Crises: Equilibrium Shifts and Large Shocks

Stephen Morris (Princeton) and Muhamet Yildiz (MIT)

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Equilibrium shifts lack good explanations

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1. Sovereign Debt Crises
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5. And so on....
We will consider a model with...
- We will consider a model with...
  - a coordination game whose payoffs depend on a "fundamental state"
• We will consider a model with...

  • a coordination game whose payoffs depend on a "fundamental state"
  • the fundamental state follows a random walk
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- there is *hysterisis*: agents keep playing the same action unless it is no longer rationalizable
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  1. Fundamentals hit a critical boundary (we will see how this boundary is determined)
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Equilibrium will shift when....

1. Fundamentals hit a critical boundary (we will see how this boundary is determined)
2. There is a large enough shock to fundamentals - even if it does not take us to the critical boundary (we will see how big this jump must be)
a continuum of players
Static Complete Information Game

- a continuum of players
- each player decides to "invest" or "not invest"
• a continuum of players
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    - $\theta$ is the fundamental state or "fundamentals"
    - $\alpha$ is the proportion of other players investing
Static Complete Information Game Equilibrium

• Equilibria...
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- if $\theta > 1$, players have a dominant strategy to invest
Equilibria...

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- If $\theta > \frac{1}{2}$, "all invest" is the latent equilibrium.
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• fundamentals evolve according to a random walk

\[ \theta_t = \theta_{t-1} + \sigma \eta_t; \]

where \( \eta_t \) is distributed according to p.d.f. \( g \) and \( \sigma \) parameterizes the size of shocks
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- Equilibrium play can depend on history in an arbitrary way; in particular, as long as \( \theta_t \) remains in the interval \([0, 1]\), we can jump around as much as we like....
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- Equilibrium selection strawmen?
  - Play latent action in every period
  - (Hysterisis) play what was played last period as long as it is still an equilibrium
At each date,

- current common fundamental is chosen according to
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- each player has own payoff type

\[ x_i = \theta + \sigma \varepsilon_i \]

where "idiosyncratic shock" \( \varepsilon_i \) is distributed according to p.d.f. \( f \)
• Rank belief: if player $i$ observes own payoff state $x_i$, what probability does he assign to player $j$ observing a lower payoff state $x_j$?
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• Player $i$’s rank belief is now

$$R(z) \equiv \Pr(x_j \leq x_i|z_i = z) = \frac{\int F(\epsilon)f(\epsilon)g(z - \epsilon)\,d\epsilon}{\int f(\epsilon)g(z - \epsilon)\,d\epsilon}$$
A Leading Example

- $f$ is standard normal distribution $N(0, 1)$
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• $g$ is Student’s t-distribution
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- $f$ is standard normal distribution $N(0, 1)$
- $g$ is Student’s t-distribution
  - variance of $\eta_t$ is unknown and distributed with inverse $\chi^2$
Figure: Rank belief function $R$. 
Key Thick Tails Assumption

- $g$ has regularly-varying tails,

$$\lim_{\lambda \to \infty} \frac{g(\lambda \eta)}{g(\lambda \eta')} \in (0, \infty) \text{ for all } \eta, \eta' \in \mathbb{R}_+,$$  \hfill (1)
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- and $f$ has thinner tails:

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- this is maintained assumption
• they are empirically common in relevant applications
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- model uncertainty
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Properties of Rank Beliefs

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- **symmetry**: $R(-z) = 1 - R(z)$; in particular, $R(0) = 1/2$.
- **single crossing at 1/2**: $R(z) > 1/2 > R(-z)$ whenever $z > 0$.
- **uniform rank beliefs**: $R(z) \to \frac{1}{2}$ as $z \to \infty$. 
**Figure:** Rank belief function under normal idiosyncratic shocks and normal or exponential common shocks
Now consider one shot Bayesian game where we fix $\theta_{-1}$, draw players’ payoff types as described above, and let each player’s payoff now depend on his payoff type, i.e., payoff to investing is $x_i + \alpha - 1$.
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Suppose that each player follows a "cutoff" strategy, investing if his normalized payoff type $z$ is above some critical threshold $z^*$.

So a necessary condition for this to be an equilibrium is $R(z) = z + \alpha - 1$.

This is also sufficient as long as higher payoff types lead to higher beliefs about fundamental state, i.e., $F_j(x_i; \alpha)$ is decreasing in $x_i$. 

Equilibria of the One-shot Bayesian Game
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Equilibria of the One-shot Game in Picture

- red line is $R(z)$, blue line is $\sigma z + \theta_{-1}$
Let $z^{**} (\theta_{-1})$ be the largest solution to

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With analogous definitions, not invest is uniquely rationalizable for types $x_i < x^*(\theta_{-1})$. 
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With analogous definitions, not invest is uniquely rationalizable for types $x_i < x^{*}(\theta_{-1})$.

If $x_i \in [x^{*}(\theta_{-1}), x^{**}(\theta_{-1})]$, both actions are rationalizable.
Fundamental Cutoffs and Discontinuity

- From the picture, define $\bar{\theta} \in (0, \bar{R})$ where $\bar{R} = \max R$
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• From the picture, define \( \bar{\theta} \in (0, \bar{R}) \) where \( \bar{R} = \max R \)
• Key discontinuity:
  • as \( \theta_{-1} \) increases to \( \bar{\theta} \), \( x^{**}(\theta_{-1}) > 0 \) decreases continuously
  • at \( \theta_{-1} = \bar{\theta} \), \( x^{**}(\theta_{-1}) \) drops discontinuously and equals \( x^{**}(\theta_{-1}) \)
- We have completely characterized individual rationalizable behavior.
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• MAIN QUESTION: How does MUR depend on $\theta_{-1}$, $\theta$ and thus on $\theta - \theta_{-1}$?
Equilibria of the One-shot Game in Picture

- red line is $R(z)$, blue line is $\sigma z + \theta_{-1}$
• invest is MUR $\iff \theta > x^{**}(\theta_{-1})$, and
• invest is MUR $\iff \theta > x^{**} (\theta_{-1})$, and
• not invest is MUR $\iff \theta < x^* (\theta_{-1})$. 
• What if $|\theta - \theta_{-1}|$ is small?
Majority Play with Small Shocks

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• can show that "strictly positive" is uniformly strictly positive
• so there exists $\Delta > 0$ such that whenever $|\theta - \theta_{-1}| \leq \Delta$, invest is MUR if and only if $\theta_{-1} > \bar{\theta}$
Majority Play with a Large Shock: How Large is Large?

- If $\frac{1}{2} < \theta_{-1} < \bar{\theta}$, then a common shock of size $z^{**} (\theta_{-1})$ will make invest MUR
Majority Play with a Large Shock: How Large is Large?

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- If $\frac{1}{2} < \theta_{-1} < \bar{\theta}$, then a common shock of size $z^{**}(\theta_{-1})$ will make invest MUR
- What can we say about $z^{**}(\theta_{-1})$?
- Want to show that $z^{**}(\theta_{-1})$ is not too high...
Figure: An upper bound for $z^{**}(\theta_{t-1})$ for $\theta_{t-1} > 1/2$. 
Majority Play with a Large Shock: How Large is Large?

\[ z^{**}(\theta_{-1}) \leq \bar{z}(\theta_{-1}) = \max R^{-1}(\theta_{-1}) \]

- Independent of \( \sigma \), it is enough to have a shock of size \( \max R^{-1}(\theta_{-1}) \)
$z^{**} (\theta_{-1}) \leq \tilde{z} (\theta_{-1}) = \max R^{-1} (\theta_{-1})$

- Independent of $\sigma$, it is enough to have a shock of size $\max R^{-1} (\theta_{-1})$
- "large but not too large"
Majority Play with a Large Shock

**Proposition**

*Invest is majority uniquely rationalizable if it was latent under the prior mean (i.e. $\theta_{-1} > 1/2$) and*

$$\theta - \theta_{-1} > \sigma\bar{Z}(\theta_{-1});$$
• Now consider the dynamic incomplete information model...
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- requires careful definition of game, strategies, solution concept (public perfect Bayesian equilibrium)...

That’s It! (Almost)
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- In each period, an equilibrium of the static game is played
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- Equilibria may have arbitrary history dependence
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Nonetheless there are things we can say independent of history;

1. If fundamentals are above the critical boundary at date $t_1$, then there is majority investment at date $t_1$.
2. If investment is latent at date $t_1$ ($t_1 = 2$) and there is a large enough shock $t_1_{\text{max}} R_1(t_1)$, then there is majority investment at date $t_1$.

Define hysterisis equilibrium (a selection from dynamic game equilibria) to be one where players invest if (i) a majority invested in the previous period and (ii) it is rationalizable to invest.

Now we switch from minority investment to majority investment only if one of the two triggers above occur.
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• Nonetheless there are things we can say independent of history;
  
  1 if fundamentals are above the critical boundary at date $t - 1$, $\theta_{t-1} \geq \bar{\theta}$, then there is majority investment at date $t$. 

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     - the critical boundary \( \bar{\theta} \) is bounded above by the maximum rank belief

  2. if invest is latent at date \( t - 1 \) (\( \theta_{t-1} \geq 1/2 \)) and there is a large enough shock \( \theta_t - \theta_{t-1} \geq \max R^{-1}(\theta_{t-1}) \), then there is majority investment at date \( t \).
• Equilibria may have arbitrary history dependence

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  1. if fundamentals are above the critical boundary at date $t - 1$, $\theta_{t-1} \geq \bar{\theta}$, then there is majority investment at date $t$.
     • the critical boundary $\bar{\theta}$ is bounded above by the maximum rank belief
  2. if invest is latent at date $t - 1$ ($\theta_{t-1} \geq 1/2$) and there is a large enough shock $\theta_t - \theta_{t-1} \geq \max R^{-1}(\theta_{t-1})$, then there is majority investment at date $t$.

• Define hysteresis equilibrium (a selection from dynamic game equilibria) to be one where players invest if (i) a majority invested in the previous period and (ii) it is rationalizable to invest.
Equilibria may have arbitrary history dependence

Nonetheless there are things we can say independent of history;

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Define hysterisis equibrium (a selection from dynamic game equilibria) to be one where players invest if (i) a majority invested in the previous period and (ii) it is rationalizable to invest.

Now we switch from minority investment to majority investment only if one of the two triggers above occur.
• If a "good" equilibrium is being played, and fundamentals are on the way down, it is better to have fundamentals drift down slowly (or bad news to be released gradually)
Implications

- If a "good" equilibrium is being played, and fundamentals are on the way down, it is better to have fundamentals drift down slowly (or bad news to be released gradually).
- If a bad equilibrium is being played, and fundamentals are heading up, it is better to have fundamentals jump up (or good news released in chunks).
Competing Hypothesis? Coordination and Common Knowledge

- Equilibrium shifts occur which triggered by common knowledge events
Competing Hypothesis?  Coordination and Common Knowledge

- Equilibrium shifts occur which triggered by common knowledge events
  - folk argument
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Questions:
Equilibrium shifts occur which triggered by common knowledge events

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Questions:

- If going from multiplicity to multiplicity, what explains direction of shift?
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Questions:

- If going from multiplicity to multiplicity, what explains direction of shift?
- Similarly, if going from uniqueness to multiplicity (c.f., global game arguments)
Equilibrium shifts occur which triggered by common knowledge events

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Questions:

- If going from multiplicity to multiplicity, what explains direction of shift?
- Similarly, if going from uniqueness to multiplicity (c.f., global game arguments)
- Feels like we go from multiplicity to uniqueness?
shift occurs to latent equilibrium not because it has become (approximate) common knowledge that things are better....
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but because shock creates lack of common knowledge that things are not good and thus strategic uncertainty (shorting market participants no longer confident that others are shorting)
• shift occurs to latent equilibrium not because it has become (approximate) common knowledge that things are better....
• but because shock creates lack of common knowledge that things are not good and thus strategic uncertainty (shorting market participants no longer confident that others are shorting)
• shock would not have worked unless good equilibrium had already become latent equilibrium
Analysis is essentially as before, except that the big shock effect goes away.
Analysis is essentially as before, except that the big shock effect goes away.

Compare (first generation) global games:
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Compare (first generation) global games:

- adding similar incomplete information
1 Analysis is essentially as before, except that the big shock effect goes away.

2 Compare (first generation) global games:
   - adding similar incomplete information
   - focus on globally unique equilibrium
1. Analysis is essentially as before, except that the big shock effect goes away.

2. Compare (first generation) global games:
   - adding similar incomplete information
   - focus on globally unique equilibrium
   - all (?) analysis away from the limit done for (silly?) normal normal case
Analysis is essentially as before, except that the big shock effect goes away.

Compare (first generation) global games:

- adding similar incomplete information
- focus on globally unique equilibrium
- all (?) analysis away from the limit done for (silly?) normal normal case

- this paper: sometimes multiplicity (resolved by hysterisis) sometimes uniqueness, intuitive rank beliefs