Arrow (1962): What is the incentive to innovate for a firm?

Abstract from all strategic considerations by assuming that only one firm has the option of innovating or not.

Want to look at the effect of initial market structure.

Assume: innovation is a process innovation that is covered by a patent of unlimited duration.

Firms produce at constant unit cost.

Market demand: $D(p)$.

Initial unit cost: $\bar{c}$

Innovation reduces unit cost to $c < \bar{c}$. 
Social Planner’s Incentive.

Planner would sell at MC.

Gain to net social surplus per unit of time:

\[ \int_{C}^{\bar{C}} D(c) dc \]

and so the discounted present value of this is the social incentive to innovate:

\[ V^S = \int_{0}^{\infty} e^{-rt} \left[ \int_{C}^{\bar{C}} D(c) dc \right] dt = \frac{1}{r} \int_{C}^{\bar{C}} D(c) dc. \]
Monopolist’s incentive to innovate.

Initial market structure: monopoly.

Let $\Pi^m(c), p^m(c)$ be the (optimal) monopoly profit and price at each instant of time when unit cost is $c$.

\[
\frac{d\Pi^m(c)}{dc} = -D(p^m(c)).
\]

so that the monopolist’s gain from cost reduction at each instant of time is:

\[
\Pi^m(c) - \Pi^m(\bar{c}) = \int_{c}^{\bar{c}} \left( -\frac{d\Pi^m(c)}{dc} \right) dc
\]

\[
= \int_{c}^{\bar{c}} D(p^m(c)) dc
\]

and the discounted present value of this gives us the monopolist’s incentive to innovate:

\[
V^m = \frac{1}{r} \int_{c}^{\bar{c}} D(p^m(c)) dc.
\]
Observe that as \( p^m(c) > c, D(p^m(c)) < D(c) \),

\[ V^m < V^S \]

This reflects the fact that the cost saving for the monopolist is for a smaller number of units sold (compared to what is socially optimal).

Price discrimination can resolve some or all of this appropriability problem.
Competition:

Initially market has many identical firms engaged in Bertrand price competition.

Sell at market price = unit cost $c$: Zero profit.

Suppose one firm obtains new technology with unit cost $c$ and receives patent on this.

Two cases.
(i) Non-drastic innovation (relatively small cost reduction):

\[ p^m(c) > \bar{c} \]

Innovating firm can charge at most \( \bar{c} \) and at each instant of time, earn profit

\[ = (\bar{c} - c)D(\bar{c}) \]

and the competitive firm’s incentive to innovate is given by:

\[ V^C = \frac{1}{r}(\bar{c} - c)D(\bar{c}) \]
Note that for all $c \geq \underline{c}$:

$$p^m(c) \geq p^m(\underline{c})$$

so that

$$p^m(c) > \bar{c}$$

and therefore,

$$V^m = \frac{1}{r} \int_{\underline{c}}^{\bar{c}} D(p^m(c)) \, dc < \frac{1}{r} \int_{\underline{c}}^{\bar{c}} D(\bar{c}) \, dc$$

$$= \frac{1}{r} (\bar{c} - \underline{c}) D(\bar{c}) = V^C$$

so that the competitive firm has a higher incentive to innovate than a monopolist.

Replacement effect: Monopolist "replaces himself" when he innovates but a competitive firm "becomes" a monopolist.
Also note,

\[ V^S = \frac{1}{r} \int_{c}^{\bar{c}} D(c) dc > \frac{1}{r} (\bar{c} - c) D(\bar{c}) = V^C. \]

Again, appropriability problem.

Thus,

\[ V^m < V^C < V^S. \]
(ii) Drastic Innovation (Large decline in unit cost).

\[ p^m(c) \leq \bar{c} \]

Innovating firm can charge monopoly price \( p^m(c) \) and at each instant of time, earn monopoly profit \( \Pi^m(c) \). The competitive firm’s incentive to innovate is then given by:

\[ V^C = \frac{1}{r} \Pi^m(c) \]
Note that

\[ V^m = \frac{1}{r} [\Pi^m(c) - \Pi^m(\bar{c})] \]

\[ < \frac{1}{r} \Pi^m(c) = V^C \]

so that the competitive firm has a higher incentive to innovate than a monopolist.
Also,

\[ V^S = \frac{1}{r} \int_{c}^{\bar{c}} D(c) dc \geq \frac{1}{r} \int_{c}^{p^m(c)} D(c) dc \]

\[ > \frac{1}{r} \int_{c}^{p^m(c)} D(p^m(c)) dc \]

\[ = \frac{1}{r} [p^m(c) - c] D(p^m(c)) \]

\[ = \frac{1}{r} \Pi^m(c) = V^C \]
Imperfect Competition (Cournot Oligopoly)

Initially, symmetric Cournot duopoly with each firm producing at unit cost $\bar{c}$.

Linear demand: $P(q) = a - q, a > \bar{c}$.

Non-drastic innovation:

$$p^{m}(c) = \frac{a + c}{2} > \bar{c}$$

Prior to innovation, equilibrium profit of each firm at each point of time:

$$\left(\frac{a - \bar{c}}{3}\right)^2$$

After innovation, innovating firm has lower cost $c$ while the other firm has cost $\bar{c}$. Equilibrium profit of innovating firm:

$$\left(\frac{a - 2c + \bar{c}}{3}\right)^2$$
Therefore the incentive to innovate is given by:

\[ V^D = \frac{1}{r} \left[ \frac{1}{9} \left\{ (a - 2c + \bar{c})^2 - (a - \bar{c})^2 \right\} \right] \]

Compare to \( V^m \)

\[ V^m = \frac{1}{r} \left[ \frac{1}{4} \left\{ (a - c)^2 - (a - \bar{c})^2 \right\} \right] \]

Drastic innovation?
Monopoly threatened by entry.

Initially, one firm (firm 1) is a monopolist producing at cost $\bar{c}$ earning profit $\Pi^m(\bar{c})$.

A potential entrant or competitor (firm 2) initially has prohibitively high unit cost.

If the monopolist is the only one to acquire new technology that reduces unit cost to $c$, his incentive to innovate is $V^m$.

If the potential entrant or competitor is the only one to acquire new technology, his incentive to do so is given by $V^C$. 
What if both firms can potentially bid to acquire the new technology? [Only one gets it eventually]

Each firm must take into account what happens if it does not acquire the technology, but rival does.

For the potential entrant, no difference in this situation.

For the incumbent, it matters. If technology goes to rival, competition will severely reduce his profit.

Let $\Pi^d(c, c), \Pi^d(c, \overline{c})$ denote the duopoly profits of the incumbent firm 1 and entrant firm 2 when the entrant gets the new technology and produces at cost $c$.

Entrant’s incentive to acquire new technology:

$$\frac{\Pi^d(c, \overline{c})}{r}$$
Incumbent’s incentive to acquire the new technology:

\[
\frac{\Pi^m(c) - \Pi^d(c, c)}{r}
\]

"Efficiency Effect":

\[
\Pi^m(c) \geq \Pi^d(c, c) + \Pi^d(c, \bar{c})
\]

Monopoly profit (at lower cost) never falls below sum of duopoly profits. [May hold with equality]

Therefore, monopolist’s incentive to remain a monopolist is greater than the entrant’s incentive to become duopolist.

If the technology is auctioned, incumbent monopolist would bid \(\Pi^d(c, \bar{c})\) or slightly above it and acquire the new technology.

(Gilbert & Newbery, 1982).
Sometimes: monopolist may acquire but not actually use the new technology.

For instance, $c$ is slightly above $\bar{c}$.

Loss of profit if technology passes to potential competitor who becomes an intense competitor.