Moldy Lemons and Market Shutdowns

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Markets with Adverse Selection

Motivation: Sudden Market Shutdowns and Non-Exclusive Contracting

- How can a market that functions well in normal times suddenly collapse under stress?
  - dry-up of asset-backed securities markets
  - freezing of interbank markets
  - derivatives markets

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- Akerlof showed adverse selection can create market shutdown
- Rothschild and Stiglitz showed screening with menus of contracts
- Non-exclusive contracting environment: agents can trade and contract simultaneously with multiple counterparties (e.g. CDOs/CLOs, derivatives, OTC, and insurance markets)

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- Moldy lemons: small shift in distribution of agents in the market

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2. We extend the model with outside options
   - sudden market shutdowns occur due to cascade of exits
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2. We extend the model with outside options
   - sudden market shutdowns occur due to cascade of exits
   - when one agent exits, incentives to remain in the market becomes **weaker** for all other agents
3. Comparative statics for how susceptible the markets are
   - coarser vs finer distribution of types (information event)
   - monitoring the best agent is important

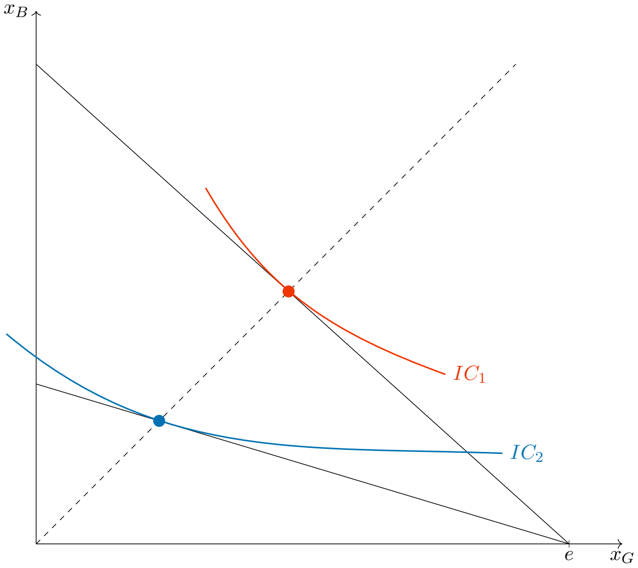
Literature

- Adverse selection:
  Akerlof (1970), Rothschild and Stiglitz (1976), Bisin and Gottardi (1999, 2003), Dubey and Geanakoplos (2002), Dubey et al. (2005), Hendren (2013, 2014), Azevedo and Gottlieb (2017)
- Sudden collapse of markets:
  Calomiris and Gorton (1991), Mishkin (1999), Ivashina and Scharfstein (2010), Covitz et al. (2013), Beltran et al. (2017), Foley-Fisher et al. (2020)
- Financial market breakdown:
  Kurlat (2013, 2016), Chari et al. (2014), Malherbe (2014), Asriyan et al. (2019), Gorton and Ordoñez (2019, 2020), Dang et al. (2020)
- Nonexclusive competition under adverse selection:
  Pauly (1974), Jaynes (1978), Hellwig (1988), Glosten (1994), Attar et al. (2011, 2014, 2021), Dubey and Geanakoplos (2019), Auster et al. (2021)

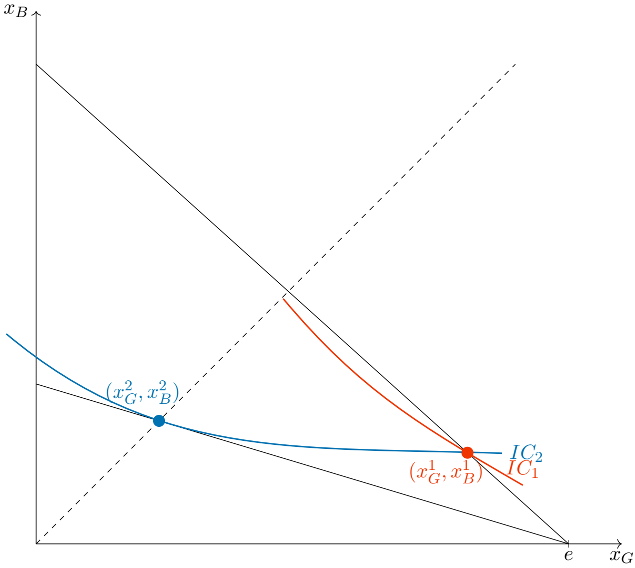
Rothschild and Stiglitz (QJE, 1976)

- Two different types of agents $i \in \{1, 2\}$
- State for each agent can be either bad with p_i or good ($p_1 < p_2$)
- Agent receives endowment e in a good state and 0 in a bad state
- Agents are risk-averse
- Suppliers are risk-neutral and competitive
- Assume single-crossing ($MRS_1 < MRS_2$ at every point)

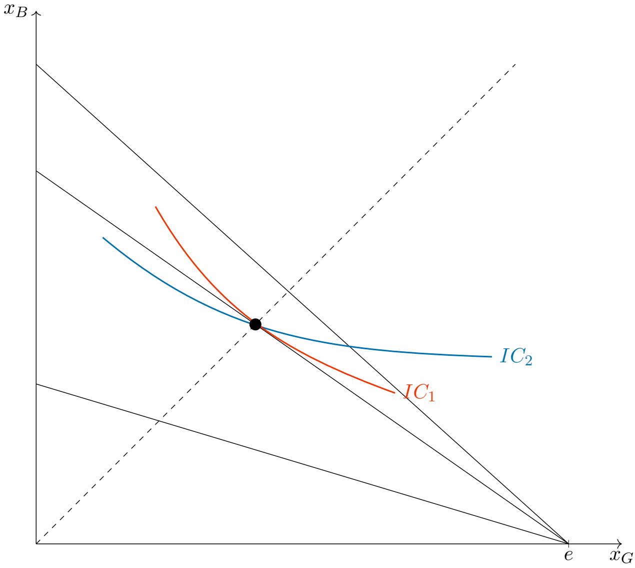
No Asymmetric Info Case



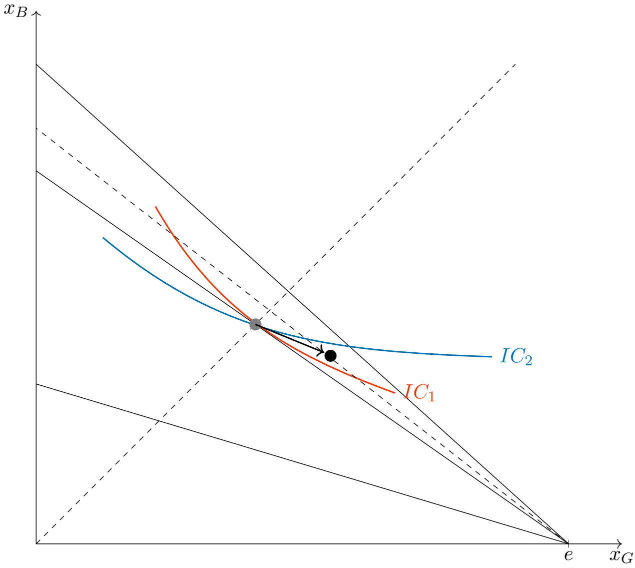
Asymmetric Info: Separating Equilibrium



Pooling Allocation



Cream-Skimming and Market Unraveling



Non-exclusive Contracts: Attar et al. (AER, 2021)

- There are n different types of agents with mass m_i for each i
- (Strict) single-crossing property
- Suppliers of contracts pay linear unit cost c_i for each i ($\uparrow$ in i)
- Non-exclusive contracts imply upper-tail conditional expected cost:

$$\bar{c}_i \equiv \frac{\sum_{j \geq i} m_j c_j}{\sum_{j \geq i} m_j}$$

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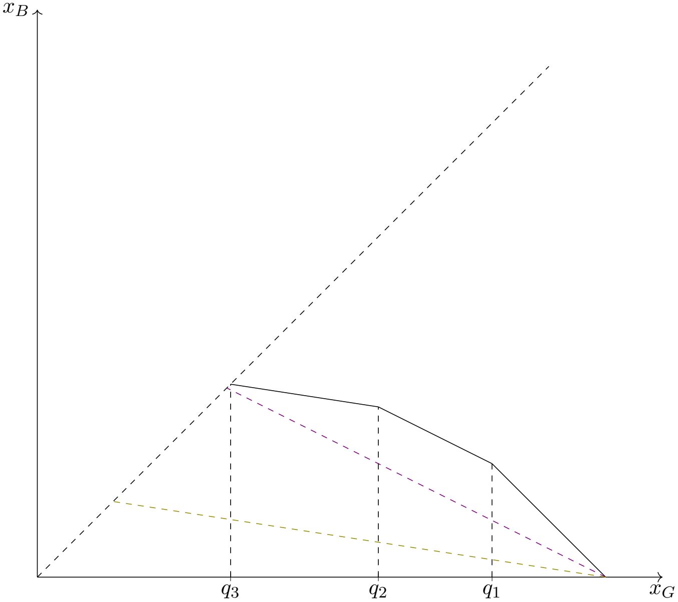
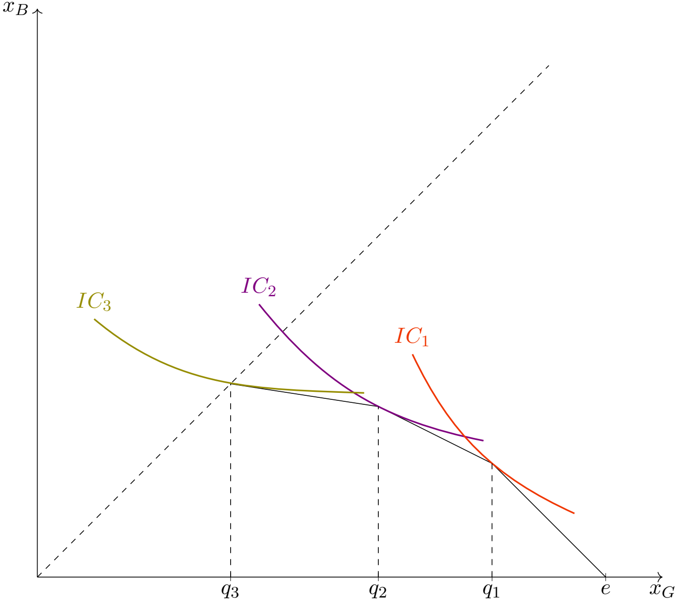
- Recast this to Rothschild Stiglitz (1976)
(Dubey and Geanakoplos (2019))
- What if we introduce moldy lemons in such models?

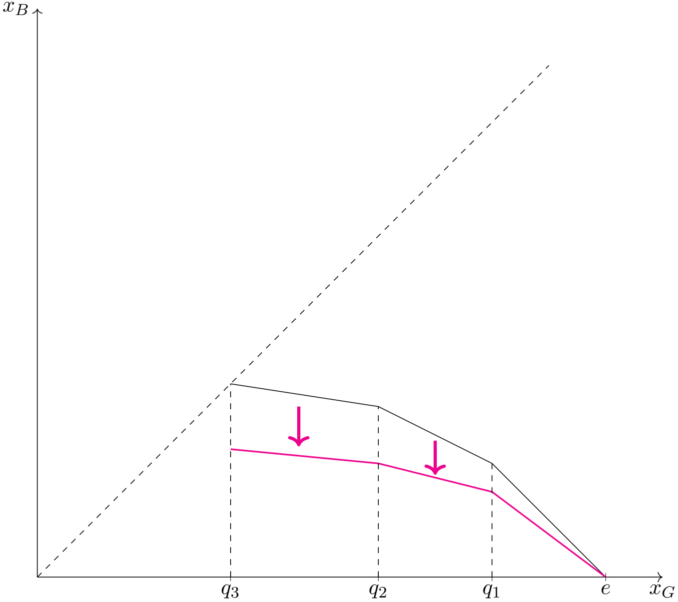
Consumption Possibility Frontier



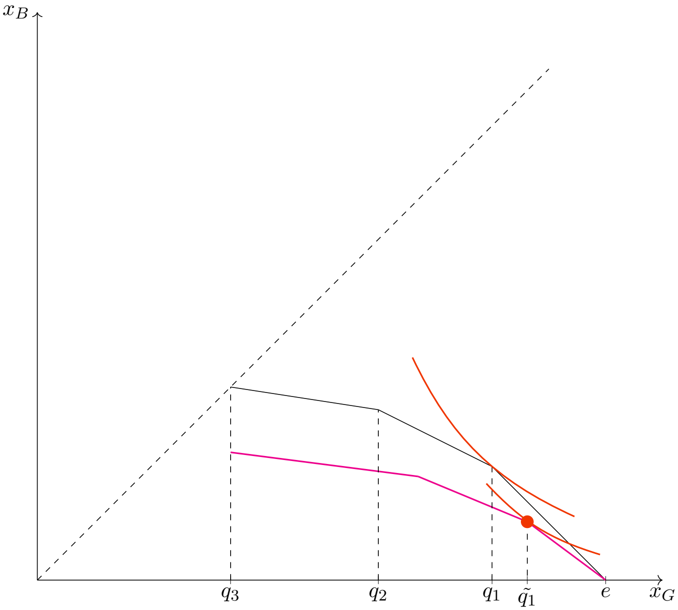
Non-exclusive Contracts with ICs



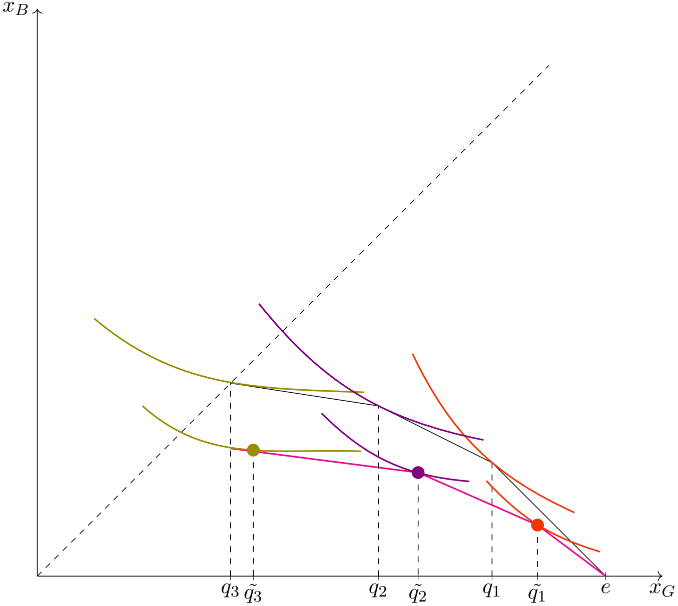
Moldy Lemons Comparative Statics



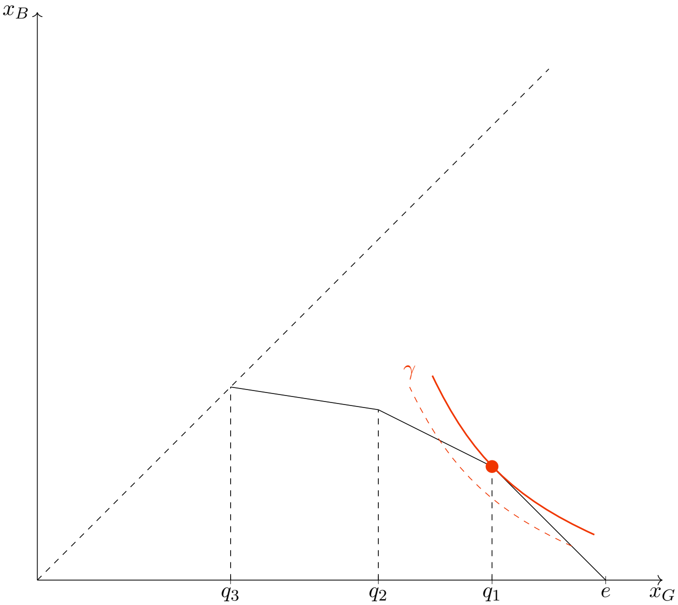
Moldy Lemons Comparative Statics with IC



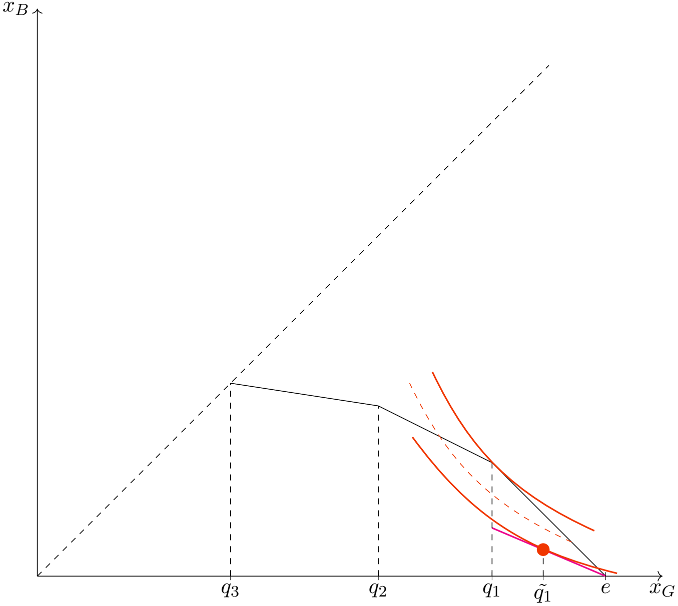
Moldy Lemons Comparative Statics Full Eqm



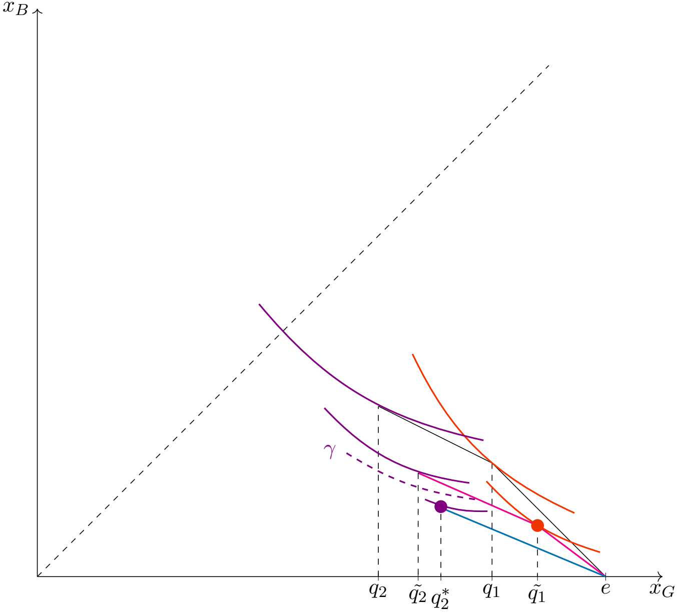
Extension with Outside Options



Initial Exit due to Outside Options



Cascade of Exits



Demand

- Type of agents: $i \in I = \{1, 2, \ldots, n\}$
- Mass: m_i for each type i
- Utility: $u_i(q, t)$ continuous, quasi-concave in (q, t) and $\downarrow$ in t
- Quantity q and transfer t

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- (Strict) Single crossing: $\forall i < j,\ q < q',\ t,\ t'$

$$u_i(q, t) \leq u_i(q', t') \Rightarrow u_j(q, t) < u_j(q', t')$$

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$$u_i(q,t) \leq u_i(q',t') \Rightarrow u_j(q,t) < u_j(q',t')$$

- MRS: $\left(\dfrac{\partial u_i}{\partial q} \Big/ \dfrac{\partial u_i}{\partial t}\right)$ but more generally

$$\tau_i(q,t) \equiv \sup \left\{ p : u_i(q,t) < \max_{q' \geq 0} u_i(q+q', t+pq') \right\}$$

- Assumption 1: $\tau_i(q,0) \leq \tau_i(0,0) \qquad \forall i, q > 0$

Supply

- Unit cost c_i for each type i
- Assume c_i is increasing in i
- $\bar{c}_i \equiv E[c_j | j \geq i] = \dfrac{\sum_{j \geq i} m_j c_j}{\sum_{j \geq i} m_j}$ (upper-tail conditional expected cost)

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- A contract (q, t) for $q \geq 0$
- A market is *entry-proof* iff for any menu of contracts offered by an entrant, there exists a best response by the buyer such that the entrant earns at most zero expected profit.

Entry-Proof in Inactive Markets

- Condition EP: $\tau_i(0,0) \leq \bar{c}_i \qquad \forall i$

- **Theorem A1.** (Attar et al. (2021))
  An inactive market is entry-proof iff condition EP holds.

- Market Breakdown: non-null contracts yield negative profits

- **Corollary A1.** (Attar et al. (2021))
  If buyers' preferences are strictly convex and strict single crossing holds, then market breakdown iff EP.

Entry-Proof in Active Markets

- Market tariff: $T(q)$ the minimum aggregate transfer
- Assume that $T(q)$ is convex and the domain is a compact interval
- $(q_i, T(q_i))_{i \in I}$ is *implemented* by $T \Rightarrow q_i = \arg\max_q u_i(q, T(q))$
- $(q_i, T(q_i))_{i \in I}$ is *budget-feasible* $\Rightarrow \sum_i m_i \left[T(q_i) - c_i q_i\right] \geq 0$

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- Entrants face types with indirect utility functions

$$u_i^T(q', t') \equiv \max\left\{u_i\left(q + q', T(q) + t'\right) : q\right\}$$

Entry-Proof in Active Markets

- New entry-proofness: $\tau_i^T(0,0) \leq \bar{c}_i$ for each i.

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- **Theorem A2.** (Attar et al. (2021))

  $(q_i, T(q_i))_{i \in I}$ is budget-feasible and implemented by an entry-proof convex market tariff T with domain $[0, q_n]$ iff

  1. $(q_0, T(q_0)) \equiv (0, 0)$.
  2. $q_i - q_{i-1} \in \arg\max\{u_i(q_{i-1} + q', T(q_{i-1}) + \bar{c}_i q' : q'\}$ for each i.
  3. $q_{i-1} < q_i \Rightarrow T$ is affine with slope $\bar{c}_i$ over $[q_{i-1}, q_i]$ for each i.

- Strategic foundation: discriminatory ascending-price auction (Attar et al. (2021)) or competitive pooling in general equilibrium (Dubey and Geanakoplos (2019))

Comparative Statics: Moldy Lemons

- **Theorem 1.** (Moldy Lemons; This Paper)
  Suppose $n+1$ type (moldy lemons) with m_{n+1} and $c_{n+1} > c_n$ enters the market. Then, for
  $\tilde{\bar{c}}_i \equiv (\bar{c}_i \sum_{j \geq i} m_j + c_{n+1} m_{n+1}) / (\sum_{j \geq i} m_j + m_{n+1}) > \bar{c}_i$

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  1. All inactive markets (market shutdown) remain inactive under the new equilibrium.

  2. All active markets will remain active and have the new steeper equilibrium slope for the aggregate tariff, $\tilde{T}$, as $\bar{\tilde{c}}_i > \bar{c}_i$ over $[\tilde{q}_{i-1}, \tilde{q}_i]$ for every i if $\tilde{q}_i > \tilde{q}_{i-1}$.

  3. Active markets become inactive and shut down iff $\tau_i^{\tilde{T}}(0,0) \leq \bar{\tilde{c}}_i$ and $\tilde{q}_i = \tilde{q}_{i-1}$.

Comparative Statics: Moldy Lemons ctd.

- Moldy lemons only make a gradual change in the market.
- cf) q_i changes continuously wrt $\bar{c}_i$ by Berge's maximum thm.
- Exit of an agent does not affect MRS at $(0, 0)$ point and incentives to enter for other agents.
- m_{n+1} has to be large enough to cause a market shutdown.

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- γ_i : utility level from outside option for type i

- Instead of the null action $u_i(0,0)$, each agent compares the set of market contracts to their outside option (individual rationality):

$$V_i(T) = \max\left\{\gamma_i,\ \max_{q\geq 0} u_i(q, T(q))\right\}$$

Akerlof Unraveling: Cascade of Exits

- Assume $u_i(q,t) \geq \gamma_i \Rightarrow u_j(q,t) > \gamma_j$, $\forall i < j,\ \forall q > 0,\ \forall t$.
  - Important to have some structure on γ to ensure existence

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- Two interpretations of outside options:
  1. Fixed entry cost $u_i(0,-\xi)$: $u_i(q,t) \geq \gamma_i \Rightarrow u_j(q,t) > \gamma_j$ for all $i < j$, because lower types value payments more
  2. Opportunity cost of agents entering a separate market that requires costly verification of agent's type: only the low type agent will be willing participate in such markets.
     (e.g. MBS with TBA vs SP markets)

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- **Proposition 2.** In any active market equilibrium, there is a cutoff $\theta \in I \cup \{0\}$ such that any agents with type less than or equal to θ exits the market and any agents with type greater than θ remain in the market.
- Agents exit the market in the order of types (e.g. $1, 2, 3, \ldots$)

Moldy Lemons and Market Shutdowns

- **Condition ML**(i): For any $j < i$, $\max_{q \geq 0} u_j\left(q, \tilde{\tilde{c}}_j q\right) < \gamma_j$
- **Theorem 2.** Any agent $j < i$ exits the market in equilibrium iff Condition ML(i) is satisfied.

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- Two roles of the outside option γ:
  1. Discontinuous jumps in q_i (e.g. $u_i(q_i, T(q_i)) = \gamma_i$)
  2. Discontinuous cascade of exits ($\because$ spillovers from other agents)

- Entry incentives go the other direction without outside options

Coarse vs Fine Partition of Types

- How sensitive are the exit-cascades to the partition of types?
- What if multiple types are grouped into one type with large mass?
- Combine type 1 and 2 together to create a new type:

$$\hat{c}_1 = \frac{m_1 c_1 + m_2 c_2}{m_1 + m_2}$$
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- Coarser partition is less vulnerable to moldy lemons
- Importance of multiple types for market shutdowns.
- Markets with increasing variety of agents can be more susceptible to small change in fundamentals.

Partition of Types and Exit-Cascades

- An economy $\{\hat{I}, \hat{m}, \hat{u}, \hat{c}, \hat{\gamma}\}$ is a *coarser partition* of $\{I, m, u, c, \gamma\}$ if
  1. $\hat{I} \subset I$.
  2. If $i \in \hat{I}$ and $i+1 \in \hat{I}$, then $\hat{m}_i = m_i$, $\hat{u}_i = u_i$, and $\hat{c}_i = c_i$.
  3. If $i \in \hat{I}$ and $i+1, \ldots, i+k \notin \hat{I}$, while $i+k+1 \in \hat{I}$ or $i+k+1 > n$, where $k \geq 1$, then agent $i \in \hat{I}$ *includes* agents $i, i+1, \ldots, i+k$ and $\hat{m}_i = \sum_{l=0}^{k} m_{i+l}$, $\hat{u}_i(q,t) = \dfrac{\sum_{l=0}^{k} m_{i+l} u_{i+l}(q,t)}{\sum_{l=0}^{k} m_{i+l}}$, $\hat{c}_i = \dfrac{\sum_{l=0}^{k} m_{i+l} c_{i+l}}{\sum_{l=0}^{k} m_{i+l}}$, and $\hat{\gamma}_i = \dfrac{\sum_{l=0}^{k} m_{i+l} \gamma_{i+l}}{\sum_{l=0}^{k} m_{i+l}}$.

- **Proposition 3.** Let $\{\hat{I}, \hat{m}, \hat{u}, \hat{c}, \hat{\gamma}\}$ be a coarser partition of $\{I, m, u, c, \gamma\}$ with $i \in \hat{I}$ and $i+1 \notin \hat{I}$. Then, there exists a moldy lemon mass, m_{n+1}, such that i does not exit in $\{\hat{I}, \hat{m}, \hat{u}, \hat{c}, \hat{\gamma}\}$, while i exits in $\{I, m, u, c, \gamma\}$.

Implications

- A small mass of moldy lemons can generate a sudden market shutdown.
  $\Rightarrow$ relatively inexpensive policy interventions can prevent amplification, leading to sudden and costly market collapses.

- The most restrictive condition is $\max_{q \geq 0} u_1(q, T(q)) \simeq \gamma_1$.
  Once agent 1 exits, the downward jumps in utility are cumulative as agent n will face the decreases in utility from exits of $1, 2, \ldots, n-1$.
  $\Rightarrow$ monitoring the best agent is important!

- Model could be applied to various contexts and markets with adverse selection.
  $\Rightarrow$ Coarse partition result provides a general theoretical underpinning of the information production literature.

Rothschild-Stiglitz Unraveling

- What if the single-crossing-like condition for outside options does not hold?
  (cf. $u_i(q,t) \geq \gamma_i \Rightarrow u_j(q,t) > \gamma_j$ for all $i < j$ and $q > 0$)

- Exit of an agent can have both direction of effects:
  - Strategic complementarity: exit of a good agent can trigger exits of worse agents
  - Strategic substitutability: exit of a bad agent can trigger entries of better agents

- Non-existence of equilibrium a la Rothschild and Stiglitz can happen

Conclusion

- Models without outside option: quantities change smoothly because an exit does **not** decrease **marginal rate of substitution**
  - Entry-Proofness is very strong and robust
    $\Rightarrow$ requires **large** mass of moldy lemons for market shutdowns
- Our model: quantities plunge because of an exit decreases **total utility**, which could trigger a cascade of exits
  - **Small** mass of moldy lemons can trigger market shutdown
- Initial trigger from incentives not change in equilibrium (bank runs)
- Simple general model provides more clear insights

Appendix

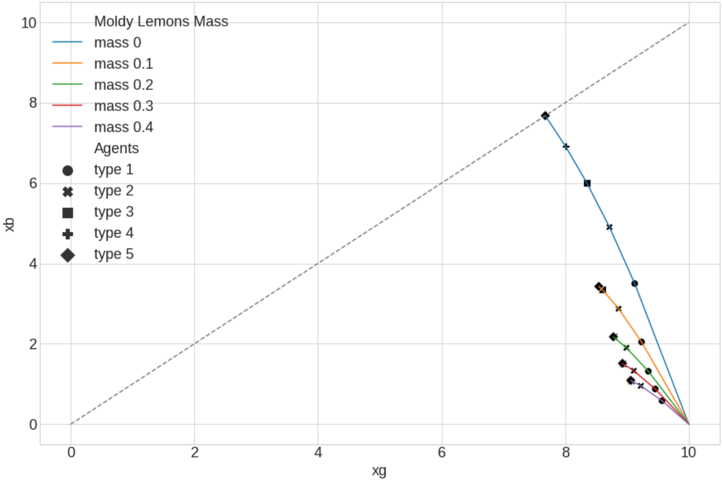
Appendix: Technical Assumptions

- $u_i^T(q', t')$ are quasiconcave in (q', t') and strictly decreasing in t'
  $\Rightarrow$ can define $\tau_i^T(q', t')$

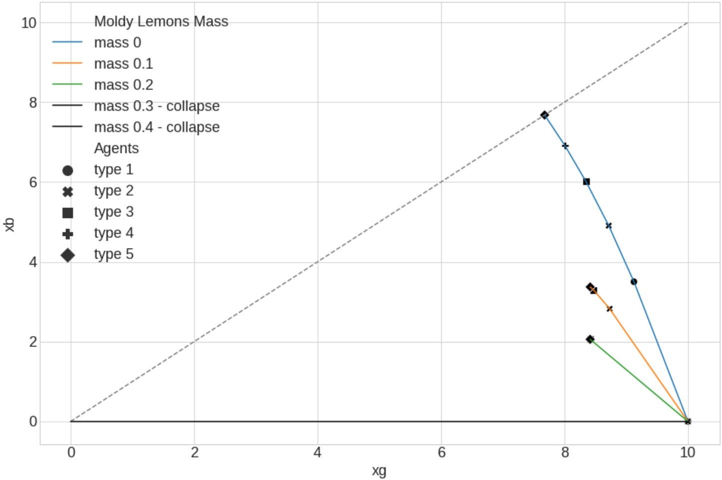
- Assumption 2: $\tau_i(q, t)$ is nonincreasing in q for all i, t

- **Lemma A1.** (Attar et al. (2021))
  If Assumption 2 holds for the primitive MRS $\tau_i(q, t)$, then
  Assumption 1 holds for the indirect MRS $\tau_i^T(q', 0)$.

Appendix: Simulation–Baseline Model



Appendix: simulation–Outside-options Model



Appendix: Simulation–Partition of Types