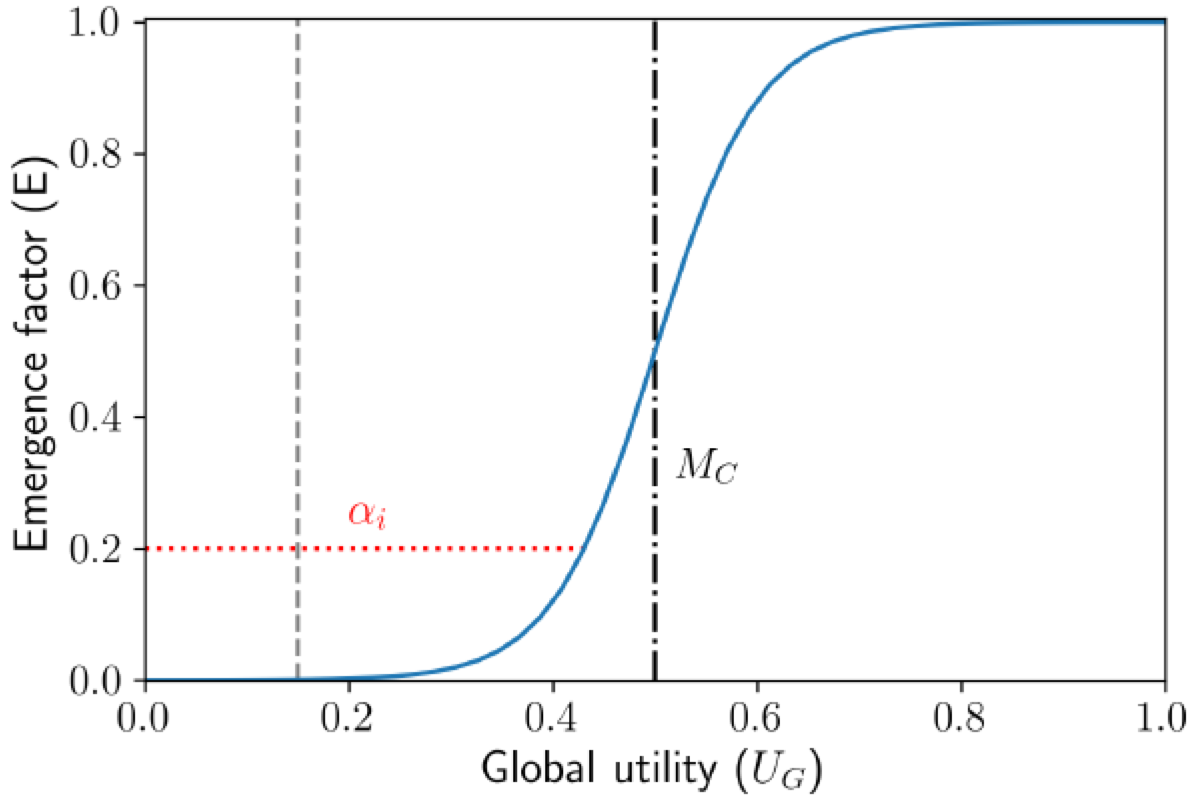
$$\overline{C} = \sum_{j=1}^{n_c} \left(\frac{n_j}{N}\right) n_j, \quad n_j > 1$$

- N is the total number of agents; n_j is the number of adopter in network component j; n_c is the total number of components. Thus, $\bar{C}$ is the weighted average size of components of adopters.

4o. Model

- Reflexivity index: $\alpha_i \sim U(0,1)$
- Emergence factor: $E(U_G)$
- Critical mass: M_c

$$E(U_G) = \frac{1}{1 + e^{-\phi(U_G - M_c)}}$$

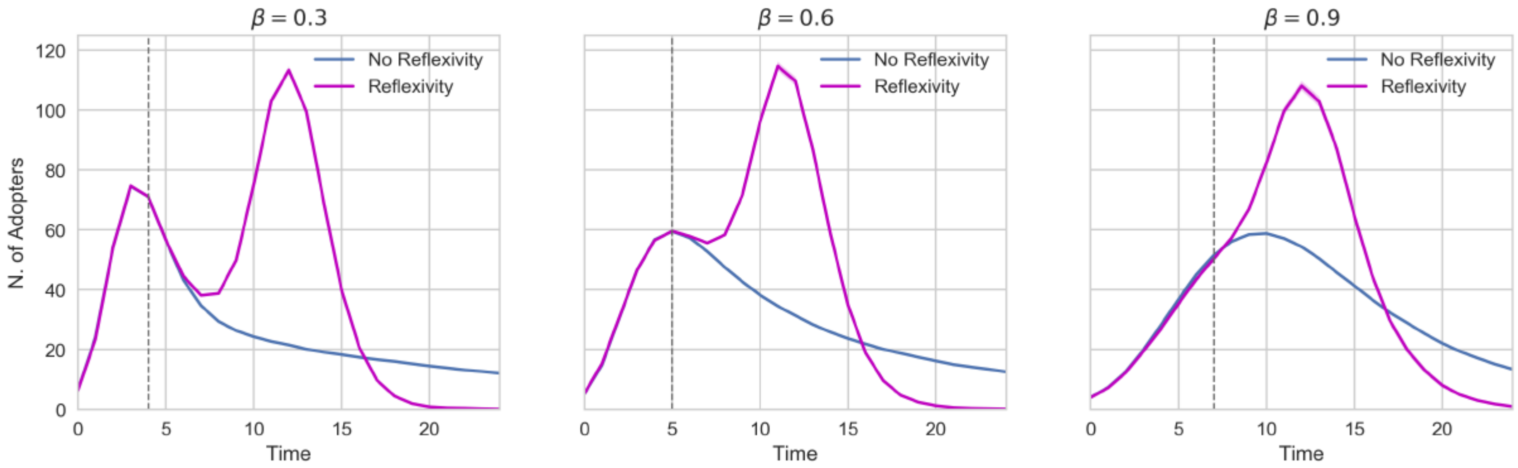


4o. Model

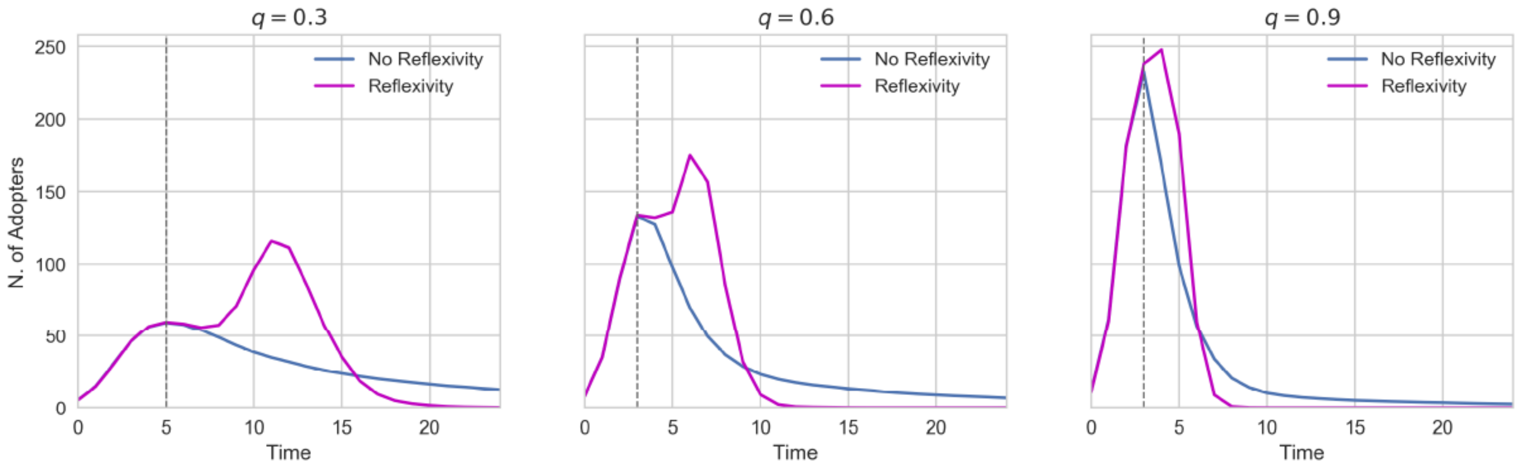
$$U_i = \begin{cases} U_{Li} + U_G - U_{Li} \cdot U_G, & E(U_G) > \alpha_i \text{ and } t_a > d_i \\ U_{Li}, & \text{otherwise} \end{cases}$$

- t_α is the time elapsed since the awareness of the emergence of a critical mass of adopters, and d_i is the time delay for including this awareness in the utility function.

5o. Results: without time delays (scale free network)



(a) For all curves $q = 0.3$



(b) For all curves $\beta = 0.6$

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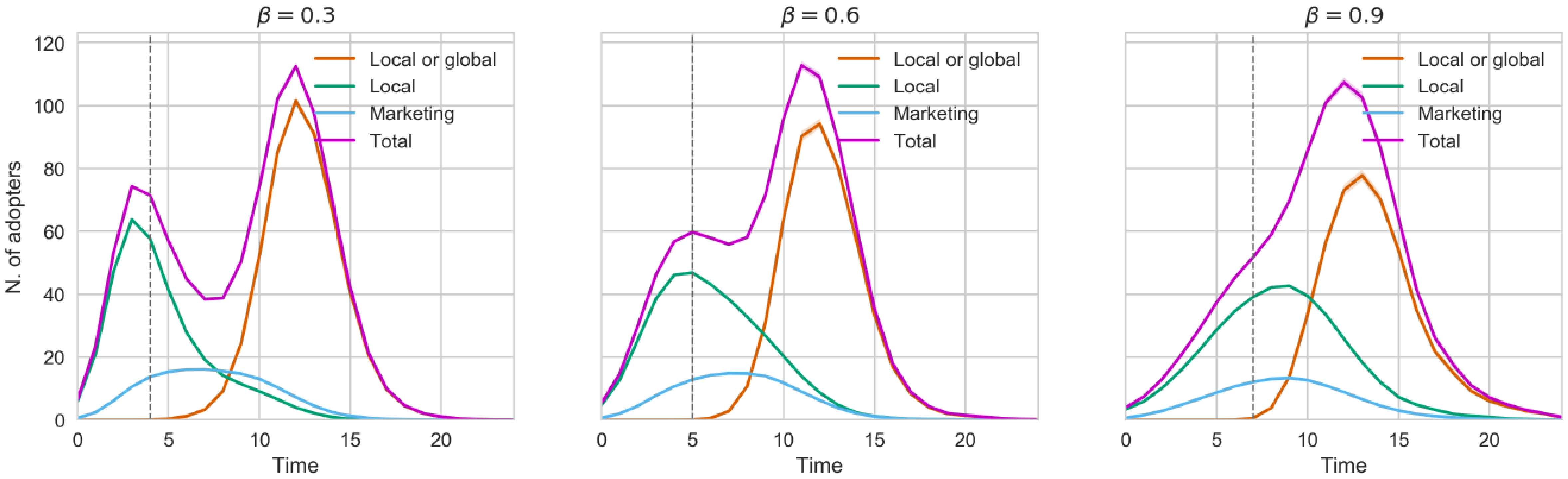

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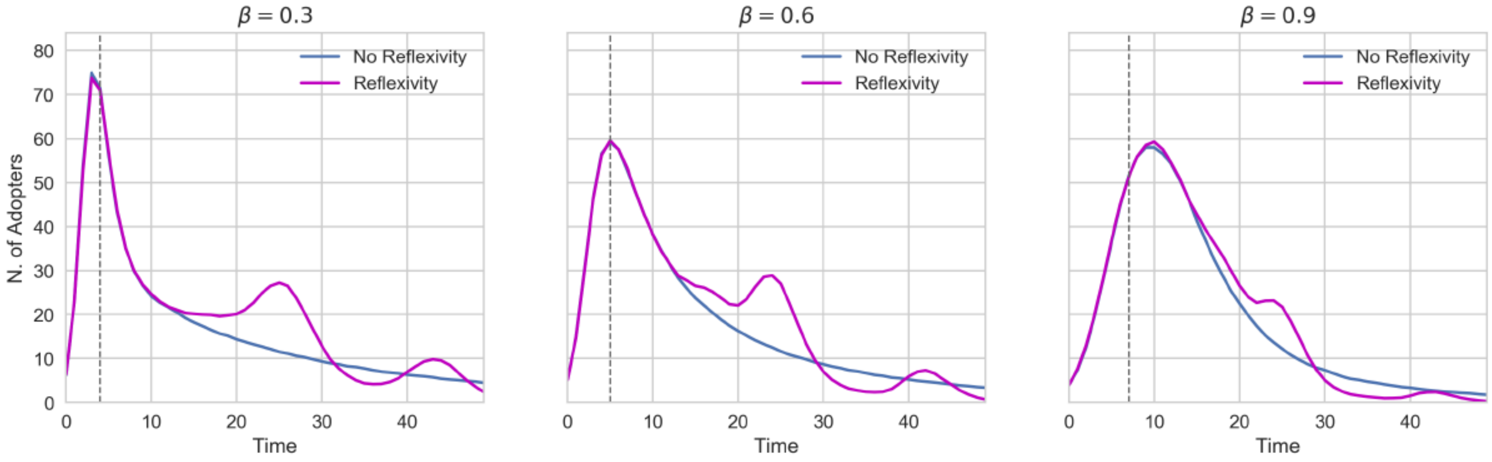

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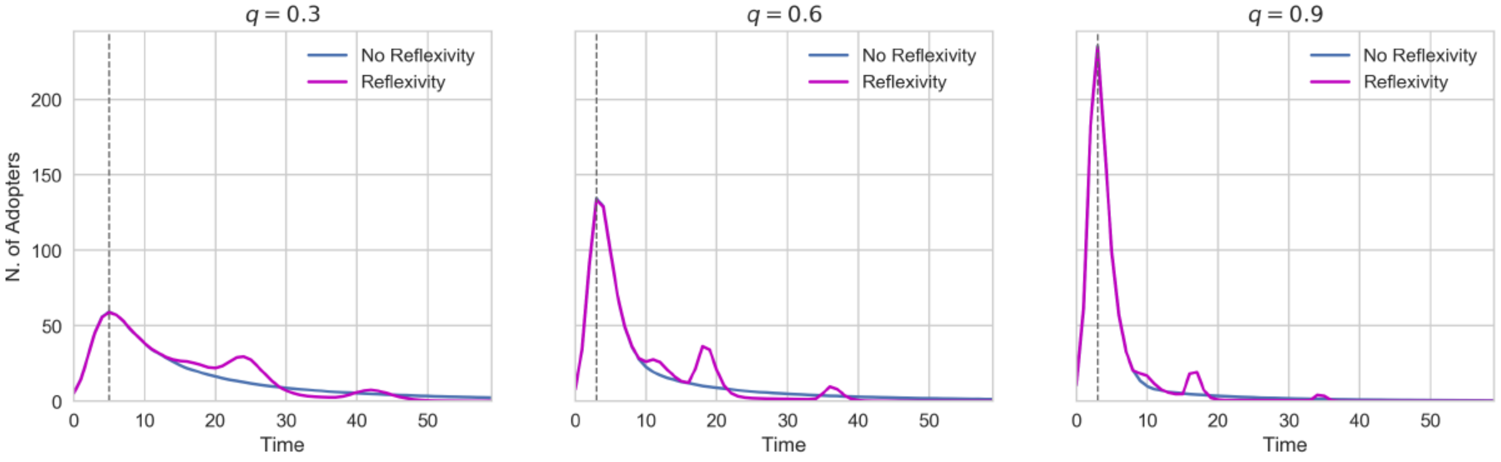
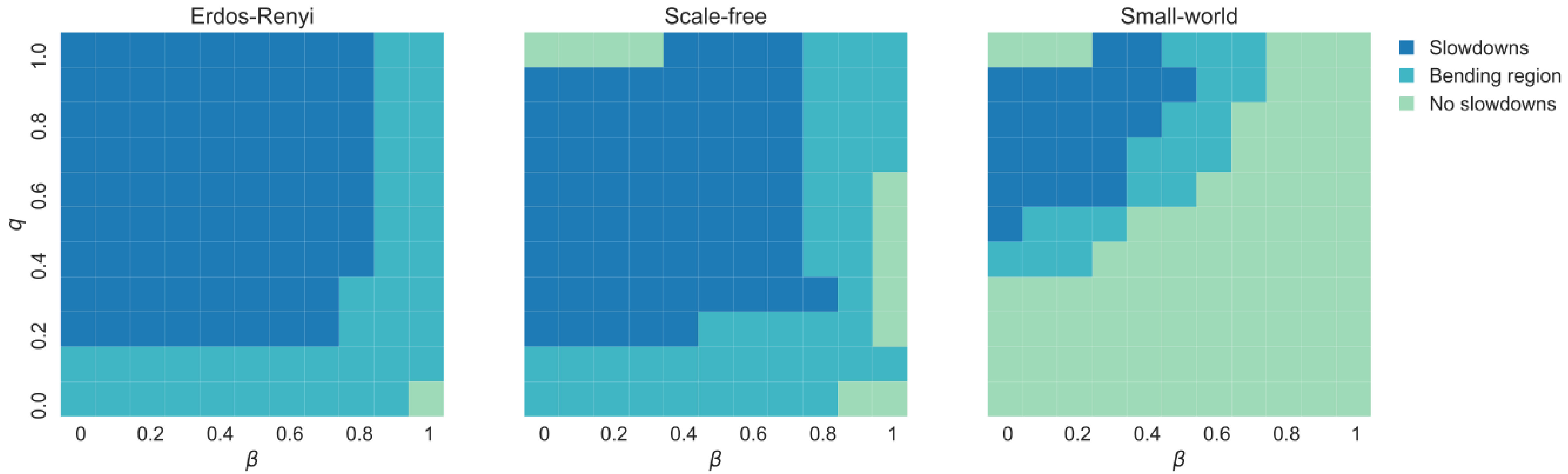


(b) For all curves $\beta = 0.6$

5o. Results: βq space



Link to the full paper:

Córdoba, C., & Garcia-Diaz, C. (2020). Reflexivity in a Diffusion of Innovations Model. *Journal of Artificial Societies and Social Simulation*, 23(3), 1-9.

http://www.doi.org/10.18564/jasss.4255

Thank you for your attention
Any questions?

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