Making Sense of the Experimental Evidence on Endogenous Timing in Duopoly Markets

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Outline of Talk

- Endogenous Timing in Oligopolistic Markets
- Theory and Experimental Evidence
- Reciprocity and Inequity Aversion
- Results
- Summary
- Extensions and Discussion

Endogenous Timing in Oligopolistic Markets

- This literature tries to identify the key factors that might lead to the endogenous emergence of sequential or simultaneous play in oligopolistic markets.
- The seminal contributions are: Saloner (1987), Hamilton and Slutsky (1990) and Robson (1990).
- However, observed behavior in experiments on the canonical models of endogenous timing is at odds with the theory.

Saloner's Duopoly Game (1987)

- Duopoly with two periods where firms can produce in <u>both</u> periods before the market clears.

- Timing of the game:

  1) Firms decide simultaneously first period output

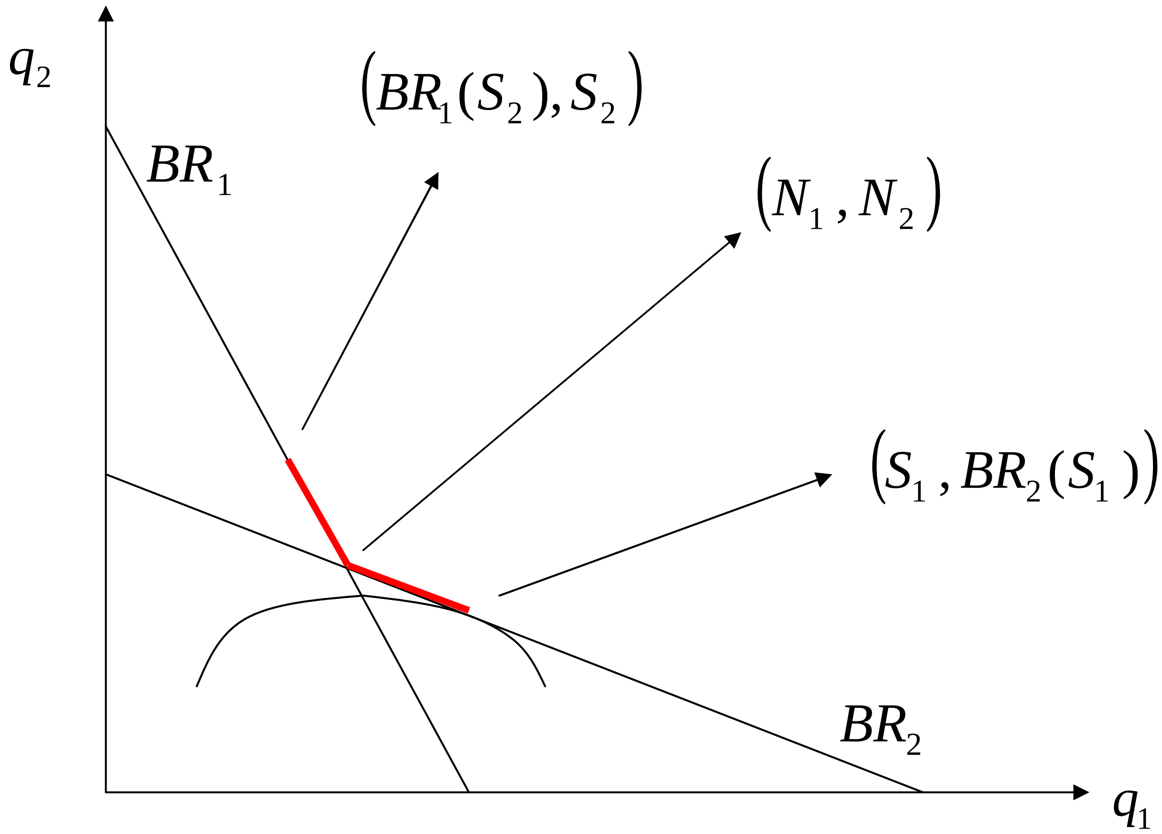
  2) Firms observe first period choices

  3) Firms decide simultaneously second period output

  4) The market clears

Saloner's Duopoly Game (1987)

- Set of SPNE is E: Outer envelope of the firms' best reply functions between (and including) the Stackelberg points.



Saloner's Duopoly Game (1987)

- The following strategy is a SPNE:

$$q_1^i = a^i \text{ s.t. } (a^1, a^2) \in E$$

$$q_i^2 = \begin{cases} N^i - q_i^1, & \text{if } q_1^i \leq N^i \text{ and } q_1^j \leq N^j \\ 0 & \text{if } q_1^i \geq N^i \text{ and } q_1^j \leq BR^j(q_1^i) \\ 0 & \text{if } q_1^i \geq BR^i(q_1^j) \text{ and } q_1^j \geq BR^j(q_1^i) \\ BR^i(q_1^j) - q_1^i & \text{if } q_1^i \leq N^i, N^j \leq q_1^j, \text{and } q_1^i \leq BR^i(q_1^j) \end{cases}$$

Experimental Evidence on Saloner's Game: Müller (2003)

1. Stackelberg outcomes are extremely rare.

2. Simultaneous-move symmetric outcomes are modal.

3. Sometimes collusive outcomes are observed.

4. There is production in both periods with 84% of production taking place in the first period.

5. Subjects seem to try to balance market shares in P2.

6. Subjects produce less than $BR(S)$ in P1.

Hamilton and Slutsky's Duopoly Game (1990)

- Two firms must decide a quantity to be produced in <u>one</u> of two periods before the market clears
- If a firm commits to a quantity in the first period, it acts as the leader but it does not know whether the other firm has chosen to commit early or not.
- If a firm commits to a quantity in the second period, then it observes the first period production of the opponent (or its decision to wait).

Hamilton and Slutsky's Duopoly Game (1990)

- Game has 3 SPNE:
  - Both firms committing in the first period to the simultaneous-move Cournot equilibrium quantities
  - Firm 1 waiting and firm 2 playing its Stackelberg leader quantity in the first period.
  - Firm 2 waiting and firm 1 playing its Stackelberg leader quantity in the first period.

Experimental Evidence on Hamilton and Slutsky's Game: Huck, Müller, and Normann (2002)

1. Stackelberg outcomes are rare.

2. Simultaneous-move Cournot outcomes are modal.

3. Behavior is quite heterogeneous: collusive outcomes are played, Stackelberg warfare is observed, and followers punish leaders.

4. Simultaneous-move outcomes are often played in the second production period.

Inequity Aversion and Reciprocity

- Willingness to give up some material payoff to move in the direction of more equitable distributions of payoffs.
- Willingness to incur losses to punish those who treat us unkindly and to reward those who treat us kindly.
- Inequity aversion and/or reciprocity have been shown to explain behavior in bargaining and trust games.
- Can they also explain behavior observed in experiments with endogenous timing in duopolistic markets?

Set-up

- Smooth Cournot model.
- Set of firms: $\{1,2\}$.
- Demand is given by $P(Q)$ with $P'(Q) < 0$
- Revenue is given by $R_i(q_i, Q_{-i}) = P(Q)q_i$
- Marginal revenue is decreasing $P'(Q) + P''(Q)q_i \leq 0$

Set-up

- Costs are given by $C_i(q_i)$ with $C_i'(q_i) \geq 0$
- Material payoff is concave in own ouput: $C_i''(q_i) - P'(Q) > 0$
- These conditions guarantee the existence and uniqueness of equilibrium in the smooth one period Cournot model of quantity competition.

Set-up

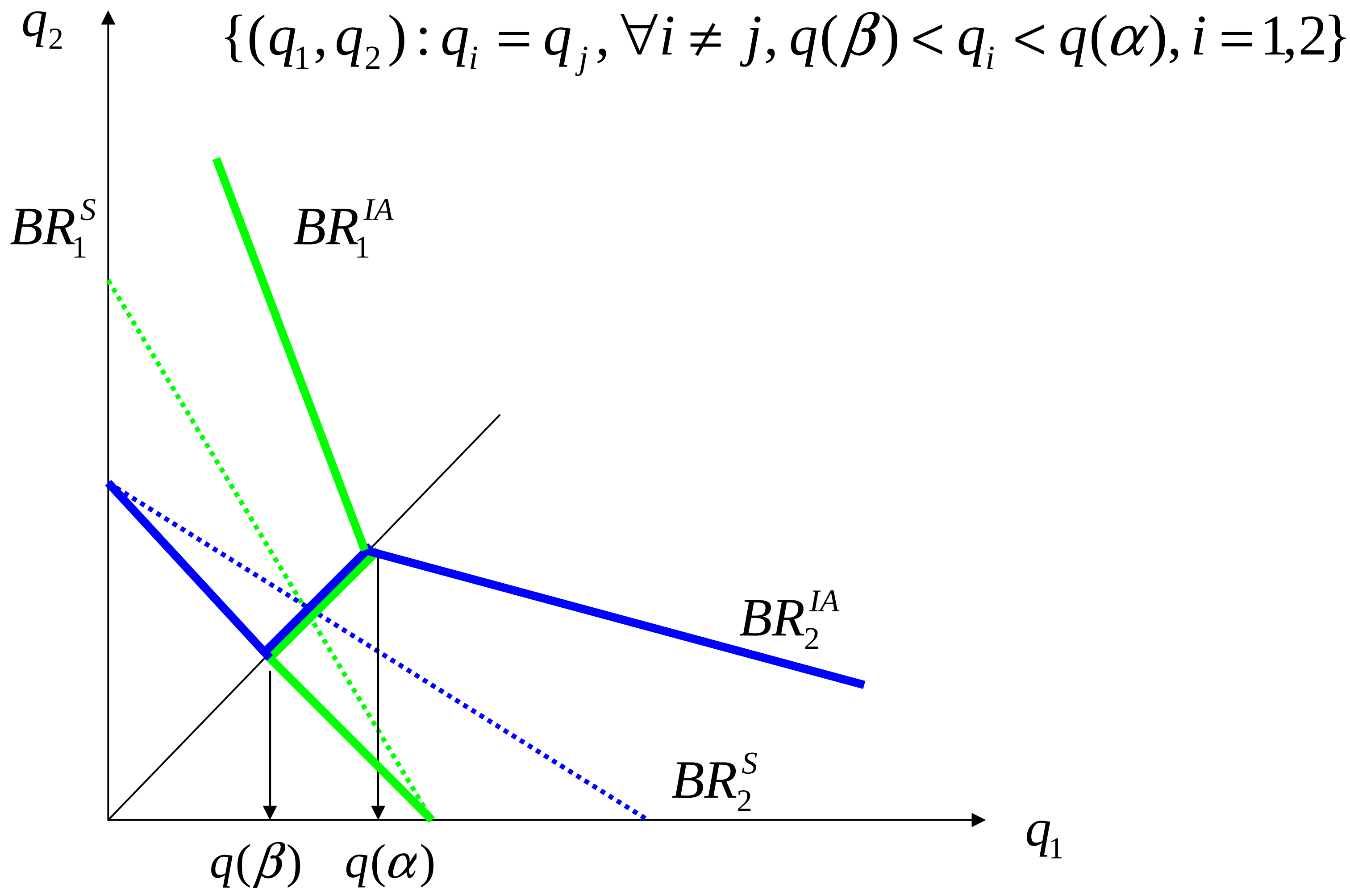
- Fehr and Schmidt's (1999) model of inequity aversion:

$$U_i(\pi_i, \pi_j) = \begin{cases} (1-\beta_i)\pi_i + \beta_i \pi_j, \text{if } \pi_j < \pi_i \\ \pi_i, \qquad\qquad\qquad\quad \text{if } \pi_j = \pi_i \\ (1+\alpha_i)\pi_i - \alpha_i \pi_j, \text{if } \pi_j > \pi_i \end{cases}$$

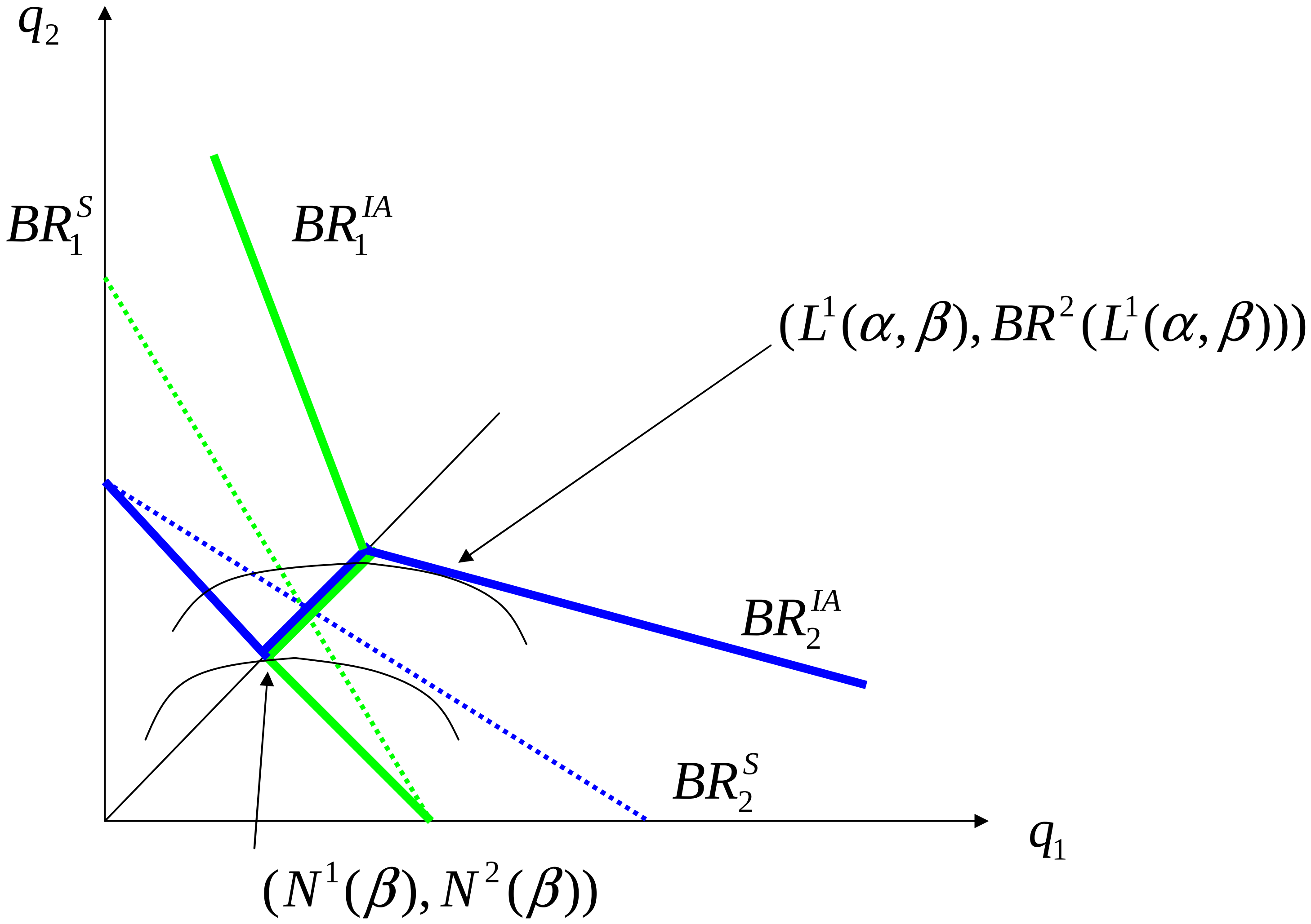
- An inequity averse player feels compassion ($0<\beta_i<1$) towards the opponent if the opponent has lower profits.

- An inequity averse player feels envy ($0<\alpha_i<1$) towards the opponent if the opponent has higher profits.

Cournot Duopoly Game with Inequity Averse Firms



Stackelberg Leadership with Inequity Averse Firms



Saloner's Duopoly Game with Inequity Averse Firms

- **Proposition 1:** If inequity aversion is relatively high, that is,

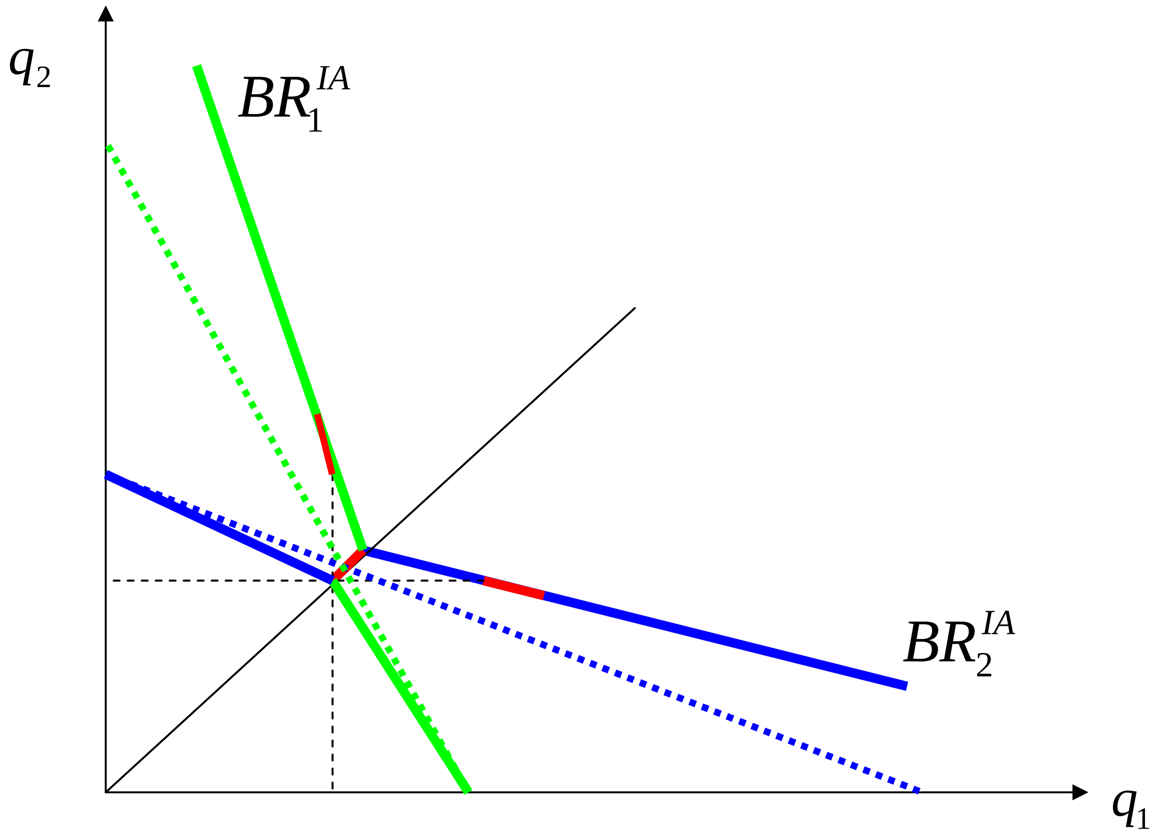
  $$U^i(N^i(\beta), N^j(\beta)) \geq U^i(L^i(\alpha,\beta), BR^j(L^i(\alpha,\beta))), \quad i \neq j = 1,2$$

  then the set of SPNE of Saloner's game coincides with the set of Nash equilibria of the single-period Cournot game.

- **Intuition**: Relatively high levels of inequity aversion increase the inequity costs of choosing a first period production that leads to asymmetric quantities and so the game has no asymmetric equilibria.

Saloner's Duopoly Game with Inequity Averse Firms

- **Proposition 2:** If inequity aversion is relatively low, then the set of SPNE of Saloner's game has three subsets.



Saloner's Duopoly Game with Inequity Averse Firms

	Sym. eq.	Asym. eq.	Coll. out.	Stack. warf.	Time prod.	Balance shares	Prod P1
Inequity Aversion							
High	Many	_	Yes	Yes	P1,P2	Yes	No
Low	Many	_	No	No	P1,P2	Yes	No
	_	Many	_	_	P1,P2	_	No

H&S's Duopoly Game with Inequity Averse Firms

- **Proposition 3**: If inequity aversion is relatively high, that is,

$$U^i(N^i(\beta), N^j(\beta)) \geq U^i(L^i(\alpha, \beta), BR^j(L^i(\alpha, \beta))), \quad i \neq j = 1,2$$

  then the set of SPNE of Hamilton and Slutsky's game coincides with the set of Nash equilibria of the single-period Cournot game.

- **Intuition**: Same as before.

H&S’s Duopoly Game with Inequity Averse Firms

- **Proposition 4**: If inequity aversion is relatively low, then the set of SPNE of H&S’s game has three subsets:
  - A set of symmetric equilibria.
  - Firm 1 is a compassionate Stackelberg leader and firm 2 is an envious Stackelberg follower.
  - Firm 2 is a compassionate Stackelberg leader and firm 1 is an envious Stackelberg follower.

H&S's Duopoly Game with Inequity Averse Firms

	Sym. eq.	Stack. eq.	Coll. out.	Stack. warf.	Time prod.	Punish leader	Cournot in P2
Inequity Aversion							
High	Many	_	Yes	Yes	P1	_	No
Low	Many	_	No	No	P1	_	No
	_	Two	_	_	_	Yes	_

Summary

- The paper incorporates inequity aversion in two canonical models of endogenous timing in oligopolistic markets.

- I find that inequity aversion can explain several experimental findings on endogenous timing games.

- I also find that high levels of inequity aversion rule out asymmetric equilibria but low levels do not.

Extensions and Discussion

- Santos-Pinto (2006) shows that general forms of inequity aversion (and reciprocity) can change equilibrium outcomes in Cournot and Bertrand games.

- More precisely, inequity aversion and reciprocity can lead to collusive outcomes and to Stackelberg warfare.

- This means that most of the findings in this paper extend to more general forms of inequity aversion and also to reciprocal preferences.

Extensions and Discussion

- However, the continuum of symmetric equilibria result is specific to piecewise linear inequity aversion.

- This implies that general forms of inequity aversion and reciprocity can not explain production in both periods in Saloner's game.

- Subjects' in experiments have incomplete information about inequity aversion parameters of their rivals.

- Maybe playing low quantities in the first period in Saloner's game is a way to signal to the rival a preference for symmetric outcomes.