E C O N O M I C S  B U L L E T I N

# Knowledge diffusion under patent with asymmetric firms

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## *Abstract*

We show that if patent protection and trade secrecy generate asymmetric market structure, an innovator may prefer patent protection than trade secrecy even if the diffusion probability is higher under the former but it increases market concentration by preventing some imitators. So, whether an innovator prefers patent protection or trade secrecy depends on the trade-off between the diffusion probability and market concentration.

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## 1. Introduction

There are two main roles of any patent system: (i) to provide stronger incentive for innovation and (ii) to promote diffusion of technical information. Though, the existing literature has largely concentrated on the former effect of patent system, the latter role of the patent system did not receive much attention.

The argument regarding knowledge diffusion under patent system presumes that all patentable inventions are patented.[1] Recently, Bessen (2005) shows that if the innovator has alternative ways, such as trade secrecy, to protect innovation, knowledge diffusion cannot be more under patent system than trade secrecy.[2] The intuition behind this result is easy to see. If the firm anticipates that knowledge diffusion will be more under patent system, it will not apply for patent protection; rather it will prefer trade secrecy to protect the technical information. Hence, the argument that patent system facilitates knowledge diffusion may be misplaced.

Though the argument in Bessen (2005) is interesting, it ignores another side of the story, viz., the effect of market structure on the decision for patenting. We show that if the imitators differ according to their ability to imitate, patent system may increase market concentration compared to trade secrecy by preventing entry of some imitators. Hence, if there are asymmetric imitators, an innovator may prefer patent protection compared to trade secrecy even if the knowledge diffusion is higher under the former. So, the trade-off is between the relative strengths of the diffusion probability and market concentration.

The remainder of the paper is organized as follows. Section 2 describes the model and shows the results. Section 3 concludes.

## 2. The model and the results

We use a model similar to Bessen (2005) with the exception that there are two imitators, who differ according to their capability for imitation or 'inventing around'. Consider an industry consisting of three risk-neutral firms where firm $I$ is an innovating firm and other two firms are firm *A* and firm *B*. We consider two regimes: one with patent and trade secrecy law, and another with trade secrecy only. Firm $I$ has an invention that gives it a temporary monopoly. However, firms *A* and *B* can compete for profits with firm $I$ either through imitation or through 'inventing around'.

Let us now define the product market profits (i.e., revenue minus total cost) of the firms by $V_M$, $V_D$ and $V_t$ respectively for the situations where only one firm produces in the market, two firms produce in the market and all three firms produce in the market. We consider symmetric product market profits for the firms under competition. We also consider the standard assumption that the profit of a firm reduces with higher competition, i.e., $V_M > V_D > V_t$.

Now, we set out the game. At stage 1, firm $I$ decides whether or not to patent, if patent protection is available. Though patenting typically costs more than trade secrecy alone, however, we assume that these costs are the same in order to focus on the effects of asymmetric product market competition under patent protection, and under trade secrecy only. At stage 2, firms $A$ and $B$ simultaneously decide whether to develop a substitute invention by 'inventing around' or imitation. We assume that the cost of imitation or 'inventing around' requires an investment $c$, and this is irrespective of firm

[1] See Friedman et al. (1991) for a discussion on this issue.

[2] We refer to Gallini (1992) for the effect of patent and trade secrecy on the incentive for innovation.

$I$ 's choice about patent protection or trade secrecy.[3] These costs are the same for both firms $A$ and $B$. However, $A$ and $B$ differs according to their success probability of inventing around. We assume that firm $A$ ($B$) invents successfully with probability $q_A^i$ ($q_B^i$), $i = S, P$, $0 \le q_A^i, q_B^i \le 1$. At stage 3, productions take place and the profits are realized.[4] We solve the game through backward induction.

Following Bessen (2005), we call $q_A^i$ and $q_B^i$ as the diffusion probabilities to firms $A$ and $B$. We do our analysis under the assumptions that (i) $q_A^i > q_B^i$, which implies that firm $A$ is more capable in developing the substitute invention than firm $B$, and (ii) the diffusion probabilities for both firms $A$ and $B$ are higher under patent than trade secrecy alone, i.e.,

$$q_A^P > q_A^S \qquad \text{and} \qquad q_B^P > q_B^S. \tag{1}$$

Note that condition (1) also implies that $q_A^P + q_B^P - q_A^P q_B^P > q_A^S + q_B^S - q_A^S q_B^S$, i.e., total diffusion probability is higher under patent than under trade secrecy only.

Though, firms $A$ and $B$ are capable of doing imitation or 'inventing around', whether both of them will imitate or 'invent around' will depend on the parametric configuration, which, in turn, will determine the innovator's preference for patent protection relative to trade secrecy alone. The following analysis will show that, if (1) is satisfied, the result of Bessen (2005) will always hold when the market structure is the same under patent protection, and under trade secrecy only. But, the result of Bessen (2005) may not hold if the market structure differs between patent protection and trade secrecy, and therefore, both the diffusion probability and the market structure are important for the choice between patent protection and trade secrecy.

Let us now define $X_B^P = q_B^P V_D - q_A^P q_B^P (V_D - V_t)$, $X_B^S = q_B^S V_D - q_A^S q_B^S (V_D - V_t)$ and $X_A^P \equiv q_A^P V_D - q_A^P q_B^P (V_D - V_t)$. Note that $X_A^P > X_B^P$ given $q_A^P > q_B^P$.

**Proposition 1:** *If $X_B^P < c < \min\{X_B^S, X_A^P\}$, firm $I$ may prefer patent protection than trade secrecy even if, in equilibrium, the total diffusion probability is higher under patent protection than under trade secrecy only.*

**Proof:** Under patent protection, at the stage 2 of the game, firm $A$ imitates but firm B does not imitate is a Nash equilibrium if $q_A^P V_D > c > X_B^P$, whereas firm B imitates but firm A does not is a Nash equilibrium if $q_B^P V_D > c > X_A^P$. On the other hand, under trade secrecy only, both firms $A$ and $B$ would imitate the technology of firm $I$ provided $c < X_B^S$. While $X_B^S < q_B^P V_D < q_A^P V_D$, we find that $X_B^S \gtreqless X_A^P$. Hence, if

[3] In general, the cost of imitation or 'inventing around' may vary depending on the innovator's choice about patent protection and trade secrecy. However, it will be easy to understand from our analysis that if the cost of imitation is lower under trade secrecy, it will strengthen our result. The same cost of imitation or 'inventing around' irrespective of patent protection or trade secrecy can be justified if we view these costs as the opportunity costs of imitation or 'inventing around' and the symmetry helps us to show the effects of asymmetric market structure for our analysis.

[4] Note that, in our general formulation, we do not model the production market competition explicitly. That is, we do not assume whether the firms compete like Bertrand oligopolists (with differentiated products) or Cournot oligopolists. Instead, we do our analysis with the reduced form profit functions $V_M$, $V_D$ and $V_t$.

$X_B^P < c < \min\{X_B^S, X_A^P\}$, both firms $A$ and $B$ imitate under trade secrecy only, whereas only firm $A$ imitates under patent protection. Therefore, in equilibrium, the total diffusion probabilities under patent and under trade secrecy only are respectively $q_A^P$ and $q_A^S + q_B^S - q_A^S q_B^S$, and the net profits of firm $I$ under patent protection and under trade secrecy are respectively

$$\pi_I^P = q_A^P V_D + (1 - q_A^P) V_M \tag{2}$$

and

$$\pi_I^S = q_A^S q_B^S V_t + (q_A^S + q_B^S - 2q_A^S q_B^S) V_D + (1 - q_A^S)(1 - q_B^S) V_M . \tag{3}$$

We find that (2) is greater than (3) provided

$$(V_D - V_t) q_A^S q_B^S - (V_M - V_D)(q_A^P - (q_A^S + q_B^S - q_A^S q_B^S)) > 0 . \tag{4}$$

Since $V_M > V_D > V_t$, (4) may hold even if, in equilibrium, the total diffusion probability is higher under patent protection than under trade secrecy only, i.e., even if $q_A^P > q_A^S + q_B^S - q_A^S q_B^S$. Q.E.D.

The following example shows that there are probabilities and the profit functions such that Proposition 1 holds. This example also shows that when Proposition 1 holds, the total diffusion probability under patent protection may also be greater than that of under trade secrecy. Suppose, the inverse market demand function is $p = 10 - Q$, where $Q$ is the industry output and $p$ is the price. Assume that the marginal cost of production for each firm is 4. Consider $q_A^P = 1$, $q_B^P = \frac{7}{10}$, $q_A^S = \frac{7}{10}$ and $q_B^S = \frac{3}{5}$. These probabilities satisfy both $q_A^i > q_B^i$, where $i = S, P$, and condition (1). Assume that, in case of competition in the product market, the firms compete like Cournot oligopolists. Straightforward calculation shows that $V_M = 9$, $V_D = 4$ and $V_t = \frac{9}{4}$ under the above demand and cost conditions. Hence, we get $X_B^P = \frac{63}{40}$ and $\min\{X_B^S, X_A^P\} = X_B^S = \frac{333}{200}$. We also find that the condition (4) holds with these parameter values, since the left hand side of the inequality (4) is $\frac{27}{200}$. Therefore, if $\frac{333}{200} > c > \frac{63}{40}$, Proposition 1 holds and the firm $I$ prefers patenting than trade secrecy. Note that, in this situation, the equilibrium probability of diffusion under patenting is 1, whereas the total probability of diffusion under 'trade secrecy only' is $q_A^S + q_B^S - q_A^S q_B^S = \frac{44}{50} < 1$. Hence, in contrast to Bessen (2005), the above example shows that the innovator (firm 1) prefers patent protection than trade secrecy only even if, in equilibrium, the probability of diffusion is higher under the former. The reason for this difference between our result and Bessen (2005) is easy to understand. Though, total diffusion probability is higher under patent protection, patent protection prevents imitation by the relatively less capable imitator (firm $B$). Hence, patent protection increases market concentration, and increases product market profit of the innovator, firm $I$. So, if the effect of market concentration under patent protection is stronger than the effect of higher diffusion probability under patent system, the innovator is better off under patent system than trade secrecy.[5]

[5] It is clear that if patenting is marginally more costly than trade secrecy only, the above result holds good.

It is worth mentioning that, in Bessen (2005), patenting may be preferred than trade secrecy even with *potentially* high diffusion probability under the former than the latter (see the lower part of region A in Bessen, 2005). However, for those parametric configurations, the *equilibrium* diffusion probability under patent is lower than the alternative diffusion probability under trade secrecy, since here imitation is not a credible threat (and therefore, does not occur) under patent protection. In contrast, we show that the innovator prefers patent protection even if the *equilibrium* diffusion probability under patenting is higher than the alternative diffusion probability under trade secrecy only.

It should be noted that the if the cost of imitation or 'inventing around' is lower under trade secrecy than under patent protection, it makes it more likely that only firm $A$ does 'inventing around' under patent protection while both firms $A$ and $B$ do imitation under trade secrecy, which strengthens our results by relaxing the condition that $c$ needs to be between $X_B^P$ and $\min\{X_B^S, X_A^P\}$.

Proposition 1 has considered the situation where asymmetric market structure evolves under patent protection and trade secrecy. However, it is easy to check that if $c < \min\{X_B^P, X_B^S\}$, both firms $A$ and $B$ do 'inventing around' or imitation under patent system and trade secrecy only. Hence, the net profits of firm $I$ under patent protection and trade secrecy only are respectively

$$\pi_I^P = q_A^P q_B^P V_t + (q_A^P + q_B^P - 2q_A^P q_B^P)V_D + (1-q_A^P)(1-q_B^P)V_M . \quad (5)$$

and

$$\pi_I^S = q_A^S q_B^S V_t + (q_A^S + q_B^S - 2q_A^S q_B^S)V_D + (1-q_A^S)(1-q_B^S)V_M . \quad (6)$$

Straightforward comparison of (5) and (6) gives the following proposition immediately.

**Proposition 2:** *If* $c < \min\{X_B^P, X_B^S\}$, *the innovator prefers trade secrecy than patent protection.*

Note that when the imitation cost is low, both firms decide to imitate the product irrespective of the regime chosen by the innovator. Hence, the market structure before the outcome of imitation[6] is the same under patent protection and under trade secrecy only. Therefore, if the market structure is similar under patent protection and trade secrecy only, the innovator prefers trade secrecy, since the total diffusion probability is higher under patent protection than trade secrecy only.[7]

Thus, the above results extend and complement Bessen (2005) for the case of multiple and asymmetric imitators.

## 3. Conclusion

Bessen (2005) shows that if imitation occurs under patent protection, an innovator seeks patent protection if the diffusion probability is lower under patent protection than trade

[6] Note that, since imitation is probabilistic, even if both firms imitate irrespective of the regime chosen by the innovator, the market structure ex-post imitation may be different under different regimes.

[7] The other case where only firm $A$ does imitation or 'inventing around' under patent protection and trade secrecy only follows immediately from Bessen (2005), and the innovator prefers trade secrecy in this situation if the diffusion probability is higher under patent protection than trade secrecy only.

secrecy. Hence, in equilibrium, patent protection cannot generate higher knowledge diffusion when the innovator has the alternative strategy of trade secrecy.

The above argument ignores the effect of market structure. We show that if patent protection and trade secrecy generate asymmetric market structure, an innovator may prefer patent protection than trade secrecy if patent protection prevents some imitators to invent around and compete in the product market, thus increasing product market concentration under patenting than trade secrecy only. We show that the innovator prefers patenting than trade secrecy, even if, in equilibrium, the diffusion probability under patenting is higher than the alternative diffusion probability under trade secrecy. Therefore, whether an innovator prefers patent protection or trade secrecy depends on the trade-off between the diffusion probability and market concentration.

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