Cognitive Ecology: System Complexity and Diversity of Models.

Johannes Castner

Columbia University

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General Interest

- Feedbacks between systems and beliefs

- Complexity and Cognition

- Sustainable Development (Collective Intelligence and Collective Action)

Motivating example: Financial Bubbles

Theories of Financial Bubbles (optimists and pessimists, e.g Scheinkman and Xiong, 2003):

- ▶ are about institutions and beliefs: short-sale constraints in the presence of pessimists and optimists
- ▶ pessimists sell all of their shares (exit the market)
- ▶ optimists borrow and buy
- ▶ the bubble ensues
- ▶ but they do not model where beliefs come from.

My dissertation:

1) Shows that the complexity of the system and cognitive bounds jointly give rise to heterogeneity of beliefs; 2) builds an experimental platform to study belief dynamics; and 3) uses this platform to test the cognitive theory of financial bubbles.
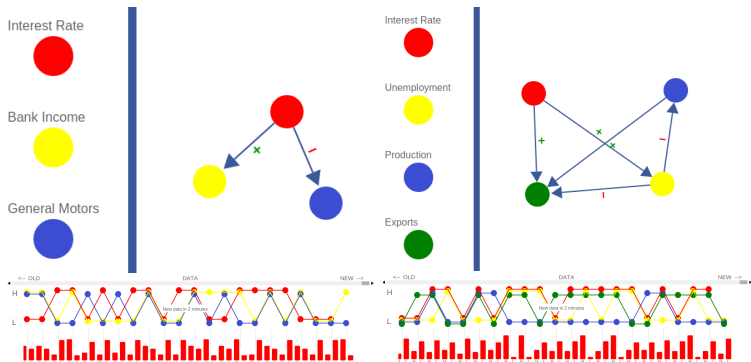
Laboratory Experiments on System Complexity and Cognitive Diversity

A participant's goal (for example): predict Interest Rates.
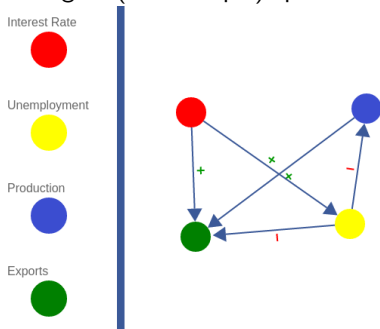
A belief system about a financial system: The nodes are variables and the arrows are causal relations.

Simple and Complex

Measuring Cognitive Diversity

Definition (*N*-Point Jensen-Shannon Divergence)

$$JSD(P_1, \ldots, P_N) = H\left(\sum_{i=1}^{N} \pi_i P_i\right) - \sum_{i=1}^{N} \pi_i H(P_i), \qquad (1)$$

where $H(P)$ is the Shannon entropy for joint-distribution P.

Definition (Cognitive Diversity)

Normalizing for group size I divide by $\sqrt{\log_2(N)}$ and I define
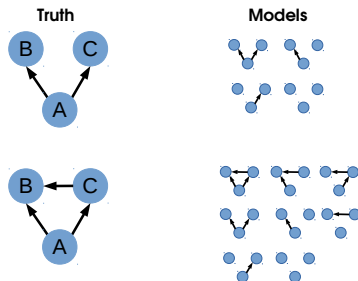Cognitive diversity as

$$CD(P_1, \ldots, P_N) = \sqrt{\frac{JSD(P_1, \ldots, P_N)}{\log_2(N)}}. \qquad (2)$$

In the 2 person case, this is a metric and I call the measure
"Cognitive Distance".

Sources of Diversity of Mental Models

1. Complexity of Causal Structure
2. Entropy
3. Attention as a limited resource (Rational Inattention)

Complexity of Causal Structure

There is a relation between the structural complexity of systems and the diversity of minds.

Entropy

If we think of causation as does Pearl (1988),

$$Pr(\text{Interest Rate} = 1 | \text{Unemployment} = a, \text{Production} = b) = 1 - (1-\pi)^a(1-\pi)^b, \tag{3}$$

where, $a, b \in [0, 1]$ and where 1 means high and 0 means low, then

- If $\pi = 0$ there is no causation at all.
- If $\pi = \frac{1}{2}$ entropy is maximal (the hardest case for inference).
- If $\pi = 1$ Equation 3 is the deterministic OR operator.

Human Cognition as a Noisy Channel

I use the Rational Inattention framework (Woodford, 2012) to show that

- optimizing agents pay more attention to data points that are more frequent
- diversity of predictions arises in low probability states of systems through imprecise updating

The more complex the system, the more low probability states it has and hence complexity induces diversity.

W		X^n		Y^n		$\hat{W}$
Message	Encoder		Channel		Decoder	Estimate of Message

The Near Future

I will continue to triangulate

- ▶ Information and Communication Theory
- ▶ Experimental Social Science
- ▶ Social Science Theory

extending my questions to

- ▶ Conformity of Beliefs
- ▶ Political Manipulation of Beliefs
- ▶ Cultural Norms and Social Aspects of Beliefs

Pearl, J. (1988). *Probabilistic Reasoning in Intelligent Systems.* Morgan Kaufmann, San Mateo, CA.

Scheinkman, J. A. and Xiong, W. (2003). Overconfidence and speculative bubbles. *Journal of Political Economy.*

Woodford, M. (2012). Inattentive valuation and reference-dependent choice. website.