Innovation or Imitation?  
The effect of spillovers and competitive pressure on firms’ R&D strategy choice

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September 2011
Outline:

- Introduction: Motivation, Related literature
- Theoretical analysis
- Empirical analysis
- Conclusions and policy implications
Motivation

The debate:

Should innovation be protected from imitation?

1 view: IPR protection provides incentives for firms to engage in R&D and encourages TT between firms (Arora and Gambardella, 1994; Gans and Stern, 2003)

2 view: The imitation can incite innovative effort of innovating firms (Aghion et al 2005, Zhow, 2009)
Motivation

In the industries there are firms that abstain from innovation, imitate or introduce market novelties:

<table>
<thead>
<tr>
<th>N</th>
<th>Industry</th>
<th>No-Innovation, %</th>
<th>Imitation, %</th>
<th>Innovation, %</th>
<th>TOTAL firms</th>
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<td>Furniture</td>
<td>33.30</td>
<td>32.98</td>
<td>33.72</td>
<td>94</td>
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Figure: German firms, 2005
Motivation

- Actually, firms make their choices of optimal R&D strategy.
- These choices determine this balance between innovating, imitating and non-innovating firms.

Research question:

- First, what is the optimal balance between innovation and imitation in the industry / market?
Contribution

- Allow firms to choose R&D strategy endogenously as a function of market factors: IPR protection, competitive pressure, product differentiation, demand uncertainty
- Analyze Social Welfare implications
- Analyze empirically the R&D strategy choice as a function of firm characteristics and market factors
Related Literature

**Innovation and competitive pressure**

- Neoschumpeterian approach to innovation in the markets: monotonic relationship OR non-monotonic relationship (inverted-U, U)

**R&D strategies and competitive pressure**

- Imitation harms innovation (Arora and Gambardella, 1994; Gallini and Scotchmer, 2002; Gans and Stern, 2003; Gans et al., 2008) OR Imitation incites innovation (Aghion, 2001; Bessen and Maskin, 2009; Zhou, 2009)
- Depending on amount of leaders firms may find more profitable one or another strategy (Segestrom, 1991)
- Firms choose asymmetric R&D performance (Amir and Wooders, 2000)
The timing of the game

I stage - R&D strategy choice

\[ x_i = x_j = 0 \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)
- (No cost reduction)

\[ x_i = 1 \neq x_j \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)
- (Firm j reduces marginal cost by \( y_{xi} \) at fixed cost \( K_i \))
- (Firm j observes \( y_{xi} \) and reduces its marginal cost by \( y_{xj} \))

\[ x_i = x_j = 1 \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)
- (Each firm reduces its marginal cost by \( y_x \) at cost \( K \))

II stage - PMC

\[ q_i, q_j \]
The timing of the game

I stage - R&D strategy choice

\[ x_i = x_j = 0 \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)

\[ x_i = x_j = 0 \] (No cost reduction)

\[ x_i = 1 \neq x_j \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)

\( (\text{Firm i reduces marginal cost by } x_i \text{ at fixed cost } K_i) \)

\[ q_i, q_j \]

\[ x_i = x_j = 1 \]
- Firm i chooses \( x_i \)
- Firm i observes \( x_j \)

\( (\text{Firm j observes } x_i \text{ and reduces its marginal cost by } x_j) \)

\[ q_i, q_j \]

\[ x_i = x_j = 1 \] (Each firm reduces its marginal cost by \( x \) at cost \( K \))

\[ q_i, q_j \]
The timing of the game - 2

I stage - R&D strategy choice

1. \( x_i = x_j = 0 \)
   - Firm i chooses \( x_i \)
   - Firm i observes \( x_j \)
   - (No cost reduction)

2. \( x_i = 1 \neq x_j \)
   - Firm i chooses \( x_i \)
   - Firm i observes \( x_j \)
   - (Firm j observes \( x_i \) and reduces its cost \( a_x x_j \))

3. \( x_i = x_j = 1 \)
   - Firm i chooses \( x_i \)
   - Firm i observes \( x_j \)
   - (Each firm reduces unit cost \( a_x \) at cost \( K \))

II stage - PMC

- \( q_i, q_j \)
The timing of the game

I stage - R&D strategy choice

1. $x_i = x_j = 0$
   - Firm $i$ chooses $x_i$
   - Firm $i$ observes $x_j$
   - (No cost reduction)

2. $x_i \neq x_j$
   - Firm $i$ chooses $x_i$
   - Firm $i$ observes $x_j$
   - (Firm $i$ reduces marginal cost by $\gamma x_i$ at fixed cost $K_i$)

3. $x_i = x_j = 1$
   - Firm $i$ chooses $x_i$
   - Firm $i$ observes $x_j$
   - (Each firm reduces its marginal cost by $\gamma x$ at cost $K$)

II stage - PMC

- $q_i, q_j$

---

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The basic duopoly framework

Stage 1: R&D strategy choice

R&D strategy choice:

\[ x_i = 1 \text{ stands for R&D} \]
\[ x_i = 0 \text{ for no-R&D} \]
\[ c_i (x_1, x_2) = \begin{cases} 
  c - \gamma x_i & \text{for } x_1 = x_2 = 1 \\
  c - \gamma (x_i + \sigma x_j) & \text{else}
\end{cases} \]

- **c** - initial marginal cost
- **\( \gamma \)** - the outcome rate of R&D investments
- **\( \sigma \)** - industry spillover level
- **\( K \)** is the difference between the fixed cost of R&D and imitation

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Imitation or Innovation? The effect of spillovers and competitive
The basic duopoly framework

Stage 2: market competition

- \( p_i = a - bq_i - dq_j, \ i, j = 1, 2, i \neq j \)
- \( b > 0 \)
- \( b - d > 0 \) (the absolute value of the own-price effect on the quantity demanded is assumed to be higher than the corresponding effect of the price of the substitute)
- \( \Pi_i (x_1, x_2) = \pi_i (x_1, x_2) - Kx_i \)
Equilibrium outcomes

- If $x_1 = x_2 = 1$ firms’ profits are:
  \[ \Pi_i(1, 1) = b \left( \frac{a - c + \gamma}{2b + d} \right)^2 - K \]

- If $x_1 = x_2 = 0$ firms’ profits are:
  \[ \Pi_i(0, 0) = b \left( \frac{a - c}{2b + d} \right)^2 \]

- If $x_1 = 1$ and $x_2 = 0$ firms’ profits are:
  \[ \Pi_1(1, 0, \sigma) = b \left( \frac{a - c}{2b + d} + \frac{(2b - d\sigma)\gamma}{4b^2 - d^2} \right)^2 - K \]
  \[ \Pi_2(1, 0, \sigma) = b \left( \frac{a - c}{2b + d} + \frac{(2b\sigma - d)\gamma}{4b^2 - d^2} \right)^2 \]
Let $\sigma$ be implicitly defined by
\[ \Pi_i(1, 1) - \Pi_2(1, 0, \sigma) = 0 \]
and $\bar{\sigma}$ by
\[ \Pi_1(1, 0, \bar{\sigma}) - \Pi_i(0, 0) = 0. \]
Figure 1. The three regions of possible equilibria for $b = 1$, $\gamma = 1$, $a = 4$, and $K = 1, 5$.
Aggregated industry output and social welfare

Aggregated industry output

\[ d = 0.6 \]

\[ d = 0.8 \]

\[ d = 1 \]

Social welfare

\[ d = 0.6 \]

\[ d = 0.8 \]

\[ d = 1 \]
**Policy implications:**

- If changes in spillovers are high: innovation is discouraged, -
- If changes in spillovers are low: imitation is incited, +
- A right level of spillovers depends on market factors and affects the firms’ R&D strategy choice in a particular market
Extension: Asymmetric firms

Figure 3. The four regions of possible equilibria for $b = 1$, $\gamma = 1$, $M = 8$, $\epsilon = 1$, and $K = 1.5$. Slivko, Theilen.
Extension: Asymmetric firms

Figure 3. The four regions of possible equilibria for $b = 1$, $\gamma = 1$, $M = 8$, and $K = 1.5$. Slivko, Theilen Imitation or Innovation? The effect of spillovers and competitive pressure on firms’ R&D strategy choice.
Extension: N firms

\[ n = 3 \quad n = 5 \quad n = 10 \]

\[
\begin{array}{c}
\text{sigma} \\
0.0 & 0.5 & 1.0 \\
\hline
0.0 & 0.5 & 1.0 \\
\hline
0.0 & 0.5 & 1.0 \\
\end{array}
\]

\[
\begin{array}{c}
d \\
0.0 & 0.5 & 1.0 \\
\hline
0.0 & 0.5 & 1.0 \\
\hline
0.0 & 0.5 & 1.0 \\
\end{array}
\]
We examine the consistency of theoretical model empirically:

- Region I - innovation, Region II - innovation and imitation, Region III - non-innovation

- Decrease in spillovers $\implies$ Increase in firms’ proneness to innovate
- Increase in a market size $\implies$ Increase in firms’ proneness to innovate
- Increase in the number of competitors $\implies$ Decrease in firms’ proneness to innovate
- Product differentiation ?
Variables:

- **Dependent variable (y):**
  
  **STR** - categorical variable:
  
  2 - *introduce innovations for the market* = "innovator"
  
  1 - *introduce innovations for the firm* = "imitator"
  
  0 - *abstain from innovation*

- **Explanatory variables (x_i):**

  1) Internal (firm) factors: SIZE02 (+), AC03 (+), GEO (+), OST, GROUP, EX02
  
  2) External (market) factors:

  - av_IPR - average success of legal IP protection in the industry nace3 (+)
  
  - TEC (+), COM (-), DIF, DEM (-)
Descriptive statistics:

<table>
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<th>Variable</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
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### Ordered logistic estimation

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<td>mfx (2)</td>
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<td>68.2%</td>
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Table 6: Ordered logistic estimation of innovativeness of firms as a function of internal and external factors. * Significant at 1%, ** Significant at 5%, *** Significant at 10%.
**Ordered logistic estimation (Model 1)**

<table>
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<th>Std. Err.</th>
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<th>mfx (2)</th>
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<td>ost</td>
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<td>0.279</td>
<td>0.041</td>
<td>0.154</td>
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Discussion

We deal with endogeneity:

- Internal factors are asked referring to period 2002-2004:
  SIZE02, AC03, EX02

- External factors:
  - Spillovers - Success of legal IPR protection mechanisms
    (3-digit NACE3 average excluding the firm in observation)
  - Competitive pressure - 1) COM, DIF are better measures than
    concentration indexes, firms can better identify their markets;
    2) COM, DIF both capture competitive pressure (Vives, 2008)
Concluding remarks and policy implications:

- The model of a firm’s R&D strategy choice is consistent with empirical findings.
- The IPR protection provides incentives to engage in R&D as it guarantees better appropriation of the benefits of innovation.
- Asymmetries: larger firms and firms with access to larger markets are more likely engage in R&D.
- The increase in the number of competitors and demand uncertainty decrease firms’ incentives to innovate.
Concluding remarks and policy implications:

- **Welfare implications:**
  - If changes in spillovers are large: innovation is discouraged, -
  - If changes in spillovers are low: imitation is incited, +
  - A right level of spillovers depends on market factors and affects the firms’ R&D strategy choice in a particular market

- **Competition policy and IP regulation must be coordinated**

- **When making decision concerning the scope and duration of patents the competitiveness and product substitutability must be taken into account, otherwise the policies are working in different directions**
THANK YOU!

questions, comments and suggestions are very WELCOME!
Equilibrium outcomes

- Assuming that firm $i$ decides to innovate, firm $j$ faces a trade-off:
  - Innovation: firm $j$ pays a cost $K$, which allows a reduction of unit production costs.
  - Imitation: firm $j$ saves a payment of $K$, but the decrease in unit production costs is lower and depends on the rival’s R&D outcome and $\sigma$. 
Equilibrium outcomes

- If $x_1 = x_2 = 1$ firms’ profits are:
  \[ \Pi_i(1, 1) = b \left( \frac{a - c + \gamma}{2b + d} \right)^2 - K \]

- If $x_1 = x_2 = 0$ firms’ profits are:
  \[ \Pi_i(0, 0) = b \left( \frac{a - c}{2b + d} \right)^2 \]

- If $x_1 = 1$ and $x_2 = 0$ firms’ profits are:
  \[ \Pi_1(1, 0, \sigma) = b \left( \frac{a - c}{2b + d} + \frac{(2b - d\sigma) \gamma}{4b^2 - d^2} \right)^2 - K \]
  \[ \Pi_2(1, 0, \sigma) = b \left( \frac{a - c}{2b + d} + \frac{(2b\sigma - d) \gamma}{4b^2 - d^2} \right)^2 \]
Equilibrium outcomes

- The parameters in focus:
  - the degree of product differentiation, $d/b$
  - level of spillovers in the industry, $\sigma$
  - returns on investment, $\gamma$
  - competitive pressure, $n$
Equilibrium outcomes

- To guarantee that costs are not too low such that making no R&D is a possible choice and that costs are not too high such that in the absence of spillovers firms are still interested to invest in R&D

- **Assumption 1.** Let $K < K < \overline{K}$, where $K$ is defined by $\Pi_i(1,1) = \Pi_i(0,0)$, and $\overline{K}$ is defined by $\Pi_i(1,1) = \Pi_2(1,0,0), \forall i = 1, 2$
Equilibrium outcomes

- Let $\sigma$ be implicitly defined by
  \[ \Pi_i(1, 1) - \Pi_2(1, 0, \sigma) = 0 \]
- and $\bar{\sigma}$ by
  \[ \Pi_1(1, 0, \bar{\sigma}) - \Pi_i(0, 0) = 0. \]
**Proposition 1.** (Existence of equilibria)

For given parameter values \((d, b, a, c, \gamma)\) the equilibrium R&D strategies are characterized as follows:

- when spillovers are low \((\sigma \leq \bar{\sigma})\) there exists a pure strategy equilibrium, in which both firms engage in R&D (Region I)
- when spillovers are intermediate \((\bar{\sigma} \leq \sigma \leq \bar{\sigma})\) there exist multiple pure strategy equilibria, in which one firm invests in R&D and another firm chooses to imitate (Region II)
- when spillovers are high \((\bar{\sigma} \leq \sigma)\) there exists a pure strategy equilibrium, in which none of the firms engages in R&D (Region III)

Furthermore, \(\frac{\partial \sigma}{\partial K} < 0, \frac{\partial \sigma}{\partial K} < 0, \frac{\partial \sigma}{\partial \gamma} < 0, \frac{\partial \sigma}{\partial \gamma} < 0, \frac{\partial \sigma}{\partial (a-c)} > 0\) and \(\frac{\partial \sigma}{\partial (a-c)} > 0\).
Aggregated industry output and social welfare

- **Proposition 2.** (The effect of spillovers parameter, $\sigma$)

Concerning the effect of change in spillovers on the industry aggregated output and social welfare we obtain that:

- the output and welfare are constant for low and high level of spillovers (in Regions I and III); the output and SW are lower in the area of high spillovers (in Region III) than in the area of low spillovers (in Region I);
- output is increasing in $\sigma$ and welfare is convex in $\sigma$ for intermediate spillovers (in Region II);
- output decreases when passing from low to intermediate and from intermediate to high spillovers. Welfare can increase or decrease when passing from low to intermediate spillovers (from Region I to Region II) and welfare decreases when...
Extension: Asymmetric firms

\[ a_1 - c_{01} > a_2 - c_{02} \]
\[ M = (a_1 - c_{01}) + (a_2 - c_{02}) \]
\[ \epsilon = \frac{a_1 - c_{01}}{M}, \epsilon \in \left(\frac{1}{2}, 1\right] \]
Extension: Asymmetric firms

Proposition 3 (The equilibria for asymmetric firms)

- For any given values of \( d \), the equilibrium R&D strategies are characterized as follows:
  - The Regions I and III become smaller as \( \sigma_2(d) < \sigma(d) \) and \( \overline{\sigma}_1(d) > \overline{\sigma}(d) \).
  - The Region II with multiplicity of equilibria (where large firm innovates and small firm imitates, or vice versa) becomes smaller as \( \sigma_1(d) > \sigma(d) \) and \( \overline{\sigma}_2(d) < \overline{\sigma}(d) \).
  - The area with pure strategy equilibrium emerges (Region IV), where the dominant strategy of large firm is to invest in R&D, and the dominant strategy of small firm is to imitate.
Extension: Asymmetric firms

**Proposition 4** (the effect of firm asymmetry, $\epsilon$)

- For given parameter values $(\sigma, d, b, a, c, \gamma)$ social welfare $W$ is increasing in firm asymmetry parameter, $\epsilon$, $\forall \epsilon \in \left(\frac{1}{2}, 1\right)$
- Establishment of innovator-imitator configuration in the market may positively affect total social welfare
**Proposition 5** *(The effect of *n*, competitive pressure, on equilibria)*

Compared to the case of symmetric firms we have:

(i) The region, in which all firms innovate (Region I) decreases with the number of firms in the market as for given *d* we have \( \sigma_n < \sigma_{n-1} \).

(ii) The region, in which none of the firms innovates (Region III) increases with the number of firms in the market as for given *d* we have \( \bar{\sigma}_n < \bar{\sigma}_{n-1} \).
Proposition 6 (The effect of \( n \), competitive pressure, on industry R&D output and welfare)

(i) Entry increases total R&D output and welfare when spillovers are low and products are highly differentiated.

(ii) Entry decreases total R&D output and welfare when spillovers are high and products are rather homogenous.

(+ ) De Bondt et al (1992) 
(-) Tishler and Milstein (2009)
The Ordinal Logit specification:

The latent variable $y_i^*$ is determined as a function of vector $x_i$:

$$y_i^* = x_i \beta + \epsilon_i$$

The probability of observing $y = m$ for given values of $x$ is

$$\Pr(y = j | x) = \Pr (\tau_{m-1} < y_i^* < \tau_m | x), \quad m = 0, 1, ..., J$$