Innovation, Licensing and Market Structure in Agricultural Biotechnology

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Motivation

- Agricultural biotechnology stylized facts:
  - Rapid innovation and firm consolidation over the past 3 decades
  - Endogenous sunk costs (R&D expenditures)
  - Complementary technologies
  - Strengthening of property rights over plant and seed varieties as well as genetic traits since the 1970s
  - Recent increase in licensing and cross-licensing of technologies between firms

Market Structure in Ag. Biotech.

- Kalaitzanodakes and Marks (2000)
  - Argue for licensing arrangements with greater flexibility under a product life-cycle framework
- Goodhue, *et al*. (2002)
  - Incentives of firms to consolidate via M&A versus exclusive or non-exclusive license agreements
- Johnson and Melkonyan (2003)
  - Choice of ownership structure and R&D investment depend upon substitutability/specificity of assets
- Shi (2009)
  - Firms consolidate or license technology depending upon subsitutability/complementarity between intellectual assets

Sutton's Capabilities Model

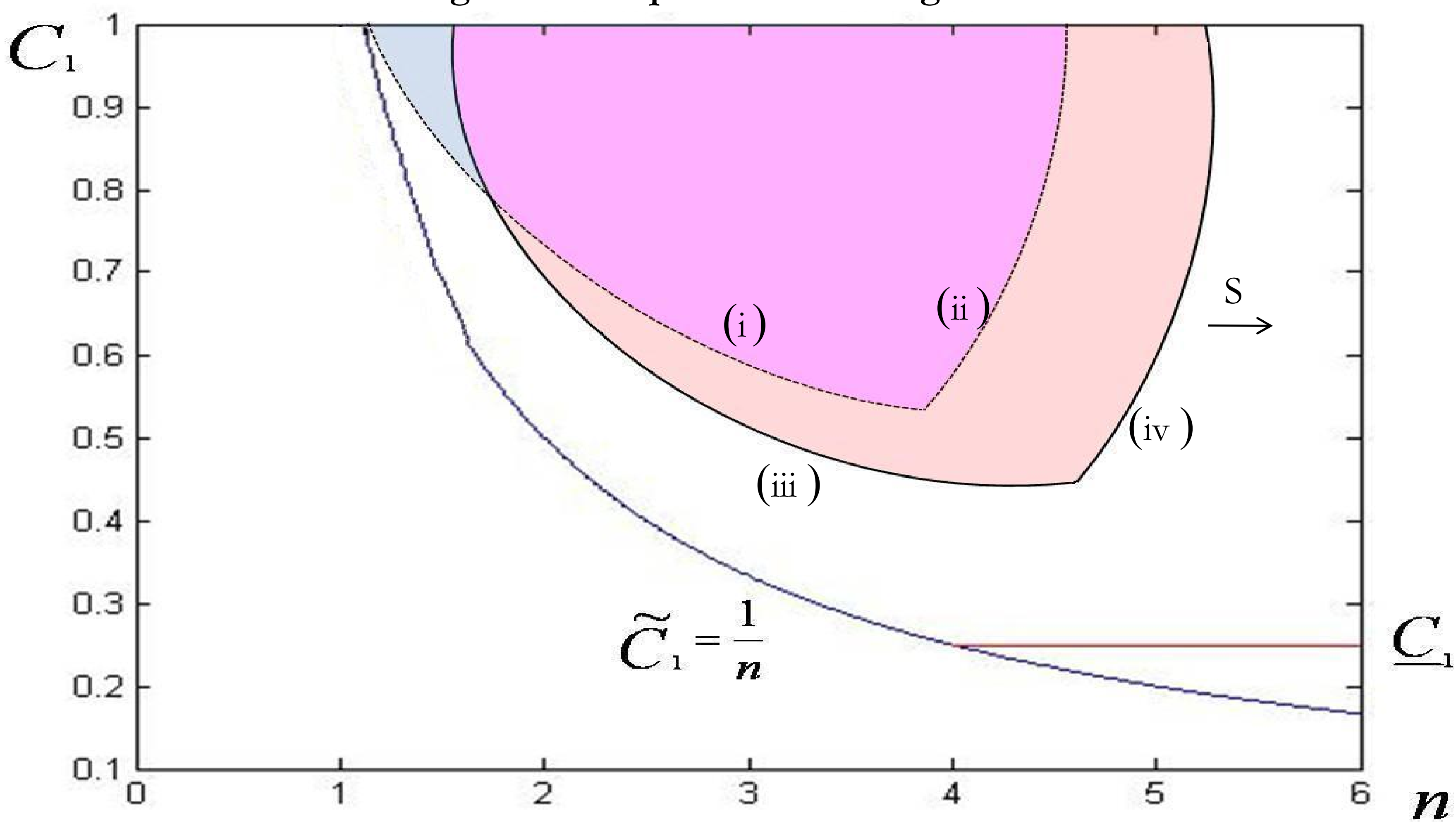
- Sutton (1997, 1998, 2008)
  - Endogenously determined market structure and sunk cost framework
  - Vertical product differentiation
    - Quality/Capability/Technology
  - Incentives to innovate (firm concentration)
  - Escalation of (sunk) R&D expenditure
  - Lower bound to industry concentration

Extending the Capabilities Model

- Incorporate the ability of firms to license technological capabilities to competitors
- Two mechanisms by which firms can improve their competence along a research trajectory:
  i. R&D expenditure
  ii. Licensing
- Lower levels of industry concentration compared to Sutton's "capability" model
  - Feasible under well-defined property rights
  - Changes the incentives of firms to innovate

Graphical Illustration

Figure 6: Δ Equilibrium Configurations



Illustrative Example

- Consumer (Linear) Demand Function:

$$U = \left[x_i - \frac{x_i^2}{u_i^2}\right] + \left[x_j - \frac{x_j^2}{u_j^2}\right] - 2\sigma\left[\frac{x_i}{u_i} \cdot \frac{x_j}{u_j}\right] + V \qquad (1),$$

- Optimal Quantity Choice:

$$x_i^* = \frac{1}{2}\left(\frac{2u_i^2 - \sigma u_i u_j}{4 - \sigma^2}\right) \qquad (5).$$

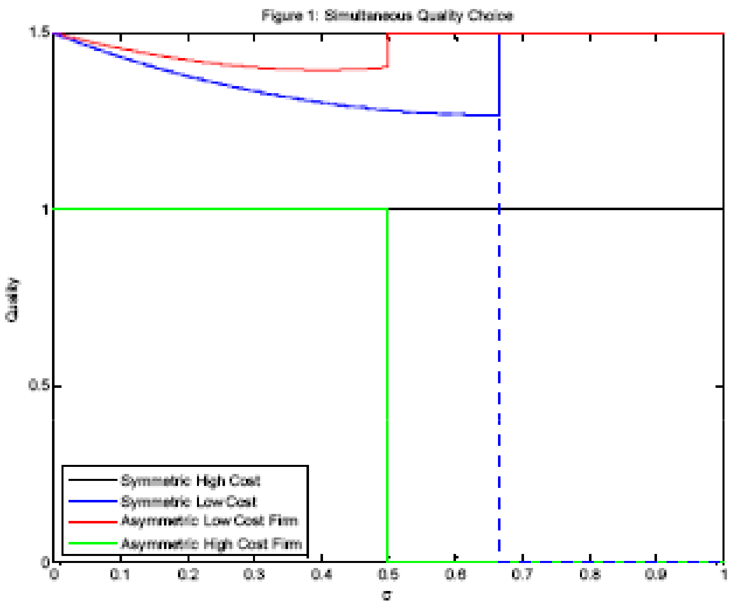
- Firm *i* Quality Choice Problem:

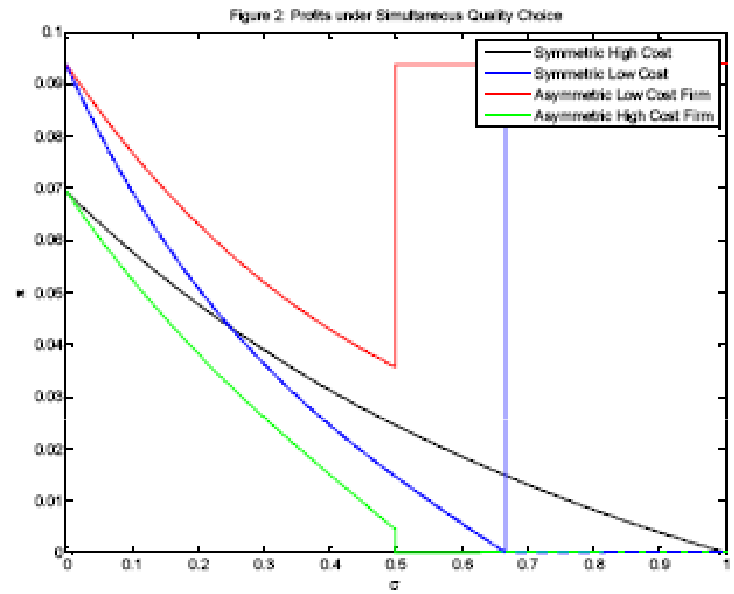
$$\max_{u_i \in \{0,[1,\infty]\}} \frac{1}{2}\left(\frac{2u_i - \sigma u_j}{4 - \sigma^2}\right)^2 - F_0(u_i)^{\beta_i} \qquad (9).$$

- Firm *i* Kuhn-Tucker First-Order Conditions:

$$u_i\left[\frac{2(2u_i - \sigma u_j)}{(4 - \sigma^2)^2} - \beta_i F_0 u_i^{\beta_i - 1}\right] = 0 \qquad (10).$$

Simultaneous Quality Choice





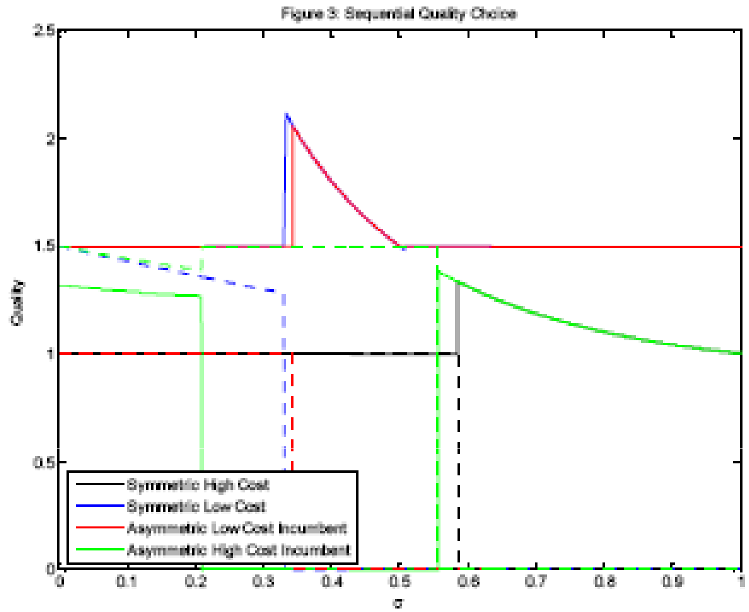
$$4u_i - 2\sigma u_j - (4-\sigma^2)^2 \beta_i F_0 u_i^{\beta_i - 1} = 0$$

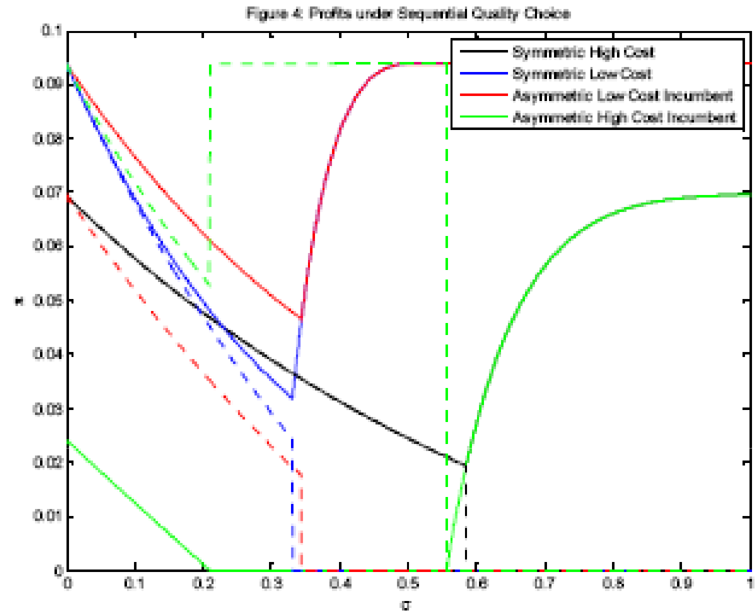
$$4u_j - 2\sigma u_i - (4-\sigma^2)^2 \beta_j F_0 u_j^{\beta_j - 1} = 0 \qquad (14).$$

subject to: $u_i, u_j \in \{0, [1, \infty)\}$

$\pi_i, \pi_j \geq 0$

Sequential Quality Choice





$$u_i^M = \begin{cases} \left[\dfrac{1}{4F_0\beta_i}\right]^{\frac{1}{\beta_i - 2}}, & \forall\, 2 < \beta_i < \dfrac{9}{2} \\ 1, & \forall\, \beta_i \geq \dfrac{9}{2} \end{cases} \qquad (15).$$

$$4u_i\left[1-(4-\sigma^2)F_0\beta_i u_i^{\beta_i-2}\right] - 2\sigma u_j\left[1-(4-\sigma^2)F_0\beta_j(\beta_j-1)u_j^{\beta_j-2}\right]$$
$$-(4-\sigma^2)F_0\beta_j(\beta_j-1)u_i u_j^{\beta_j-1}\left[4-(4-\sigma^2)^2F_0\beta_i u_i^{\beta_i-2}u_j^{-1}\right]=0 \qquad (17).$$

$$\bar{u}_i \geq \sigma^{-1}\left[2-(2F_0)^{\frac{1}{2}}(4-\sigma^2)\right] \qquad (19).$$

$$4u_j - 2\sigma u_i - (4-\sigma^2)^2 F_0\beta_j u_j^{\beta_j-1} = 0$$

Sequential Quality Choice under Licensing

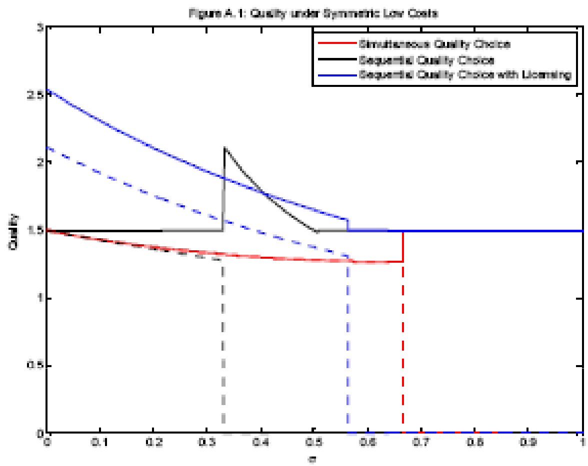
$$\max_{u_i, v_j, \alpha} \frac{1}{2}\left(\frac{2u_i - \sigma(\delta u_i + v_j)}{4-\sigma^2}\right)^2 - F_0 (u_i)^{\beta_i} + \frac{\alpha}{2}\left(\frac{2(\delta u_i + v_j) - \sigma u_i}{4-\sigma^2}\right)^2$$

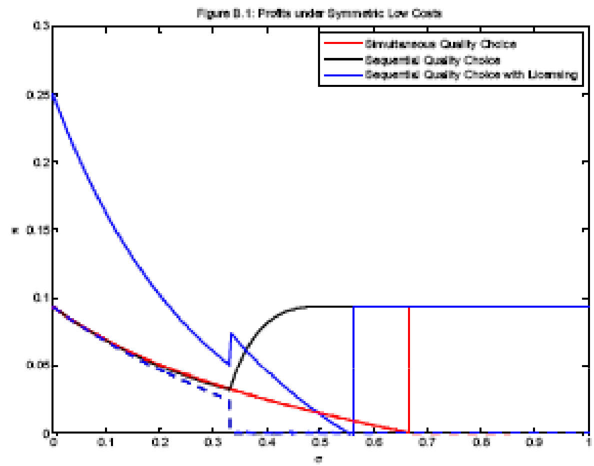
$$\begin{gathered} s.t.\ (1-\alpha)\left(4(\delta u_i + v_j) - 2\sigma u_i\right) - (4-\sigma^2)^2 \beta_j F_0 {v_j}^{\beta_j - 1} \leq 0 \\ \frac{(1-\alpha)}{2}\left(\frac{2(\delta u_i + v_j) - \sigma u_i}{4-\sigma^2}\right)^2 - F_0 v_j^{\beta_j} - T_0 \geq \bar{\pi}_j \\ u_i \in \{0, [1, \infty)\} \\ v_j \geq 0 \\ \alpha \in [0,1] \\ \pi_i, \pi_j \geq 0 \end{gathered} \qquad (20).$$

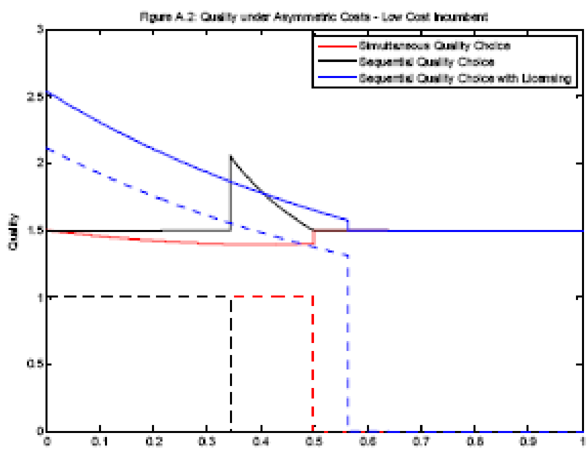
$$\alpha^* = 1 - 2\left(\frac{4-\sigma^2}{(2\delta - \sigma)u_i}\right)^2 \left[T_0 + \bar{\pi}_j\right] \qquad (21).$$

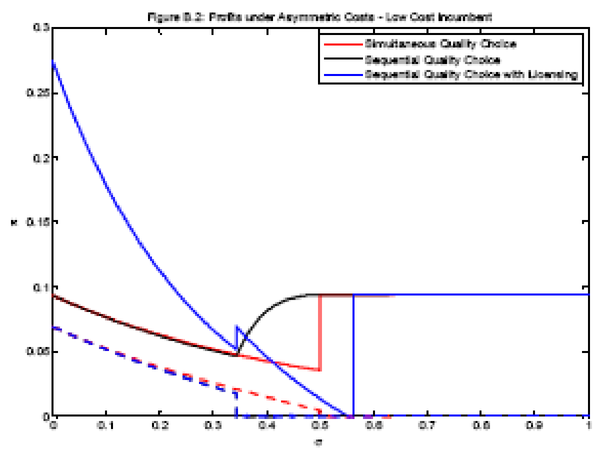
$$u_i^* = \left[\frac{(2-\sigma\delta)^2 + (2\delta - \sigma)^2}{(4-\sigma^2)^2 F_0 \beta_i}\right]^{\frac{1}{\beta_i - 1}} \qquad (22).$$

Sequential Quality Choice under Licensing



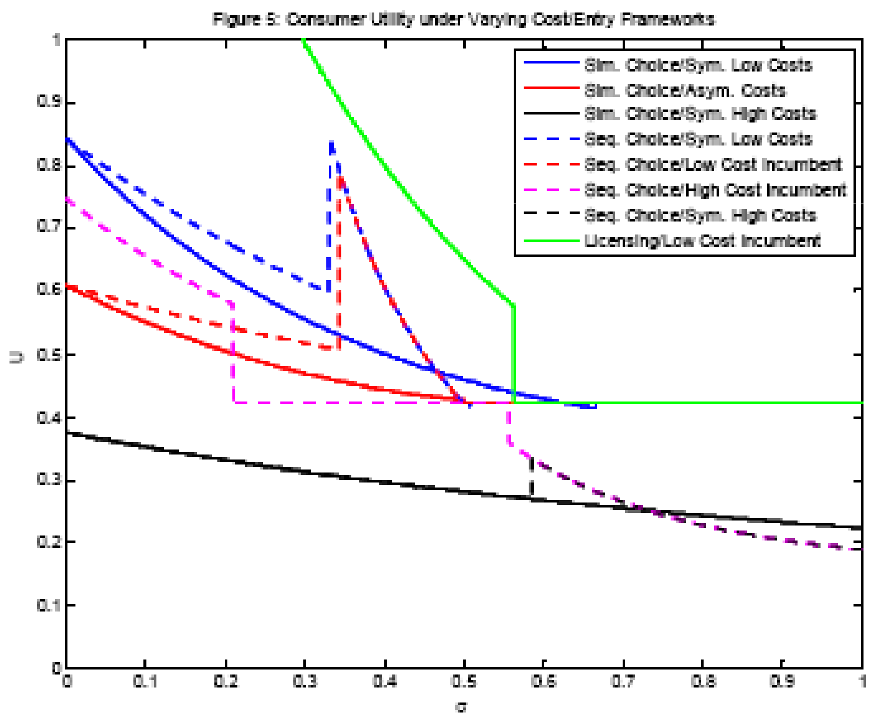






Illustrative Example

- Consumer Utility:



Questions/Comments

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