Innovation, Licensing, and Price vs. Quantity Competition

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Abstract: In this paper, we develop a differentiated duopoly model with endogenous cost-reducing R&D and review the argument on welfare effect of price and quantity competition in the presence of technology licensing. We show that the standard conclusion on duopoly (Singh and Vives, 1984) can be completely reversed. Cournot competition induces lower R&D investment than Bertrand competition does. Moreover, Cournot competition leads to lower prices, lower industry profit, higher consumer surplus and higher social welfare than Bertrand competition.

Keywords: Cost-reducing innovation; licensing; Cournot competition; Bertrand competition; Welfare

JEL Classification: L13; D43

We thank Hongyan Fu for her excellent research assistance. The usual caveat applies.

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1. Introduction

In their seminal work, Singh and Vives (1984) (henceforth SV) consider a differentiated duopoly model and derive the well-known proposition that Bertrand competition leads to lower prices and higher welfare compared to Cournot competition. Industry profits are lower (higher) in Bertrand than in Cournot competition when the goods are substitutes (complements). The standard view that Bertrand equilibrium is welfare superior to Cournot equilibrium has recently been challenged by a number of theoretical models.

In the present paper, we develop a differentiated duopoly model where one of the firms engages in cost-reducing innovation and licenses its innovation to its rival firm by means of two-part tariff. The purpose of this paper is two-fold. The first is to study the innovator’s incentive to do R&D in the presence of licensing for the case in which the innovator itself is a producer within the industry. The second and also most important goal of the paper is to show that, as a consequence of R&D and licensing, the existing welfare ranking obtained by SV is overturned.

We find that, in the absence of technology licensing, the innovating firm invests more in R&D under Cournot (Bertrand) competition when the products are more (less) differentiated. While industry profit is lower, consumer surplus and social welfare are higher under Bertrand than under Cournot competition. This conclusion confirms the results in SV. However, in the presence of technology licensing, Cournot competition

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1 We will discuss the implications of fixed fee and royalty contract in section 6.
produces lower R&D expenditure, lower industry profits, greater consumer surplus and greater social welfare. This finding shapes a sharp contrast to the standard results developed in SV.

To fully understand the intuition underlying the results, we need to explain three effects. One is efficiency effect induced by R&D investment. The second one is price effect. That is, without R&D and licensing, fierce competition in Bertrand case reduces prices and increases outputs and hence, improves consumer surplus and social welfare. The third one is collusive effect resulted from a licensing agreement including a positive royalty rate. As suggested by Fauli-Oller and Sandonis (2002, 2003), using a contract with a positive royalty rate allows the licensor not only to manipulate the licensee’s marginal cost but also to strategically make itself a commitment to charge a higher price, and thereby raises the licensing income. As a consequence, the usage of positive royalty rate plays a role in softening competition through making both the licensor and the licensee less aggressive.

Without technology licensing, only the first two effects arise. When the products are less homogenous, competition is weak, the mode of competition is less important, and a Cournot competitor will do more R&D. However, when the products are more homogenous, competition is fierce and hence, under Bertrand competition, a firm has a strong incentive to differentiate itself from its rival by doing more R&D. In the absence of licensing, the price effect plays a key role. Therefore, as predicted by SV, industry profit is higher under Cournot competition, but consumer surplus and social welfare are higher under Bertrand competition. However, under the circumstance of
licensing, a Bertrand competitor has an incentive to do more R&D which allows it to charge a higher royalty rate, and thereby induces strong collusive effect. The collusive effect benefits the producers but hurts the consumers. As a result, industry profit is higher, but consumer surplus and social welfare are lower in Bertrand than in Cournot competition.

This paper marries two strands of literature: first, studies on technology licensing and second, analyses on welfare implications of quantity and price competition. The former issue has developed mainly along two lines: One strand focuses on the licensing contracts. Major contributions are provided by Erkal (2005), Kabiraj (2004), Kamien and Tauman (1986, 2002), Katz and Shapiro (1985) and Wang (1998). The focus of these studies is to analyze whether a fixed fee or a royalty contract is optimal when the innovating firm itself is (not) a producer. The second strand emphasizes welfare effects and antitrust implications of technology licensing, see for instance, Fauli-Oller and Sandonis (2002, 2003) and Kabiraj (2005). Neither of these approaches integrated R&D decision and welfare comparison between Bertrand and Cournot competition, which are the tasks of the current paper.

Regarding the latter issue, there are some notable works. Some models seem to support the standard welfare ranking in SV. For example, Motta (1993) develops a vertical product differentiation model with endogenous quality choice and shows that

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2 In an interesting paper, Poddar and Sinha (2004) have analyzed the licensing contract by using a linear city model.
3 Very recently, the literature on licensing models has become richer and more diverse. For example, Liao and Sen (2005) discuss the welfare implications of licensing in the presence of subsidy. Lin (1996) demonstrates that fixed-fee licensing may encourage collusion. Mukherjee (2005) analyzes the effect of licensing on non-cooperative and cooperative R&D. Mukherjee and Mukherjee (2005) model technology licensing between foreign and domestic firms.
the economy as a whole is better off under price competition than under quantity competition. Zanchettin (2006) uses a differentiated duopoly model with asymmetric costs and demonstrates that, although industry profit is higher under Bertrand competition when asymmetry is strong and/or products are weakly differentiated, price competition always produces lower prices and larger welfare than quantity competition. However, there are some models that tend to alter the welfare result in SV. By incorporating input outsourcing, Arya et al. (2007) find that the standard conclusions on Cournot and Bertrand competition can be completely reversed. Hackner (2000) extends the model of SV to allow for arbitrary number of firms, and argues that the results in SV are sensitive to the duopoly assumption. Mukherjee (2007) builds an asymmetric cost duopoly model with homogenous products and shows that whether Bertrand competition is more efficient than Cournot competition depends on the bargaining power of the licenser and the cost difference between the firms. Qiu (1997) focuses on a cost-reducing model and argues that Cournot competition induces higher R&D expenditure than Bertrand competition, but the traditional welfare conclusion in SV relies on R&D productivity, spillovers and product differentiation. Finally, Symeonidis (2003) develops a differentiated duopoly model with product R&D and finds that quantity competition always generates more R&D investment, higher prices and greater profits. The welfare implication is dependent on R&D spillovers and product differentiation.

The existing literature either assumes away R&D decisions or rules out technology licensing. Our model differs from models of “pure licensing”, such as the
ones used by Kamien and Tauman (1986, 2002), Mukherjee (2007) and Wang (1998), in important ways, including endogenous cost-reducing R&D. The present model is also different from such models of pure welfare comparisons between Cournot and Bertrand equilibrium like those in SV, Motta (1993), Qiu (1997) and Symeonidis (2003) by allowing for both R&D investment and technology licensing.

The remainder of the paper is organized as follows. In the next section, the baseline model is provided. It augments the SV model by incorporating cost-reducing innovation and technology licensing. The licensing contract is assumed to be two-part tariff. In section 3, we derive the pre- and post-licensing equilibrium by modeling the market structure as a Cournot duopoly. We show that, under quantity competition, it is profitable for the patent holding firm to transfer its innovation by means of two-part tariff. In section 4, we repeat the same exercise in a Bertrand game. In section 5, we compare R&D incentive, industry profit, consumer surplus and social welfare under quantity and price competition. Section 6 concludes the paper with some discussions on the implications of a fixed fee or a royalty licensing contract.

2. The basic model

There are two firms, 1 and 2, each producing a good, good 1 and 2. The inverse demands are $p_i = 1 - x_i - dx_j$, where $p_i$ is the price of firm $i$, $x_i$ and $x_j$ are the outputs of firms $i$ and $j$, $i, j = 1, 2$, $i \neq j$. $d \in (0, 1)$ captures the degree of product differentiation. The two firms have identical initial marginal cost $c$, $c < 1$. Different from Qiu (1997) and Symeonidis (2003), who model R&D rivalry, we
assume that only firm 1 can undertake a cost-reducing R&D.\textsuperscript{4} In the present paper, we abstract from issues of uncertainty regarding the outcome of innovation. If firm 1 engages in process innovation, then by spending $\frac{1}{2}k^2$ on R&D it can reduce its marginal cost by $k$.\textsuperscript{5} Throughout this paper, to rule out corner solutions and guarantee positive, post-innovation costs of production in both price and quantity competition, we assume that $c$ is large enough. The two firms compete in either Cournot or Bertrand fashion.

The timing of the game is as follows. First, firm 1 decides whether to invest in a cost-reducing innovation with a certain outcome of success. Second, if firm 1 makes an investment and obtains an innovation, it decides whether to license its technology. When firm 1 decides to transfer its technology, it makes firm 2 a take-it-or-leave-it offer in the form $(r, f)$, where $r$ is a per-unit output royalty and $f$ is a fixed fee. Third, firm 2 decides whether to accept this two-part tariff. If firm 2 rejects, it competes with firm 1 by employing its initial technology. If it accepts, firm 2 competes with firm 1 by utilizing the new technology. We will solve the game by using backward induction.

3. Cournot competition

In this section, we consider a Cournot duopoly producing differentiated products. We will derive the optimal investment, firms’ profits, consumer surplus and social welfare pre- and post- licensing.

3.1 Pre-licensing equilibrium

\textsuperscript{4} The R&D models used in Motta (1993) and Symeonidis (2003) are product innovations.

\textsuperscript{5} There are many papers that have used this approach to model process innovations, for instance, Lin and Saggi (2002) and Qiu (1997).
We start our analysis by considering the case where licensing does not occur. To ensure that firm 2 produces positive outputs, we further assume that \( 0 < d < 0.806 \).

This assumption implies that the products are not too close substitutes. If technology transfer does not occur, firm 1 owns a cost advantage when it competes with its rival. As a consequence, when the goods are too homogenous, firm 2 may find it unprofitable to produce any positive amount of output. Our assumption here excludes the situation where firm 2’s production is not profitable without licensing. In this case, the firms’ profit functions are given by

\[
\pi_1 = (1 - x_1 - dx_2 - c + k)x_1 - \frac{k^2}{2} \quad \text{and} \quad \pi_2 = (1 - x_2 - dx_1 - c)x_2. \tag{1}
\]

It is straightforward to obtain the outputs and profits

\[
x_1 = \frac{2 - 2c - d + cd + 2k}{4 - d^2}, \quad x_2 = \frac{2 - 2c - d + cd - dk}{4 - d^2},
\]

\[
\pi_1 = \frac{[2 - c(2 - d) - d + 2k]^2}{(4 - d^2)^2} - \frac{k^2}{2}, \quad \pi_2 = \frac{[2 - c(2 - d) - d - dk]^2}{(4 - d^2)^2}. \tag{2}
\]

By maximizing its profit, firm 1 chooses its optimal investment

\[
k = \frac{4(1-c)(2-d)}{8-8d^2 + d^4}.
\]

Substituting \( k \) into (2) leads to the equilibrium outputs and profits

\[
x_1 = \frac{(1-c)(8 - 4d - 2d^2 + d^3)}{8 - 8d^2 + d^4}, \quad x_2 = \frac{(1-c)(4 - 4d - 2d^2 + d^3)}{8 - 8d^2 + d^4},
\]

\[
\pi_1 = \frac{(1-c)^2(2 - d)^2}{8 - 8d^2 + d^4}, \quad \pi_2 = \frac{(1-c)^2(4 - 4d - 2d^2 + d^3)^2}{(8 - 8d^2 + d^4)^2}. \tag{3}
\]

Therefore, we have the consumer surplus and social welfare

\[
CS = \frac{x_1^2 + 2dx_1x_2 + x_2^2}{2} = \frac{(1-c)^2(40 - 16d - 56d^2 + 20d^3 + 24d^4 - 8d^5 - 3d^6 + d^7)}{(8 - 8d^2 + d^4)^2}. \tag{4}
\]

\[
W = \pi_1 + \pi_2 + CS = \frac{(1-c)^2(88 - 80d - 80d^2 + 76d^3 + 16d^4 - 16d^5 - d^6 + d^7)}{(8 - 8d^2 + d^4)^2}. \tag{5}
\]
3.2. Cournot equilibrium under licensing

If firm 1 licenses its technology by using two-part tariff contract \( (r_i, f_i) \), it will set the fixed fee \( f_i \) as high as possible to extract the increased profits of firm 2. The firms’ profit functions are

\[
\pi_i = (1 - x_i - dx_i - c + k_i)x_i + r_ix_i + f_i - \frac{k_i^2}{2} \quad (6)
\]

\[
\pi_{2i} = (1 - x_{2i} - dx_{2i} - c + k_i - r_i)x_{2i} - f_i \quad (7)
\]

Solving (6) and (7) yields the optimal outputs

\[
x_{1i} = \frac{2 - 2c + 2k_i - d + cd - k_id + r_id}{4 - d^2}, \quad x_{2i} = \frac{2 - 2c + 2k_i - 2r_i - d + cd - k_id}{4 - d^2}
\]

Substituting the outputs into profit function and maximizing firm 1’s profit, we have

the optimal royalty rate \( r_i = \frac{d(2-d)^2(1-c+k_i)}{8-6d^2} \). Substituting \( r_i \) into (6) and taking

first order condition with respect to \( k_i \) gives us the optimal investment level

\[
k_i = \frac{(1-c)(8-8d+d^2)}{d(8-7d)}. \quad (8)
\]

Hence we have the optimal royalty rate, outputs, prices and profits

\[
r_i = \frac{(1-c)(2-d)^2}{8-7d}, \quad x_{1i} = \frac{(1-c)(4-2d-d^2)}{d(8-7d)}, \quad x_{2i} = \frac{4(1-c-d+cd)}{d(8-7d)}
\]

\[
p_{1i} = \frac{c(4+2d-5d^2)-2(2-3d+d^2)}{(8-7d)d}, \quad p_{2i} = \frac{c(4-2d^2-d^3)-(1-d)(2-d)^2}{(8-7d)d}
\]

\[
\pi_{1i} = \frac{(1-c)^2(8-8d+d^2)}{2d(8-7d)} - \frac{(1-c)^2(4-4d-2d^2+d^3)^2}{(8-8d^2+d^4)^2}, \quad \pi_{2i} = \pi_2. \quad (9)
\]

Observe that the optimal royalty rate is positive. When the patent holding producer transfers its technology to its rival firm, it prefers to use a contract including a positive royalty, which relax post-licensing competition through raising the licensee’s marginal
Technology licensing provides the patentee some licensing revenue, but intensifies market competition. It is profitable if and only if the post-licensing profit is higher than pre-licensing profit. Since

\[
\pi_{tt} - \pi_1 = \frac{1}{2} (1-c)^2 \left( \frac{(8-8d + d^2)}{(8d - 7d^2)} \right) - \frac{2(2-d)^2}{8-8d^2 + d^4} - \frac{2(4-4d - 2d^2 + d^3)^2}{(8-8d^2 + d^4)^2} > 0,
\]

we have the following statement:

**Lemma 1.** Under Cournot competition, the patent holding firm has an incentive to transfer its technology by using two-part tariff.

Lemma 1 says that, under quantity competition, the patent holding firm is willing to license its innovation by means of two-part tariff. The result underlying this proposition can be explained as follows. Technology licensing generates two offsetting effects: on one hand, it makes firm 2 more efficient and hence reduces firm 1’s profit. On the other hand, it produces some licensing income for firm 1. Under two-part tariff contract, the second effect dominates. Thus it is profitable for firm 1 to license its innovation to firm 2.

The corresponding consumer surplus and social welfare are

\[
CS_t = \frac{(1-c)^2 (32-16d - 36d^2 + 12d^3 + 9d^4)}{2(8-7d)^2 d^2}
\]

(10)

\[
W_t = \frac{(1-c)^2 (16 + 24d - 78d^2 + 38d^3 + d^4)}{(8-7d)^2 d^2}.
\]

(11)

4. Bertrand competition

In the previous section, we have analyzed the case of Cournot competition. In this section, we extend our analysis to the case of Bertrand duopoly. We will derive...
the equilibrium outcomes.

4.1 Pre-licensing equilibrium

Based on the linear inverse demands, the direct demand functions are

\[ x_i^b = \frac{1 - d - p_i^b + dp_j^b}{1 - d^2}, \quad i, j = 1, 2, \quad i \neq j, \quad d \in (0, 1). \]

Without licensing, we need the condition \( d < 0.674 \) to ensure that firm 2 is active. This assumption is similar to the one used in the Cournot case. Since Bertrand competition is more intense than Cournot competition, the less efficient firm is active if and only if the products are more differentiated under the former case than under the latter one.

If licensing does not happen, the firms’ profit functions are

\[ \pi_1^b = \left(\frac{1 - d - p_i^b + dp_j^b}{1 - d^2}\right) (p_i^b - c + k^b) - \frac{(k^b)^2}{2} \]

\[ \pi_2^b = \left(\frac{1 - d - p_j^b + dp_i^b}{1 - d^2}\right) (p_j^b - c). \]

Standard calculations yield the equilibrium outcomes

\[ k^b = \frac{2(1-c)(1-d)(2+d)(2-d^2)}{(8-16d^2+7d^4-d^6)} \]

\[ p_1^b = \frac{c[8-(2-d)(5+d(4+d))d^2]-(1-d)d^2(2+d)(3-d^2)}{(8-16d^2+7d^4-d^6)} \]

\[ p_2^b = \frac{(1-d)(1+d)[4-(2-d)(1+d)(2+d)d]+c[4+(2-d)(2+d)(1-d(2+d))d]}{(8-16d^2+7d^4-d^6)} \]

\[ x_1^b = \frac{(1-c)(2+d)^2(2-3d+d^2)}{(8-16d^2+7d^4-d^6)}, \quad x_2^b = \frac{(1-c)(4-4d-4d^2+d^3+d^4)}{(8-16d^2+7d^4-d^6)} \]

\[ \pi_1^b = \frac{(1-c)^2(2-d-d^2)^2}{(8-16d^2+7d^4-d^6)^2}, \quad \pi_2^b = \frac{(1-c)^2(1-d^3)(4-4d^2-4d^2+d^3+d^4)^2}{(8-16d^2+7d^4-d^6)^2}. \]

Consumer surplus and social welfare are respectively given by
\[ CS^b = \frac{(1-c)^2(40-16d^2-96d^2+12d^3+82d^4+10d^5-27d^6-7d^7+3d^8+d^9)}{(8-16d^2+7d^4-d^8)^2} \]  
\[ (15) \]

\[ W^b = \frac{(1-c)^2(88-80d-216d^2+164d^3+198d^4-106d^5-91d^6+29d^7+21d^8-3d^9-2d^{10})}{(8-16d^2+7d^4-d^8)^2} \]
\[ (16) \]

### 4.2 Licensing equilibrium

Under two-part tariff \((r_z, f_z)\), the patent holding firm licenses its superior technology to the licensee and, in turn, charges a fixed fee to appropriate as much profit as possible from the licensee. The firms’ post-licensing profit functions are

\[ \pi^b_{1z} = \frac{1-d - p^l_{1z} + dp^l_{1z}}{1-d^2}(p^l_{1z} - c + k^b) + r_z \frac{1-d - p^l_{2z} + dp^l_{2z}}{1-d^2} + f_z - \frac{(k^b)^2}{2} \]  
\[ \pi^b_{2z} = \frac{1-d - p^l_{2z} + dp^l_{2z}}{1-d^2}(p^l_{2z} - c + k^b) - r_z \frac{1-d - p^l_{2z} + dp^l_{2z}}{1-d^2} - f_z \]  
\[ (17) \]

Straightforward computations lead to the equilibrium values

\[ r_z = \frac{(1-c)(1+d)(2+d)^2}{8+d+9d^2}, \quad k^b = \frac{(1-c)(8+9d^2+d^3)}{d(8+d+9d^2)} \]

\[ p^b_{1z} = \frac{c(4+6d+5d^2+3d^3)-2(2-d+2d^2-3d^3)}{(8+d+9d^2)d} \]

\[ p^b_{2z} = \frac{c(4+4d+4d^2+5d^3+d^4)-(4-4d+3d^2-4d^2+d^3)}{(8+d+9d^2)d} \]

\[ x^b_{1z} = \frac{(1-c)(4+2d+5d^2+d^3)}{(8+d+9d^2)d}, \quad x^b_{2z} = \frac{2(1-c)(2+d^2)}{(8+d+9d^2)d} \]

\[ \pi^b_{1z} = \frac{(1-c)^2}{2d(8+d+9d^2)(8-16d^2+7d^4-d^8)^2} [(512-256d^2-992d^2+352d^3)
\[ +(128d^4-336d^5+928d^6+272d^7-746d^8)
\[ +(10d^9+309d^{10}-43d^{11}-80d^{12}+4d^{13}+9d^{14}+d^{15})] \]
\[ \pi_{2i}^b = \frac{(1-c)^2(1-d^2)(4-4d^4-d^2+4d^3)}{(8-16d^2+7d^4-d^4)} \]  \hspace{1cm} (19)

Direct comparisons between firm 1’s profits yields \( \pi_{1i}^b - \pi_{1i}^b > 0 \).

**Lemma 2.** Under Bertrand competition, it is profitable for the patent holding firm to transfer its technology by means of two-part tariff.

This lemma is similar to the one we obtained in Cournot case. When considering technology licensing, the patentee has to balance the gain from licensing income and the loss from fiercer competition. In this case, the licensing revenue more than compensate for the increase in competition and hence, the innovating firm has an incentive to transfer its innovation. More importantly, under price competition, the patent holding firm has a strong incentive to commit itself to a higher price, which improves its licensing profit. A contract with a positive royalty rate provides such a commitment. The usage of a contract including a positive royalty rate makes both the licensor and the licensee less aggressive and thereby leads to a collusive effect. This is also noted by Fauli-Oller and Sandonis (2002, 2003).

Consumer surplus and social welfare are given by

\[ CS_i^b = \frac{(1-c)^2(32+48d+76d^2+84d^3+49d^4+30d^5+5d^5)}{2d^2(8+d+9d^2)^2} \]  \hspace{1cm} (20)

\[ W_i^b = \frac{(1-c)^2(16+56d+42d^2+114d^3+33d^4+56d^5+7d^5)}{d^2(8+d+9d^2)^2} \]  \hspace{1cm} (21)

**5. Bertrand vs. Cournot**

In this section, we compare the equilibrium outcomes under quantity and price competition. We start our analysis with considering the case where licensing does not occur.
5.1 Bertrand and Cournot competition without licensing

We first investigate firm 1’s R&D incentive under price- and quantity-setting regime.

**Proposition 1.** If licensing does not occur, then the optimal investment is higher under Cournot (Bertrand) competition if $d < 0.502$ ($0.502 < d < 0.674$).

The proof of the proposition follows directly from the straightforward comparison. The intuition behind this proposition is obvious. When the degree of product differentiation is high, the competition is not fierce. The mode of competition is less important. Firm 1 is likely to invest more in R&D under quantity competition. However, when the goods are closer substitutes, competition turns to be intense and the type of competition becomes more important. So, to soften competition, a Bertrand competitor has a stronger incentive to differentiate itself from its rival firm. R&D investment plays such a role of differentiation. Therefore, R&D expenditure is higher in the case of price competition.

In contrast to Qiu (1997) and Symeonidis (2003), who show that quantity competition always induces more R&D effort than price competition, our result implies that, depending on the degree of product differentiation, the innovating firm may not invest more in R&D when the product market involves quantity competition. The difference between our result and theirs is resulted from the difference in model structures. Different from their models, we do not allow R&D rivalry and hence assume away spillover effect. In the present model, the innovation benefits the R&D firm only. As a consequence, the innovating firm gains a large cost advantage over its
rivalry firm and seizes a substantially large market share (size effect). Hence, when the products become more homogenous, a firm has stronger incentive to invest in its R&D in price than in quantity competition.

We now turn to compare firms’ profits under price and quantity competition. A simple and direct comparison (3) and (14) immediately leads to the following statement.

**Proposition 2.** Without technology licensing, firm 1’s profit is higher under both modes of competition \((\pi_1 > \pi_2, \pi_1^b > \pi_2^b)\). Furthermore, the profit differential is larger in Cournot (Bertrand) than in Bertrand (Cournot) equilibrium if \(0 < d < 0.502\) (\(0.502 < d < 0.674\)). That is, if \(0 < d < 0.502\), then \((\pi_1 - \pi_2) > (\pi_1^b - \pi_2^b)\); if \(0.502 < d < 0.674\), then \((\pi_1 - \pi_2) < (\pi_1^b - \pi_2^b)\).

Due to the cost differences, the innovating firm ends up enjoying a competitive advantage over its rival firm. Hence, the result of the first part in the proposition is hardly surprising. However, the result of the second part in the proposition needs some explanation. As suggested by Zanchettin (2006), in the case of asymmetric duopoly, price competition produces (i) price effect which entails lower prices under price competition, and (ii) selection effect which increases the market share of the more efficient firm. While the price effect results in lower profits for both firms under price than under quantity competition, the selection effect works in the opposite direction for the efficient firm’s profit. Moreover, with the rise in the degree of firms’ asymmetry or product substitutability, the price effect weakens but the selection effect becomes stronger. When the degree of product differentiation is relatively large
(0 < d < 0.502), the lower R&D expenditure under price competition creates smaller degree of asymmetry, the price effect is strong while the selection effect is weak, hence profit differential is lower under price competition. However, when the products become close substitutes (0.502 < d < 0.674), the bigger R&D effort under price competition generates higher degree of asymmetry, the price effect is weak but the selection effect is strong, thus price differential is higher under price competition.

It follows to compare industry profits, consumer surplus and social welfare under Bertrand and Cournot competition.

**Proposition 3.** In the absence of technology licensing, industry profit is higher under Cournot competition. But consumer surplus and social welfare are higher under Bertrand competition.

The proof is trivial and is omitted. The conclusion in proposition 3 confirms the result of SV. However, there are two effects here: one is the *efficiency effect* due to the process R&D. This effect plays a role in both improving economic efficiency and softening market competition. The other effect is the *price effect*. Regardless of the degree of product differentiation, price effect plays a dominant role in producing lower Bertrand profits. Moreover, lower prices under price competition improve consumer surplus. Therefore, Bertrand competition is welfare superior to Cournot competition.

Our result in this proposition is consistent with the one found out by Symeonidis (2003) in the context of product innovation. In that case, R&D investment boosts demand. However, this result is different from the one obtained by Motto (1993), who
uses a vertical product differentiation model and shows that Bertrand profit is always higher than Cournot profit. The reason for the difference is that, in the model by Motto firms may differentiate their products by increasing quality difference, and hence soften competition, more in Bertrand than in Cournot case. This effect is absent from the present model.

5.2 Bertrand and Cournot competition with licensing

We first focus on R&D incentives. Direct comparison yields the following statement.

**Proposition 4.** *In the presence of technology licensing, the innovating firm invests more in R&D under Bertrand than under Cournot competition.*

As is pointed out in section 5.1, Qiu (1997) and Symeonidis (2003) show that quantity competition always produces higher R&D investment than price competition, which is the opposite of our result. However, they use models with R&D rivalry and technology spillover. In that case, firms are symmetric. In the symmetric case, the innovation benefits both the R&D and non-R&D firms, which weakens the size effect but strengthens the strategic effect (a firm’s R&D lowers its marginal cost and affects its rival’s production decision). When the strategic effect prevails, a firm will invest more in R&D under quantity competition. This follows because the strategic effect is positive in quantity competition but negative in price competition. ⁶

In contrast, when only one of the two firms is permitted to conduct R&D, the innovating firm gains a greater comparative advantage over its rival firm. The size

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⁶ Please see Qiu (1997) for the detailed discussion.
effect dominates the strategic effect. Moreover, with the opportunity of licensing, a patent holding producer can choose a contract including a positive royalty rate to control the licensee’s marginal cost. The positive royalty rate results in a *collusive effect* under price competition. As a result, the licensor has a strong incentive to set a larger royalty rate in Bertrand case than in Cournot case.  

In order to charge a higher royalty, an innovator needs to make higher investment in its innovation. Therefore, in the present model, an innovating firm has an incentive to do more R&D in Bertrand than in Cournot competition.

We now turn to the profit comparison. Simple computation gives us the following conclusion.

**Proposition 5.** The licensor (licensee) obtains higher profit in Bertrand (Cournot) equilibrium. Moreover, profit differential and industry profit are greater under Bertrand than under Cournot competition. That is, 

\[ \pi_{1t} < \pi_{1t}^b, \quad \pi_{2t} > \pi_{2t}^b, \]

\[ (\pi_{1t} - \pi_{2t}^b) \geq (\pi_{1t} - \pi_{2t}) \quad \text{and} \quad (\pi_{1t}^b + \pi_{2t}^b) \geq (\pi_{1t} + \pi_{2t}). \]

Under price competition, the collusive effect produced by the royalty is so strong that it dominates the price effect and makes licensing even more profitable. Therefore, the licensor gains more profits in Bertrand than in Cournot case. In contrast, due to the inclusion of a fixed fee in the licensing contract, the collusive effect does not benefit the licensee. But the price effect under price competition reduces the licensee’s

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7 \( r_2 - r_1 = \frac{8d(1-c)(1-d)(8 + d + 2d^2)}{(8 - 7d)(8 + d + 9d^2)} > 0. \)

8 If the two products are independent goods \( d = 0 \), then \( \pi_{1t}^b - \pi_{2t}^b = (\pi_{1t} - \pi_{2t}) \) and \( (\pi_{1t}^b + \pi_{2t}^b) = (\pi_{1t} + \pi_{2t}). \)
profit. Hence, the licensee’s profit is lower in price than in quantity equilibrium. However, under Bertrand competition, the collusive effect reduces the competition and benefits the industry as a whole. As a result, Bertrand aggregate profit exceeds Cournot aggregate profit. This result is in contrast to the standard conclusion regarding profit ranking in SV.

The ranking on profit differentials in proposition 5 follows from the facts that (1) the licensor obtains greater profit in price competition than in quantity competition but, (2) the licensee gains larger profit in the latter case than in the former case. Note that the licensee obtains the same market profit as in the status quo. The ranking on profit differential implies that, with technology licensing, the increase in industry profit is higher under Bertrand competition than under Cournot competition. This conclusion is again resulted from the collusive effect under Bertrand competition.

Finally, we compare consumer surplus and social welfare. Direct comparing (10), (11), (20) and (21) establishes the following statement.

**Proposition 6.** In the case of technology licensing, consumer surplus and social welfare are higher under Cournot competition than under Bertrand competition.

The intuition behind this proposition is clear. Under price competition, although R&D incentive is stronger, the cost reduction of the licensee is lower than under Cournot competition. This follows from the collusive effect induced by patent licensing. The efficiency gain from patent licensing that permits the diffusion of

\[ (k_i - r_2) - (k_i - r_1) = -\frac{8d(1-c)(1-d)(8-d+2d^2)}{(8-7d)(8+d+9d^2)} < 0. \]
superior technology is at the cost of the usage of a contract that results in higher price in the market. Hence, outputs (prices) are higher (lower) under the quantity-setting regime than under the price-setting regime. As a consequence, consumer surplus is higher in the Cournot case than in the Bertrand case. The gain in consumer surplus under Cournot competition relative to Bertrand competition outweighs the loss in industry profits. Consequently, Cournot competition is welfare superior to Bertrand competition.

The main message contained in proposition 6 is that, in terms of greater consumer surplus and social welfare, Cournot competition is more efficient than Bertrand competition. This stands in contrast to the traditional efficiency result obtained by SV. Our result is also different from the ones developed by Motta (1993) and Zanchettin (2006), who confirm SV’s welfare ranking by respectively using a vertical product differentiation model and an asymmetric duopoly model. Our finding is (partially) consistent with the ones in Arya et al. (2007), Qiu (1997) and Symeonidis (2003).

6. Discussion and conclusions

In this paper, we reexamine the argument on welfare effect of price and quantity competition by using a differentiated duopoly model where one of the firms firstly invests in cost-reducing innovation, and then licenses its technology to its rival firm through two-part tariff. We show that, under the circumstance of R&D and licensing,

\[ p_t^b - p_t = - \frac{24(1-c)(1-d)d^2}{64 - 48d + 65d^2 - 63d^3} < 0, \quad x_t^b - x_t = \frac{2(1-c)(4-d)d^2}{64 - 48d + 65d^2 - 63d^3} > 0, \]

\[ p_{2t} - p_{2t}^b = - \frac{2(1-c)(8-11d + 4d^2 - d^3)d}{64 - 48d + 65d^2 - 63d^3} < 0, \quad x_{2t} - x_{2t}^b = \frac{2(1-c)(8-11d)d}{64 - 48d + 65d^2 - 63d^3} > 0. \]
the traditional efficiency result obtained by SV is overturned. Bertrand competition induces higher R&D effort than Cournot competition. Furthermore, Bertrand competition results in higher industry profit, lower consumer surplus and lower social welfare than Cournot competition.

In the present study, we have considered two-part tariff licensing contract. It is natural to test the robustness of our results under fixed fee or royalty contract. It turns out that the welfare ranking in terms of consumer surplus and social welfare in proposition 6 does not change. However, the ranking on R&D incentive and profits in proposition 4 and 5 may be reversed. Straightforward calculations reveal that, if the patent holding firm chooses fixed fee licensing, then quantity competition generates larger R&D expenditure ($k_f > k_f^b$), higher industry profit ($\pi_{1f} > \pi_{1f}^b$, $\pi_{2f} > \pi_{2f}^b$), greater consumer surplus ($CS_f > CS_f^b$) and higher social welfare ($W_f > W_f^b$).

Furthermore, if the licensor uses royalty licensing, then in price competition, R&D expenditure is higher ($k_r^b > k_r$), industry profit is greater ($\pi_{1r} < \pi_{1r}^b$, $\pi_{2r} < \pi_{2r}^b$), but consumer surplus and social welfare are lower ($CS_r > CS_r^b$, $W_r > W_r^b$).
References


21. Symeonidis, G., 2003, Comparing Cournot and Bertrand equilibria in a
