Some results from a simple agent-based choice model

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How to choose...

Not an easy question... But say that we start out with the simplest possible ”herding” choice model.

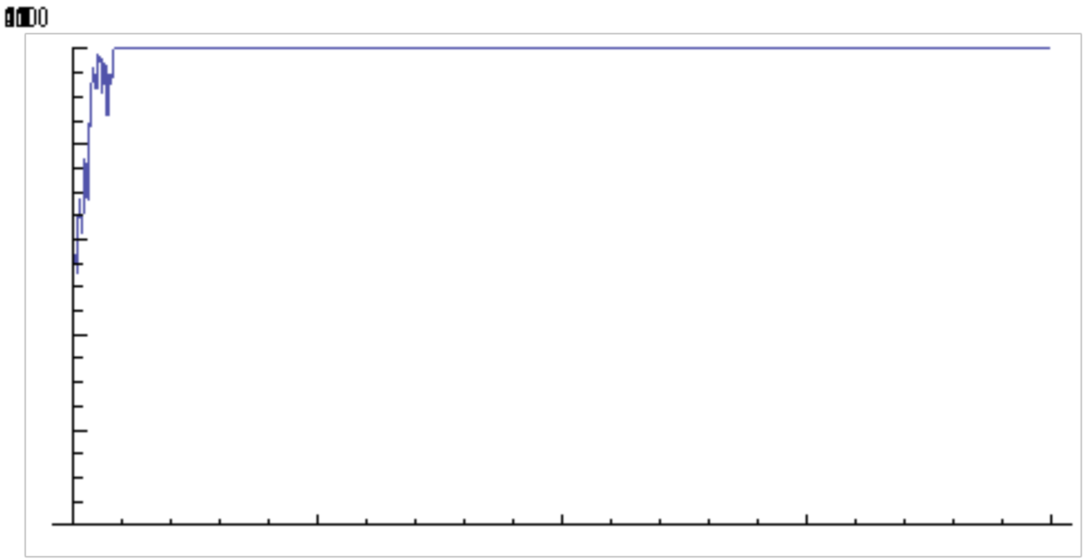
We have a population of agents differing only in which choice they currently hold.

Each update, a number of agents update their choice as follows:

$$p_i = \rho_i$$

That is, the probability of chosing option i is equal to the relative proportion of agents currently holding choice i.

Not surprisingly(!), this leads to a rapid fixation of either of the choices. For example, with two choices



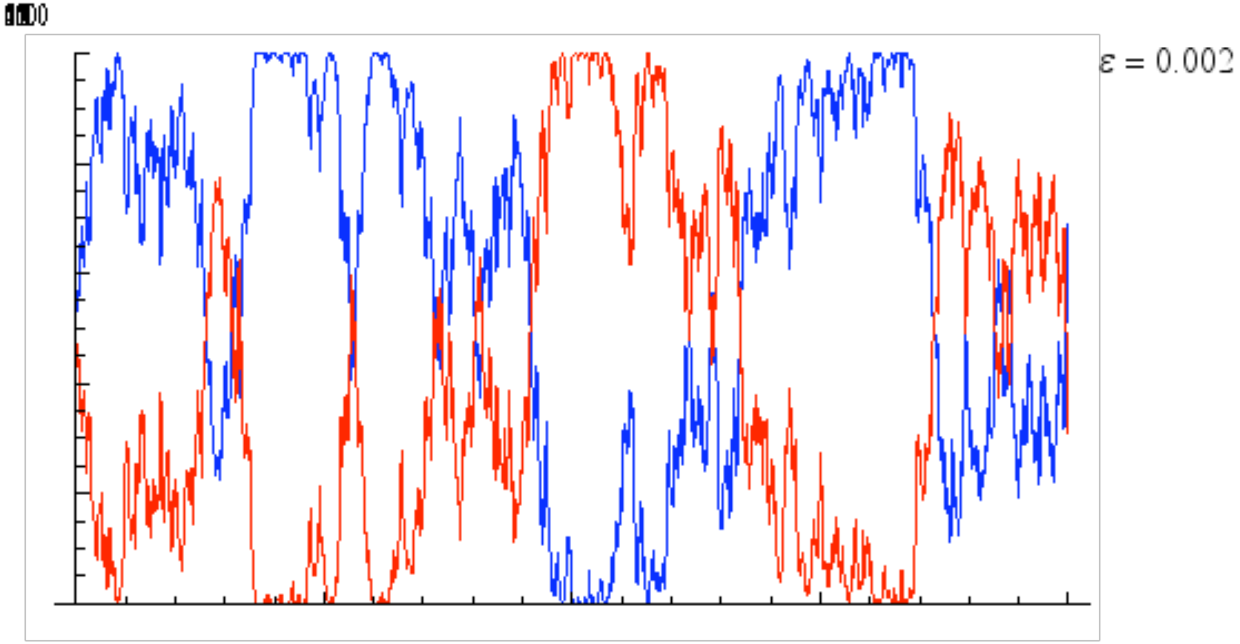
Adding a small modification to this model, it has been investigated in both biology and economics:

$$p_i = \rho_i + \varepsilon$$

The probabiliy of selecting options never drops to zero (Kirman 1993).

The model now begins to behave in a more interesting fashion...

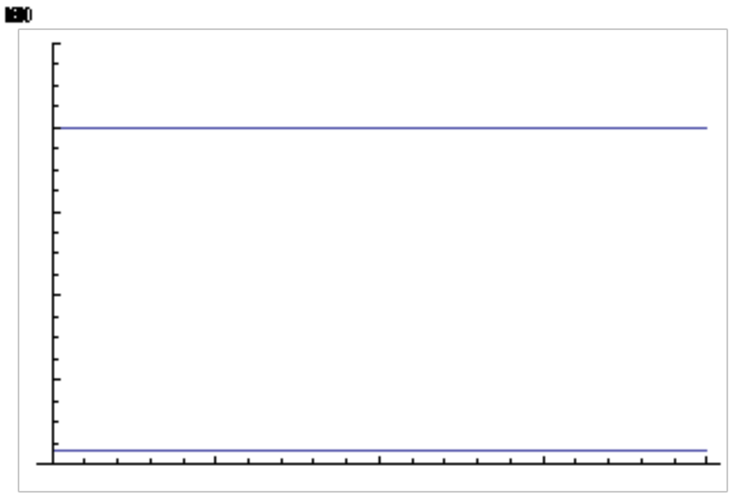
Alan Kirman. “Ants, rationality, and recruitment.” *The Quarterly Journal of Economics, 108(1):137-156, (1993)* The population does spend most of the time near fixation, but switches occasionally between the choices.



Now say that the options are also associated with what we might call an ”intrinsic” or ”self-regarding” goodness.

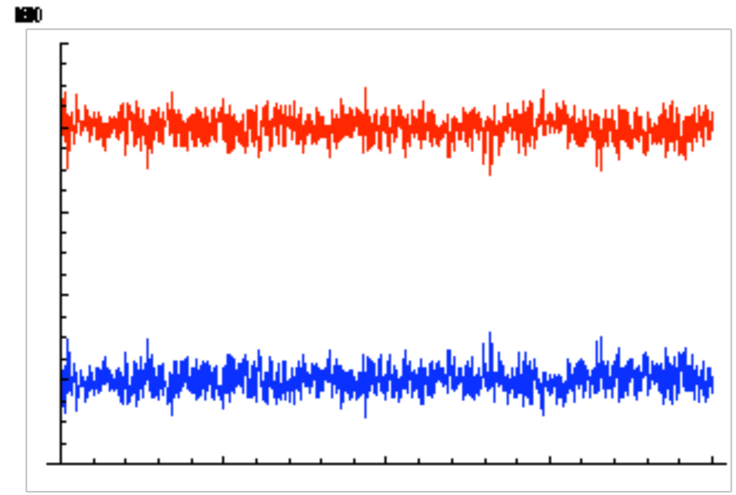
$$p_i = \beta g_i + (1 - \beta)\rho_i$$

We have a parameter so we can tune how much attention agents pay to the other-regarding (herding) and the self-regarding (intrinsic) goodness of the choices.



Average and standard deviation over 10,000 runs

$\beta = 0.5$

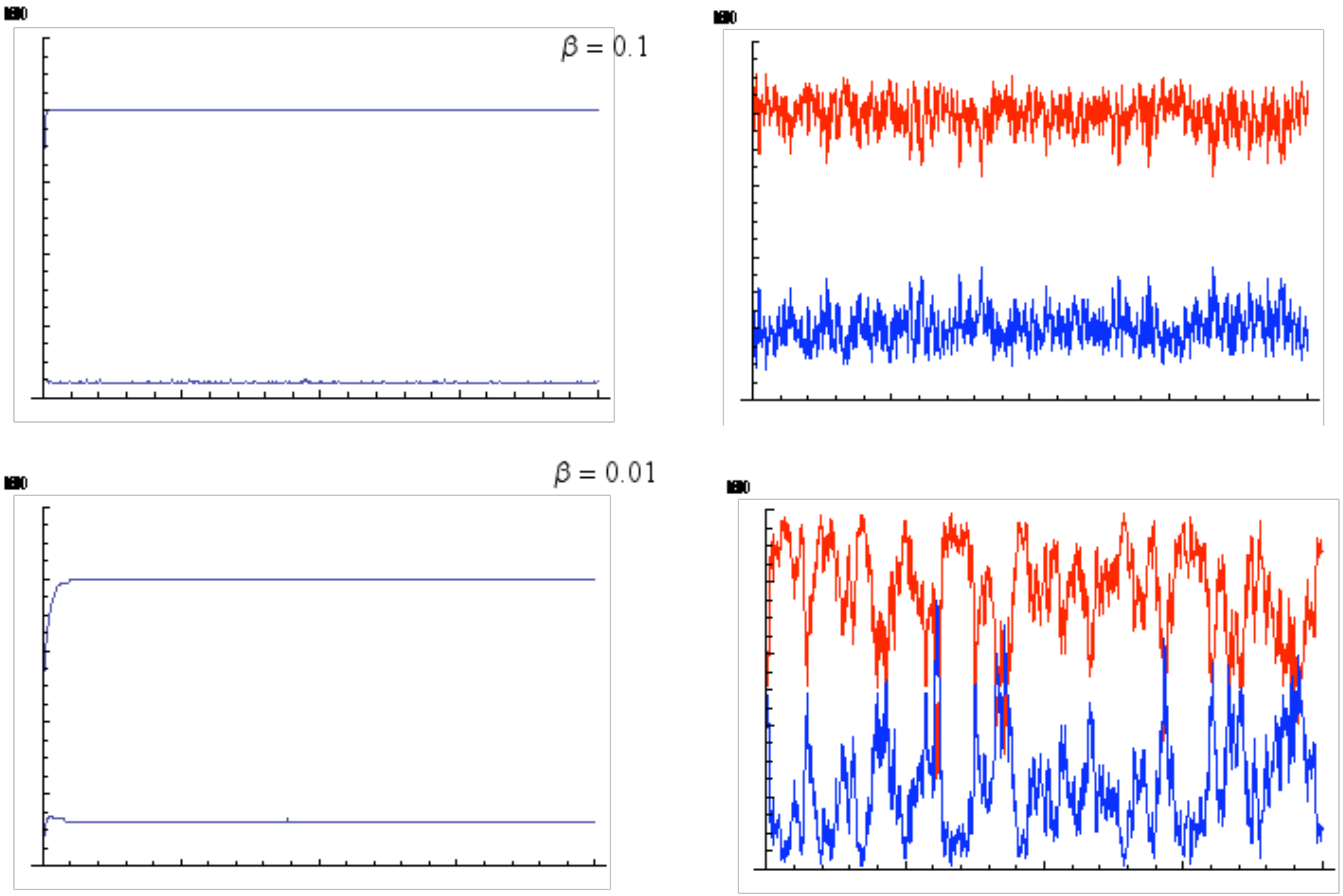


Time evolution with two choices over 100,000 updates (sampled every 50th.) Population is 100,000 agents.

$$g_{red} = 4 \qquad g_{blue} = 1$$

$$\frac{\rho_{red}}{\rho_{blue}} = \frac{g_{red}}{g_{blue}}; \rho_{red} + \rho_{blue} = 1$$

Now say we tune down β from β=0.5 in the previous slide.



Isn’t herding behavior supposed to be a self-reinforcing process?

If we boost this self-reinforcement with a bonus that will benefit it from the beginning, shouldn’t this just drive it more rapidly to fixation?

Indeed, already the herding-with-epsilon model was surprising: how can the population decide to shift all of a sudden?

We start with the simple herding model with two options *a* and *b* ...

$n_a, n_b =$ Number of agents currently holding options *a* and *b* respectively.

$n = n_a + n_b$; i.e. The total number of agents.

$$\rho_a = \frac{n_a}{n} \qquad \rho_b = \frac{n_b}{n}$$

Now, the rate at which holders of *a* reconsider their choice:

$$\frac{dn_a}{dt} = r(n_b \rho_a - n_a \rho_b) = r(n_b \rho_a - n_a(1-\rho_a)) = r(n\rho_a - n_a) = r(n_a - n_a) = 0$$

Rate of change

b :ers changing into *a*

a :ers changing into *b*

This means that <u>all proportions of *a* and *b* holders are fixed points</u>. However, they are not attracting and are thus unstable.

So what we have in herding behavior – at least in this model of herding – is not a question of the system being attracted to the boundaries, but that the system performs a <u>random walk with sticky boundary conditions</u>...

This is half the mystery with the intrinsic goodness effect...

What seemed like a positive feedback (herding) with an additional boost for one of the choices, is in fact something different...

We used

$$p_i = \beta g_i + (1-\beta)\rho_i$$

...and get as the rate of choosing *a* (in the two-options case):

b :ers changing into *a*

a :ers changing into *b*

$$\frac{dn_a}{dt} = r(n_b(\beta g_a + (1-\beta)\rho_a) - n_a(\beta g_b + (1-\beta)\rho_b)) = r(n_b \beta g_a - n_a \beta g_b)$$

$$= r(n\beta g_a - n_a \beta) = r\beta(n g_a - n_a) = r\beta n(g_a - \rho_a)$$

...which is a stable fixed point when $g_a = \rho_a$

Hence, normalizing the goodness such that $g_a + g_b = 1$

...we explain the behavior of the agent-based simulation model.

Corollaries

- Two options with the same intrinsic goodness is not the same as two options without intrinsic goodness
- Paying low attention to a large benefit is not the same as paying high attention to a small benefit

Does this say anything about reality?

Good question... this is work in progress. At least it points to a great ontological uncertainty in even very simple models.

Testing for robustness to *parameter values* is clearly not enough: tiny aspect of the choice of ontology can completely change the behavior of the model.