Intensity of Competition and Adoption of Product Innovations: Comparing Incentives for Innovations and Welfare under Cournot and Bertrand Competition

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Abstract

We examine the possible superiority of Cournot versus Bertrand competition in the context of product innovations. We show a non-monotone relation between the intensity of competition and incentives for innovations, and find conditions under which both consumer surplus and social welfare are higher under Cournot competition, whereas industry profits may be lower. Regarding the forces behind the result that social welfare is higher under Cournot competition, we also present new insights.

Keywords: Product Innovations, Incentives for Innovations, Cournot Competition, Bertrand Competition, Welfare Analysis

JEL Classification: L13, O31, O33

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1. Introduction

The seminal works of Singh and Vives (1984) and Motta (1993) compare Cournot and Bertrand equilibria in horizontally and vertically differentiated duopoly markets, respectively. They establish the well-known welfare results that, from a static viewpoint, consumer surplus and social welfare are higher under Bertrand than under Cournot competition.[1] It is an open question, however, whether the same conclusion holds in a dynamic setting where firms can engage in either product (i.e., quality-improving) or process (i.e., cost-reducing) innovations.

Delbono and Denicolò (1990) first address this issue in a homogeneous good oligopoly with process innovations. They find that incentives for innovations are stronger under Bertrand competition, but social welfare may be higher under Cournot competition (they call this “dynamic efficiency”). Qiu (1997) studies this question in Singh and Vives’s (1984) horizontal differentiation model in the context of process innovations with spillovers, demonstrating that Cournot firms have stronger incentives for innovations and social welfare may be higher under Cournot competition if, among other conditions, spillovers are sufficiently large. Pal (2010) and Mukherjee (2011) consider duopolistic firms’ incentives for process innovations in the absence of spillovers, finding that incentives for innovations may be stronger or weaker, while social welfare is indeed likely to be higher under Cournot competition. All these studies compare Cournot and Bertrand equilibria in the context of process innovations. Interestingly, while they obtain diverse

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[1] For the ranking of profits, Singh and Vives (1984) find in their horizontal differentiation model that Cournot (Bertrand) competition yields greater industry profits in the case of substitutes (complements). Motta (1993) finds in his vertical differentiation model that industry profits are higher under Cournot (Bertrand) competition in the case of variable (fixed) costs of quality improvement.

results regarding which competition mode leads to stronger incentives for innovations, they all reach the common conclusion that there are conditions under which social welfare is higher under Cournot competition, though consumer surplus is still lower.

The objective of the present paper is to continue this line of studies (on comparing incentives for innovations and the resulting dynamic efficiency of Cournot versus Bertrand competition) by switching attention from process to product innovations. This is an important direction, because as Mansfield (1988) and Scherer and Ross (1990) document,[2] product innovations are empirically at least as important as process innovations, but have received relatively little attention in the theoretical literature. To fill this gap, we employ a standard vertical differentiation model *à la* Shaked and Sutton (1982) to evaluate the relative dynamic efficiency of Cournot versus Bertrand competition in the context of product innovations. In particular, we consider a three-stage simultaneous-move game in which two firms first independently and simultaneously decide whether or not to adopt a product innovation at a given cost. For this, we follow Beath et al. (1987) to model product innovation as extending the upper bound of the adopting firm's feasible quality spectrum. In the second stage, just like in Beath et al. (1987), the duopoly firms select product qualities endogenously from their respective quality spectrums determined in the first stage. They lastly compete in the product market either in Cournot or Bertrand fashion in the third stage.[3]

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[2] Mansfield (1988) documents that American firms devote about two-thirds of their R&D expenditures on product innovations and about one-third on process innovations. Scherer and Ross (1990) argue that product innovations are empirically more important than process innovations for U.S. corporations, since they put forth much more R&D efforts on product innovations and obtain significantly more patents on product innovations than on process innovations.

[3] Beath et al. (1987) consider Bertrand competition only. They focus on the issue of persistence or reversal of quality leadership with a sequence of product innovations, while we focus on comparing the dynamic efficiency of Cournot versus Bertrand competition in the context of product innovation.

We first present that innovation adoption patterns differ under both competition regimes. In particular, we are more likely to observe global and no adoption of a product innovation under Cournot, and partial adoption under Bertrand competition. Second, incentives for adopting a product innovation are stronger (weaker) under Cournot than under Bertrand competition if adoption costs are relatively low (high). For intermediate values of adoption costs, incentives for adoption are exactly the same under both competition regimes. Third, when Cournot competition leads to stronger incentives for adoption and the innovation sizes are sufficiently large, both consumer surplus and social welfare are higher under Cournot than under Bertrand competition. Notice that this is a stronger conclusion regarding the possible superiority of Cournot competition than the aforementioned studies that consider process innovations. In those studies, consumer surplus is always lower under Cournot competition, though social welfare may be higher. Furthermore, while firms tend to differentiate their qualities more under Bertrand competition, in our vertical differentiation model with product innovation adoption and endogenous choice of quality we present that, in one instance, equilibrium qualities and the degree of vertical product differentiation are identical under both competition regimes.

Symeonidis (2003) is the only other paper we know of that also compares welfare under Cournot and Bertrand competition in the context of product innovations. He finds that both consumer surplus and social welfare are likely to be higher under Cournot competition, provided that spillovers are sufficiently large and the degree of horizontal differentiation is small. Relative to Symeonidis (2003) and the strand of literature on the dynamic efficiency of Cournot versus Bertrand competition, our contributions are as follows. First, by considering a model different from Symeonidis (2003), we reinforce his main point that consumer surplus is likely to be higher under Cournot competition in the context of product innovations, though not in the context of process innovations. This is because product innovations raise consumers' utility directly (by increasing quality that directly enters each consumer's utility function), while process innovations affect consumers' utility indirectly (by reducing the firm's marginal cost, which then leads to an increase in output).

Second, while Symeonidis (2003) requires sufficiently large spillovers for Cournot competition to yield higher consumer surplus and social welfare, we establish the same superiority of Cournot competition in a model without spillovers. In other words, the present paper indentifies new circumstances and conditions under which Cournot competition gives rise to higher consumer surplus and social welfare.

Third, regarding the forces behind the result that social welfare (which is the sum of consumer surplus and industry profits) is higher under Cournot than under Bertrand competition, we find new insights. In Symeonidis (2003) industry profits are always higher under Cournot competition, while consumer surplus may be higher or lower. Consequently, social welfare is higher under Cournot competition in Symeonidis (2003) for two cases: (i) industry profits and consumer surplus rank in opposite directions (with profits being higher yet consumer surplus lower under Cournot competition), but the ranking of industry profits dominates (note that this case is similar to what happens in models with process innovations); and (ii) consumer surplus and industry profits rank in the same direction, with both being higher under Cournot competition such that social welfare is also higher (note that this case cannot arise in models with process innovations). Our model not only encompasses these two cases, but also finds a third, novel case in which consumer surplus is higher, industry profits are lower, and social welfare turns out to be higher under Cournot competition. In our novel case (which arises when innovation sizes are sufficiently large), a switch from Bertrand to Cournot competition enhances social welfare, because the increase in consumer surplus outweighs the decrease in industry profits.

The present paper is also closely related to the literature on the relation between intensity of competition and incentives for innovations, which dates as far back as Schumpeter (1942) and Arrow (1962). Schumpeter (1942) argues forcefully that monopoly power provides greater incentives for innovations than perfect competition, while Arrow (1962) demonstrates convincingly that the opposite result holds. While early studies focus on the comparisons of these two polar market structures,[4] an increasing interest has turned to oligopoly industries (especially Cournot and Bertrand competition), with Schumpeter (1942) and Arrow (1962) taken as important benchmarks. On the one hand, Delbono and Denicolò (1990) show that Bertrand competition provides greater incentives for innovations (an 'Arrow-like result'). On the other hand, Qiu (1997), Bonanno and Haworth (1998), and Symeonidis (2003) find that Cournot competition leads to stronger incentives (a 'Schumpeter-like result'). Most studies, however, find a mixed result (i.e., a non-monotone relation between intensity of competition and incentives for innovations), including Bester and Petrakis (1993), Boone (2001), Pal (2010), Belleflamme and Vergari (2011), and Mukherjee (2011), as all of them consider process innovations.[5] The present paper contributes to this strand of literature by showing a non-monotone relation (i.e., a mixed result) as well, but in the context of product instead of process innovations.

The paper is also related to the literature on endogenous quality choice under price and quantity competition. On the one hand, Shaked and Sutton (1982), Tirole (1988), and Choi and Shin (1992) show that under price

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4 See Reinganum (1989) for a comprehensive and insightful review.

5 Among these studies, Boone (2001) and Belleflamme and Vergari (2011) assume that only one out of *n* oligopolistic firms can adopt an exogenously given cost-reducing technology to become the single user of the process innovation. Likewise, Bester and Petrakis (1993) assume that only one of the two duopolistic firms can reduce its cost by spending a given cost. In contrast, Pal (2010) and Mukherjee (2011) consider duopoly models in which both firms are allowed to adopt or engage in process innovations, which our modeling resembles more.

competition, firms always differentiate their product qualities in order to soften price competition. In the extreme, one may even observe maximal differentiation (see, for example, Tirole (1988)). On the other hand, Gal-Or (1983), Bonanno (1986), and Ireland (1987) find that under quantity competition, the result of minimum differentiation may arise. Motta (1993) compares duopolistic firms' endogenous quality choice under both price and quantity competition, reaching the conclusion that product differentiation always occurs in equilibrium regardless of competition modes and that firms differentiate their qualities more under Bertrand competition. Relative to this literature, our addition is to present an instance in which equilibrium qualities and the degree of vertical product differentiation are identical under both competition regimes.

Following Bonanno and Haworth (1998), a sequence of papers such as Weiss (2003) and Filippini and Martini (2010) study duopoly firms' choices between product and process innovations under Cournot and Bertrand competition. The present paper departs from these papers in that we focus on welfare comparisons of Cournot versus Bertrand competition in the context of product innovations, while they focus on comparing incentives for different types of innovations instead of consumer and social welfare.[6]

The remainder of the paper is organized as follows. Section 2 sets up our model, which resembles Shieh and Peng (2000), but departs from them in one important way. While they consider Bertrand competition, this paper considers both Cournot and Bertrand competition and is thus able to pursue comparisons between Cournot and Bertrand equilibrium outcomes (in terms

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[6] In addition, since Singh and Vives's (1984) classic work, there is a huge body of literature comparing Cournot and Bertrand equilibria from various angles (see among others, Delbono and Denicolò (1990), Häckner (2000), Hsu and Wang (2005), Zanchettin (2006), and Mukherjee (2010)). Among these different angles, the present paper relates to the particular strand of literature stemming from Delbono and Denicolò (1990), who focus on comparing the dynamic efficiency of Cournot versus Bertrand competition with innovations.

of incentives for innovations, industry profits, consumer surplus, social welfare, and degree of vertical differentiation). Section 3 characterizes equilibrium outputs and prices under both competition regimes. Section 4 analyzes equilibrium quality choice. Section 5 compares incentives for product innovation adoption. Section 6 compares welfare. Section 7 concludes. All proofs are relegated to the Appendix.

2. The Model

Consider a standard vertical differentiation model *à la* Shaked and Sutton (1982) and Tirole (1988). There are two firms, 1 and 2, producing a commodity that can be produced at a number of different quality levels, q. Product quality is restricted to one dimension, with larger values of q indicating higher quality levels. To analyze duopoly firms' incentives for innovation and to compare the resulting welfare under different competition modes, we consider the following three-stage game. In the first stage, a product innovation is made available for adoption at a given cost, k. Knowing this, the duopoly firms simultaneously and independently decide whether or not to adopt the innovation. We follow Beath et al. (1987) to model a product innovation as an extension of the upper bound of the adopting firm's feasible quality spectrum. In particular, if the innovation is not adopted, then the feasible quality spectrum of a non-innovating firm is given by $[0, \overline{q}]$, where $\overline{q}$ represents the current state-of-the-art quality. If the innovation is adopted, then the innovating firm's feasible quality spectrum is expanded to $[0, \overline{\overline{q}}]$, where $\overline{\overline{q}} > \overline{q} > 0$. Note that possessing the technical know-how to produce a good of quality $\overline{\overline{q}}$ enables a firm to produce any good of quality $q < \overline{\overline{q}}$. Let $\Delta q \equiv \overline{\overline{q}} - \overline{q}$, where Δq represents the size of product innovation. We further follow Shaked and Sutton (1982) and Beath et al. (1987) to assume that there are zero costs of production.[7]

With their respective quality spectrums determined in the first stage, the duopoly firms independently and simultaneously select product qualities, q_1 and q_2, in the second stage. They then compete in the product market either in Cournot or Bertrand fashion in the last stage. With Cournot competition they simultaneously choose output levels x_1 and x_2, while in the case of Bertrand competition they simultaneously set prices p_1 and p_2.

Assume that consumers have unit demand for this good. If a consumer buys a product of quality q_i from firm *i* at price p_i, then her consumer surplus is given by $U = \theta q_i - p_i$, where θ is a taste parameter and *i* = 1, 2. Assume that θ is uniformly distributed over the interval [0, 1] with unit density. Note that the lower bound of θ equal to zero implies that the market will be uncovered. If a consumer does not buy, then she receives zero consumer surplus. Let θ_1 denote the consumer who is indifferent between buying from firm 1 and not buying. We have $\theta_1 = p_1 / q_1$. Similarly, let θ_2 denote the consumer who is indifferent between buying from firm 2 and not buying. We have $\theta_2 = p_2 / q_2$. Finally, let θ_m denote the consumer who is indifferent between buying from firm 1 and buying from firm 2. We thus have $\theta_m = (p_2 - p_1)/(q_2 - q_1)$.

To describe the demand functions facing the duopoly in the third stage, we assume that $q_1 \leq q_2$ without loss of generality (since the analysis for the case with $q_1 > q_2$ can be inferred from that for $q_1 < q_2$ with the subscripts reversed). We first consider the case where qualities chosen in the second stage are such that $q_1 < q_2$. Given this, demand functions in the third stage are as follows:

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[7] In the literature the assumption of zero costs of production is justified as follows: Even though the higher quality could be produced at zero costs, in equilibrium, the low-quality producer will still refrain from increasing its quality so as to avoid fierce price competition. An earlier version of this paper shows that our results remain true if we consider an alternative unit cost function, $c(q_i) = \alpha q_i$, where $0 < \alpha < 1$. We discuss in the conclusion what happens to our results if we consider a quadratic cost function of quality.

$$
\begin{cases}
x_1(p_1, p_2; q_1, q_2) = \theta_m - \theta_1 = \dfrac{(p_2 - p_1)}{(q_2 - q_1)} - \dfrac{p_1}{q_1}, \\[2ex]
x_2(p_1, p_2; q_1, q_2) = 1 - \theta_m = 1 - \dfrac{(p_2 - p_1)}{(q_2 - q_1)},
\end{cases}
\tag{1}
$$

where $0 < \theta_1 < \theta_m < 1$ and $\theta_2 < \theta_m$. From (1), we have inverse demand functions given by:

$$
\begin{cases}
p_1(x_1, x_2; q_1, q_2) = q_1 - q_1 x_1 - q_1 x_2, \\
p_2(x_1, x_2; q_1, q_2) = q_2 - q_1 x_1 - q_2 x_2.
\end{cases}
\tag{2}
$$

Next, consider the case where qualities chosen in the second stage are such that $q_1 = q_2 = q$. In such subgames, demand functions under Bertrand competition are given by:

$$
x_i(p_i, p_j; q_1 = q_2 = q) =
\begin{cases}
0, & \text{if } p_i > p_j, \\[1ex]
\dfrac{1}{2}\left(1 - \dfrac{p}{q}\right), & \text{if } p_i = p_j = p, \\[2ex]
1 - \dfrac{p_i}{q}, & \text{if } p_i < p_j,
\end{cases}
\tag{3}
$$

where i = 1, 2, j = 1, 2, and $i \neq j$. With Cournot competition, the total demand is given by $X(p; q) = 1 - p/q$, such that the inverse demand function is given by:

$$
p(x_1, x_2; q_1 = q_2 = q) = q(1 - X) = q(1 - x_1 - x_2) \cdot
\tag{4}
$$

The appropriate equilibrium concept for the three-stage simultaneous-move game is that of the subgame perfect Nash equilibrium. Using backward induction, we first characterize equilibrium prices and outputs in the third stage, followed by equilibrium qualities chosen in the second stage, and then innovation adoption decisions in the first stage.

3. Equilibrium Prices and Outputs in the Third Stage

Under Cournot competition, in the subgames where $q_1 < q_2$ the duopoly's profit functions (gross of adoption costs) are:

$$\begin{cases} \pi_1^C(x_1, x_2; q_1, q_2) = (q_1 - q_1 x_1 - q_1 x_2)x_1, \\ \pi_2^C(x_1, x_2; q_1, q_2) = (q_2 - q_1 x_1 - q_2 x_2)x_2, \end{cases} \tag{5}$$

where the superscript C stands for Cournot competition. Simultaneously solving the first-order conditions for the maximization problems in (5) yields the Cournot equilibrium. Plugging the equilibrium outputs into (2) and (5) yields the associated equilibrium prices and profits (gross of adoption costs). We now have the following.

$$\begin{cases} x_1^C(q_1, q_2) = \dfrac{q_2}{(4q_2 - q_1)}, \\ x_2^C(q_1, q_2) = \dfrac{(2q_2 - q_1)}{(4q_2 - q_1)}, \\ p_1^C(q_1, q_2) = \dfrac{q_1 q_2}{(4q_2 - q_1)}, \\ p_2^C(q_1, q_2) = \dfrac{q_2(2q_2 - q_1)}{(4q_2 - q_1)}, \\ \pi_1^C(q_1, q_2) = \dfrac{q_1 {q_2}^2}{(4q_2 - q_1)^2}, \\ \pi_2^C(q_1, q_2) = \dfrac{q_2(2q_2 - q_1)^2}{(4q_2 - q_1)^2}, \end{cases} \tag{6}$$

where $x_1^C(\cdot) < x_2^C(\cdot)$, $p_1^C(\cdot) < p_2^C(\cdot)$, and $\pi_1^C(\cdot) < \pi_2^C(\cdot)$ for all $q_1 < q_2$; and the inequalities behind the inverse demand functions, $0 < \theta_1 < \theta_m < 1$ and $\theta_2 < \theta_m$, are indeed satisfied.

In the subgames where $q_1 = q_2 = q$, the Cournot firms' profit functions are given by:

$$\begin{cases} \pi_1^C(x_1, x_2; q_1 = q_2 = q) = q(1 - x_1 - x_2)x_1, \\ \pi_2^C(x_1, x_2; q_1 = q_2 = q) = q(1 - x_1 - x_2)x_2. \end{cases} \tag{7}$$

Solving the first-order conditions simultaneously and then substituting into (4) and (7) yield:

$$\begin{cases} x_1^C(q_1 = q_2 = q) = x_2^C(q_1 = q_2 = q) = \dfrac{1}{3}, \\ p^C(q_1 = q_2 = q) = \dfrac{q}{3}, \\ \pi_1^C(q_1 = q_2 = q) = \pi_2^C(q_1 = q_2 = q) = \dfrac{q}{9}. \end{cases} \tag{8}$$

Under Bertrand competition, in the subgames where $q_1 < q_2$, the duopoly's profit functions (gross of adoption costs) are given by:

$$\begin{cases} \pi_1^B(p_1, p_2; q_1, q_2) = p_1\left[\dfrac{(p_2 - p_1)}{(q_2 - q_1)} - \dfrac{p_1}{q_1}\right], \\ \pi_2^B(p_1, p_2; q_1, q_2) = p_2\left[1 - \dfrac{(p_2 - p_1)}{(q_2 - q_1)}\right], \end{cases} \tag{9}$$

where the superscript B stands for Bertrand competition. Simultaneously solving the first-order conditions and then plugging the equilibrium prices into (1) and (9) yield:

$$\begin{cases} p_1^B(q_1,q_2) = \dfrac{q_1(q_2-q_1)}{(4q_2-q_1)}, \\ p_2^B(q_1,q_2) = \dfrac{2q_2(q_2-q_1)}{(4q_2-q_1)}, \\ x_1^B(q_1,q_2) = \dfrac{q_2}{(4q_2-q_1)}, \\ x_2^B(q_1,q_2) = \dfrac{2q_2}{(4q_2-q_1)}, \\ \pi_1^B(q_1,q_2) = \dfrac{q_1q_2(q_2-q_1)}{(4q_2-q_1)^2}, \\ \pi_2^B(q_1,q_2) = \dfrac{4q_2^{\,2}(q_2-q_1)}{(4q_2-q_1)^2}, \end{cases} \tag{10}$$

where $p_1^B(\cdot) < p_2^B(\cdot)$, $x_1^B(\cdot) < x_2^B(\cdot)$, and $\pi_1^B(\cdot) < \pi_2^B(\cdot)$ for all $q_1 < q_2$, and the inequalities behind the demand functions given in (1) are satisfied.

In the subgames where $q_1 = q_2 = q$, the unique Bertrand-Nash equilibrium is given by both firms pricing at the marginal cost. We thus have:

$$\begin{aligned} p_i^B(q_1 = q_2 = q) &= 0, \\ x_i^B(q_1 = q_2 = q) &= \frac{1}{2}, \\ \pi_i^B(q_1 = q_2 = q) &= 0, \end{aligned} \tag{11}$$

where $i = 1, 2$.

4. Equilibrium Qualities in the Second Stage

Under Cournot competition, if both firms choose different qualities, then from (6) we have:

$$\begin{cases} \dfrac{\partial \pi_1^C(q_1, q_2)}{\partial q_1} = \dfrac{(4q_2 + q_1)q_2^{\ 2}}{(4q_2 - q_1)^3} > 0, \\ \dfrac{\partial \pi_2^C(q_1, q_2)}{\partial q_2} = \dfrac{(2q_2 - q_1)(8q_2^{\ 2} - 2q_1 q_2 + q_1^{\ 2})}{(4q_2 - q_1)^3} > 0. \end{cases} \tag{12}$$

If both firms choose the same quality, then from (8) we have:

$$\frac{\partial \pi_1^C(q_1 = q_2 = q)}{\partial q} = \frac{\partial \pi_2^C(q_1 = q_2 = q)}{\partial q} = \frac{1}{9} > 0. \tag{13}$$

The positive signs of the partial derivatives in (12) and (13) imply that each firm can increase profits by unilaterally increasing its own quality, such that in equilibrium each firm produces its maximum possible quality. Recall that our analysis thus far has assumed $q_1 < q_2$ or $q_1 = q_2$. The analysis for the case with $q_1 > q_2$ is similar to that for $q_1 < q_2$, except for the relabeling of subscripts, which we omit without loss of generality. We thus have the following lemma, for which the Appendix provides the formal proof.

Lemma 1. *Anticipating Cournot competition in the third stage, the subgame perfect Nash equilibrium qualities chosen in the second stage,* (q_1^C, q_2^C)*, are given by:*

(1) $(q_1^C, q_2^C) = (\overline{q}, \overline{q})$ *if neither firm adopts the product innovation in the first stage,*
(2) $(q_1^C, q_2^C) = (\overline{\overline{q}}, \overline{q})$ *if only firm 1 adopts,*
(3) $(q_1^C, q_2^C) = (\overline{q}, \overline{\overline{q}})$ *if only firm 2 adopts, and*
(4) $(q_1^C, q_2^C) = (\overline{\overline{q}}, \overline{\overline{q}})$ *if both firms adopt.*

Lemma 1 establishes that the Cournot firms always fully utilize their technical know-how to produce their maximum possible qualities regardless of the outcomes of innovation adoption. Therefore, when both firms make the same innovation adoption decisions in the first stage, their equilibrium qualities involve zero product differentiation. When they make different adoption decisions and thus have *asymmetric* quality spectrums in the second stage, the degree of product differentiation is exactly the size of the product innovation, Δq.

It is worth mentioning that our results in Lemma 1 are basically in line with previous studies on vertical product differentiation under Cournot competition, such as Bonanno (1986), Gal-Or (1983), Ireland (1987), and Motta (1993), who find minimum differentiation in the absence of product innovations. Lemma 1 can be seen as an extension of their results to an environment with product innovation and asymmetric quality spectrums.

Under Bertrand competition, it is clear from (10) and (11) that in equilibrium the duopoly firms always choose distinct qualities, since product differentiation leads to positive profits for both firms, while identical quality results in zero profits. From (10) we have:

$$\begin{cases} \dfrac{\partial \pi_1^B(q_1,q_2)}{\partial q_1} = \dfrac{q_2^{\,2}(4q_2-7q_1)}{(4q_2-q_1)^3} = 0 \;\Rightarrow\; \hat{q}_1(q_2) = \left(\dfrac{4}{7}\right) q_2, \\ \dfrac{\partial \pi_2^B(q_1,q_2)}{\partial q_2} = \dfrac{4q_2(4q_2^{\,2}-3q_1q_2+2q_1^{\,2})}{(4q_2-q_1)^3} > 0. \end{cases} \tag{14}$$

Equation (14) shows that the Bertrand firms differentiate their qualities in such a way that the high-quality firm produces its maximum possible quality, while the low-quality firm's best response is given by 4/7 of the high-quality firm's quality.[8] If the low-quality firm's best response is within its feasible quality spectrum, then it will be able to make its best response; otherwise, the best it can do is to produce the upper bound of its quality spectrum.

Recall that our analysis thus far has assumed that $q_1 < q_2$ or $q_1 = q_2$. The analysis for the case with $q_1 > q_2$ can be inferred from that for $q_1 < q_2$ with the subscripts reversed. Thus, for each innovation adoption

8 Choi and Shin (1992) and Rosenkranz (1997) also find a similar result.

decision made in the first stage, a complete characterization of equilibrium qualities in the second stage will consist of *two* quality pairs: one with firm 2 producing higher quality (in subgames with $q_1 < q_2$) and the other with firm 1 producing higher quality (in subgames with $q_1 > q_2$). We then have the following lemma.

Lemma 2. *Anticipating Bertrand competition in the third stage, the subgame perfect Nash equilibrium qualities chosen in the second stage,* (q_1^B, q_2^B), *are given by:*

(1) $(q_1^B, q_2^B) = ((4/7)\overline{q}, \overline{q})$ *or* $(\overline{q}, (4/7)\overline{q})$ *if neither firm adopts the innovation,*

(2) $(q_1^B, q_2^B) = ((4/7)\overline{q}, \overline{q})$ *or* $(\overline{\overline{q}}, \min\{(4/7)\overline{\overline{q}}, \overline{q}\})$ *if only firm 1 adopts,*

(3) $(q_1^B, q_2^B) = (\min\{(4/7)\overline{\overline{q}}, \overline{q}\}, \overline{\overline{q}})$ *or* $(\overline{q}, (4/7)\overline{q})$ *if only firm 2 adopts, and*

(4) $(q_1^B, q_2^B) = ((4/7)\overline{\overline{q}}, \overline{\overline{q}})$ *or* $(\overline{\overline{q}}, (4/7)\overline{\overline{q}})$ *if both firms adopt.*

In parts (2) and (3) of Lemma 2, we use the expression, $\min\{(4/7)\overline{\overline{q}}, \overline{q}\}$, to denote the sole non-innovating firm's quality. Given $\overline{\overline{q}} = \overline{q} + \Delta q$, it is straightforward to show that the value of $\min\{(4/7)\overline{\overline{q}}, \overline{q}\}$ equals $(4/7)\overline{\overline{q}}$ if $\Delta q \le 0.75\overline{q}$ (i.e., the innovation size is small such that the non-innovating firm's best response is feasible) and equals $\overline{q}$ if $\Delta q > 0.75\overline{q}$ (i.e., the innovation size is large such that the non-innovating firm's quality constraint is binding). One may find it odd that $((4/7)\overline{q}, \overline{q})$ is also a Nash equilibrium in part (2) and $(\overline{q}, (4/7)\overline{q})$ a Nash equilibrium in part (3), since the sole innovating firm's newly adopted innovation is not utilized at all. This observation is entirely correct. When we consider equilibrium innovation adoption in the next section, we will see that contingent on $((4/7)\overline{q}, \overline{q})$ being the second-stage Nash equilibrium, firm 1 will not adopt innovation in the first stage. In other words, ((adopt, not),

$((4/7)\overline{q},\overline{q})$) cannot be supported as a subgame perfect equilibrium outcome, even though $((4/7)\overline{q},\overline{q})$ is a Nash equilibrium in the second stage. Similarly, ((not, adopt), $(\overline{q},(4/7)\overline{q})$) cannot arise as a subgame perfect equilibrium outcome either.

Lemma 2 shows that regardless of the innovation adoption decisions made in the first stage, Bertrand firms always differentiate their qualities in the second stage, such that the firm that produces lower quality may not produce its best possible quality. This is in contrast with Cournot firms' quality choices characterized in Lemma 1 where each Cournot firm produces its maximum possible quality. The intuition for the contrasting results goes as follows. In a vertical product differentiation model, consumers are willing to pay higher prices for higher quality, such that firms have a tendency to increase the quality of their products. However, as Shaked and Sutton (1982) and Bonanno (1986) point out, in the case of Bertrand competition, there is a counteracting force at work-price competition will become too fierce if firms' qualities are too close. Thus, under Bertrand competition firms will choose to maintain some degree of product differentiation in order to avoid fierce price competition. By contrast, under Cournot competition, this counteracting force is absent, such that both firms will increase their qualities to the upper bounds of their quality spectrums. It is conceivable that these contrasting concerns behind the choices of qualities lead to different incentives for innovation adoption, which we now turn to.

5. Equilibrium Innovation Adoption in the First Stage

We use global, partial, and no adoption to refer to the equilibrium outcomes in which both firms adopt, one firm adopts, and neither firm adopts, respectively.

5.1 Cournot competition

Substitution of the equilibrium quality levels, (q_1^C, q_2^C), given in Lemma 1 into (6) and (8) yields the associated equilibrium profits, for which the Appendix gives the expressions. We summarize the Cournot firms' first-stage interactions in the following payoff matrix.

		Firm 2	
		adopt	not
Firm 1	adopt	$\pi_1^C(\bar{\bar{q}}, \bar{\bar{q}}) - k$, $\pi_2^C(\bar{\bar{q}}, \bar{\bar{q}}) - k$	$\pi_1^C(\bar{\bar{q}}, \bar{q}) - k$, $\pi_2^C(\bar{\bar{q}}, \bar{q})$
	not	$\pi_1^C(\bar{q}, \bar{\bar{q}})$, $\pi_2^C(\bar{q}, \bar{\bar{q}}) - k$	$\pi_1^C(\bar{q}, \bar{q})$, $\pi_2^C(\bar{q}, \bar{q})$

A straightforward analysis yields the Nash equilibrium in innovation adoption. Defining $k_1(\Delta q) \equiv (\bar{q} + \Delta q)(15\bar{q} + 16\Delta q)\Delta q / 9(3\bar{q} + 4\Delta q)^2$ and $k_2(\Delta q) \equiv (21\bar{q}^2 + 56\bar{q}\Delta q + 36\Delta q^2)\Delta q / 9(3\bar{q} + 4\Delta q)^2$, where $k_1(\Delta q)$ and $k_2(\Delta q)$ are functions of Δq with $k_2(\Delta q) > k_1(\Delta q)$ for all values of $\Delta q > 0$, we have the following proposition.

Proposition 1. *Anticipating Cournot competition in the last stage, the equilibrium patterns of product innovation adoption in the first stage are characterized by global, partial, and no adoption for* $k \le k_1(\Delta q)$*,* $k_1(\Delta q) < k \le k_2(\Delta q)$*, and* $k > k_2(\Delta q)$*, respectively.*

Proposition 1 establishes that global adoption by Cournot firms can always arise as an equilibrium outcome regardless of the innovation size, provided that the adoption cost, *k*, is low enough. This is because under Cournot competition, the amount of quality improvement provided by the innovation is fully incorporated into the innovating firm's post-innovation quality. Thus, both firms can benefit from adoption even if the innovation size is small. We will see below that this is no longer the case under Bertrand competition.

5.2 Bertrand competition

Lemma 2 shows that for each possible adoption decision made in the first stage, there are *two* pairs of equilibrium qualities in the subsequent quality-setting stage. Due to this multiplicity of Nash equilibria in the second stage, to characterize the Nash equilibrium in the first stage, we can no longer draw a payoff matrix as that for Cournot competition. Instead, we need to consider eight possible equilibrium paths (i.e., the four possible first-stage outcomes, each of which are followed by two possible second-stage equilibria) in the two-stage reduced form of the three-stage game, as shown in Figures 2 and 3 (and the related analysis) of Shieh and Peng (2000). Let $k_3(\Delta q) \equiv (6\overline{q} + 7\Delta q)/48$, $k_4(\Delta q) \equiv (\overline{q} + \Delta q)(3\overline{q} - 4\Delta q)^2 / 48(3\overline{q} + 4\Delta q)^2$, and $k_5(\Delta q) \equiv 4\Delta q(\overline{q} + \Delta q)^2 / (3\overline{q} + 4\Delta q)^2 - \overline{q}/48$, where $k_3(\cdot)$, $k_4(\cdot)$, and $k_5(\cdot)$ are functions of Δq with $k_4(\cdot) < k_5(\cdot)$ for all values of Δq. With suitable modifications of notations, we obtain equilibrium adoption patterns under Bertrand competition from Propositions 2 and 3 of Shieh and Peng (2000) as follows.

Lemma 3. *Anticipating Bertrand competition in the last stage, the equilibrium patterns of product innovation adoption in the first stage are given by:*

(1) *If* $\Delta q \leq 0.75\overline{q}$, *then global adoption can never arise as an equilibrium outcome regardless of the values of k. We have partial and no adoption as equilibrium outcomes for* $k \leq k_3(\Delta q)$ *and* $k > k_3(\Delta q)$, *respectively.*

(2) *If* $\Delta q > 0.75\overline{q}$, *then equilibrium outcomes are characterized by global, partial, and no adoption for* $k \leq k_4(\Delta q)$, $k_4(\Delta q) < k \leq k_5(\Delta q)$, *and* $k > k_5(\Delta q)$, *respectively.*

Lemma 3 states that unlike Cournot competition, under Bertrand competition a necessary condition for global adoption to be an equilibrium outcome is that the innovation size is large enough (i.e., $\Delta q > 0.75\overline{q}$), such that even the firm that engages in lower quality production in the subsequent quality-setting stage finds adoption beneficial.

5.3 Comparing equilibrium adoption patterns

We depict in Figure 1 the duopoly's innovation adoption patterns under both competition regimes. We draw the threshold values for adoption patterns under Cournot competition as solid curves, $k_1(\Delta q)$ and $k_2(\Delta q)$, while the threshold values for adoption patterns under Bertrand competition are dashed curves, $k_3(\Delta q)$, $k_4(\Delta q)$, and $k_5(\Delta q)$, where $k_1(\Delta q)$, $k_2(\Delta q)$, $k_3(\Delta q)$, $k_4(\Delta q)$, and $k_5(\Delta q)$ are functions of Δq. It can be shown that $k_1(\Delta q)$ and $k_2(\Delta q)$ increase in Δq at a decreasing rate, while $k_3(\Delta q)$, $k_4(\Delta q)$, and $k_5(\Delta q)$ increase in Δq at constant, increasing, and decreasing rates, respectively. (Please refer to the Appendix.) Moreover, we have $k_1(\Delta q) > k_4(\Delta q)$ for $\Delta q > 0.75\overline{q}$, $k_2(\Delta q) < k_3(\Delta q)$ for $\Delta q \le 0.75\overline{q}$, and $k_2(\Delta q) < k_5(\Delta q)$ for $\Delta q > 0.75\overline{q}$, such that the curve $k_1(\Delta q)$ lies above $k_4(\Delta q)$ and the curve $k_2(\Delta q)$ lies below $k_3(\Delta q)$ and $k_5(\Delta q)$.

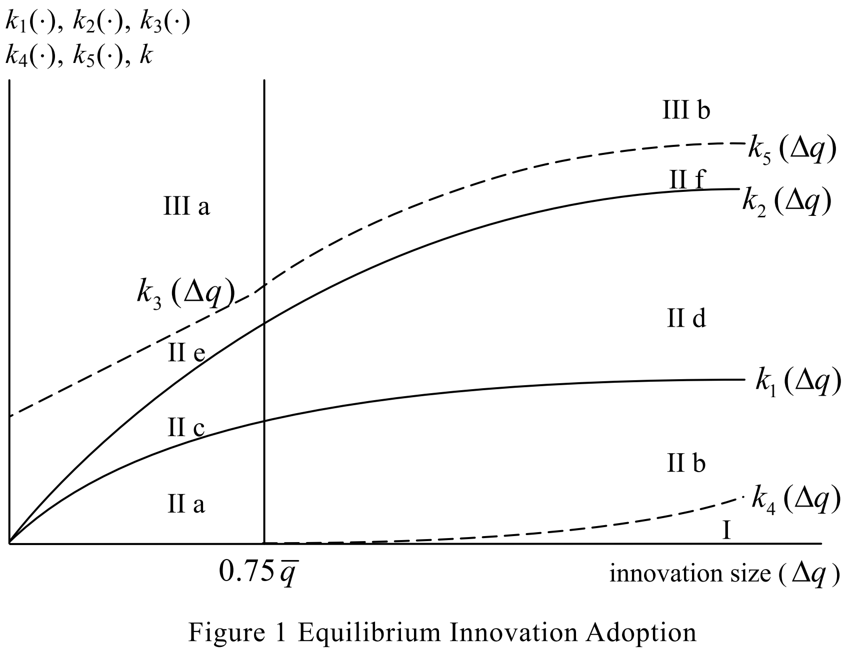

Figure 1 Equilibrium Innovation Adoption

We first describe Cournot firms' adoption patterns shown in Figure 1. Proposition 1 implies that regions I, IIa, and IIb correspond to the parameter spaces for global adoption, IIc and IId for partial adoption, and IIe, IIf, IIIa, and IIIb for no adoption. As for Bertrand competition, Lemma 3 implies that: In the case of small innovations (i.e., $\Delta q \leq 0.75\overline{q}$), regions IIa, IIc, and IIe correspond to partial adoption and IIIa for no adoption; and in the case of large innovations (i.e., $\Delta q > 0.75\overline{q}$), region I corresponds to global adoption, IIb, IId, and IIf for partial adoption, and IIIb for no adoption. Comparing adoption patterns under both competition regimes yields the following.

Proposition 2.

(1) *The parameter space for global adoption is larger under Cournot than under Bertrand competition. In particular, in regions IIa and IIb of Figure 1 the innovation is adopted by both Cournot firms, but only by one Bertrand firm, such that incentives for product innovation adoption are stronger under Cournot competition.*

(2) *The parameter space for no adoption is also larger under Cournot than under Bertrand competition. In particular, in regions IIe and IIf the innovation is adopted by neither Cournot firm, but still adopted by one Bertrand firm, such that incentives for product innovation adoption are stronger under Bertrand competition.*

(3) *The parameter space for partial adoption is smaller under Cournot than under Bertrand competition. In IIc and IId where the innovation is adopted by exactly one firm under both competition regimes, the incentives for innovation are identical under both competition regimes.*

Proposition 2 shows that adoption patterns concentrate more on global and no adoption under Cournot competition, while they concentrate more on partial adoption under Bertrand competition. In other words, we are more likely to observe global adoption of a product innovation under Cournot competition and partial adoption under Bertrand competition. Which competition mode leads to more innovating behavior? We find a non-monotone relation between intensity of competition and incentives for product innovation adoption. On the one hand, Cournot firms are more innovating in regions IIa and IIb, since both Cournot firms adopt while only one Bertrand firm adopts. On the other hand, Bertrand competition leads to more innovating behavior in regions IIe and IIf, where one Bertrand firm adopts while no Cournot firms adopt. The intuitions for our results are as follows.

We first explain why incentives for product innovation are stronger under Cournot competition when adoption costs are relatively low (in regions IIa and IIb). Recall that following all possible combinations of adoption decisions made in the first stage, Cournot firms always fully utilize their technical know-how in the second stage to produce their best possible qualities allowed by technological conditions. Hence, when both Cournot firms adopt the innovation, they both get to benefit fully and equally from the innovation (and thus have the same willingness to pay for the innovation). By contrast, under Bertrand competition firms always differentiate their qualities in order to soften price competition. Thus, when the innovation size is small (i.e., in IIa), the firm that engages in the production of lower quality in the subsequent stage finds adoption unnecessary. Even when the innovation size is large (i.e., in IIb), if both firms adopt, there is still one firm unable to fully utilize the innovation to produce the best possible quality. Such a firm then has a smaller willingness to pay for the innovation and will stop adopting as long as the adoption cost turns higher.

We next discuss the reason why incentives for product innovation are stronger under Bertrand competition when adoption costs are relatively high (in regions IIe and IIf), where neither Cournot firm adopts, but one Bertrand firm is still adopting. The intuition is that it is more valuable to become a sole innovating firm under Bertrand competition. In particular, in the case of small innovations, the profit of a sole innovator is greater under Bertrand competition, because the degree of product differentiation is larger. In the case of large innovations, even though the post-innovation qualities and the degree of product differentiation are identical under both competition regimes, the sole innovator still gains more from the adoption under Bertrand competition, because its pre-innovation quality and profits are lower. Lastly, given that the parameter spaces for global and no adoption are larger under Cournot competition, the remaining space for partial adoption is of course smaller.

6. Welfare Analysis

We now compare consumer surplus, industry profits, and social welfare under both competition regimes. We would like to know whether or not and to what extent the conventional results regarding superiority of Bertrand competition hold in our dynamic setting with product innovation.

6.1 Equal incentives for innovation under both competition regimes

This subsection considers three cases in which adoption patterns are exactly the same under both competition regimes. We first look at the baseline case where no adoption is the Nash equilibrium in the first stage under both competition regimes (i.e., regions IIIa and IIIb). The subsequent equilibrium qualities are given by $(\overline{q}, \overline{q})$ under Cournot and by $((4/7)\overline{q}, \overline{q})$ under Bertrand competition. (While there are two symmetric quality pairs under Bertrand competition, without loss of generality, we focus on the one with $q_1 < q_2$ here and in our subsequent analysis.) Finding equilibrium outputs and prices from (8) and (10), and by direct comparisons, we have the following.

Lemma 4. *In parameter regions IIIa and IIIb where no adoption prevails under both competition regimes, industry profits are greater, consumer surplus is smaller, and social welfare is lower under Cournot competition.*

Lemma 4 establishes that in the absence of innovation adoption, conventional welfare results indeed hold in our model regarding superiority of Bertrand competition in terms of consumer and social welfare (see, for example, Singh and Vives (1984) and Motta (1993)).[9] As for the ranking of industry profits, our result is also consistent with these studies.[10]

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9 Motta (1993) shows in his model with an *open* quality spectrum (which is bounded below but not bounded above) and quadratic costs of quality that consumer and social welfare are lower under Cournot competition. Note that the duopoly firms will not increase their quality to an infinitely high level in Motta (1993) because it is not economically optimal, even though it is technologically feasible. The present paper departs from Motta (1993) at the outset by considering a *closed* quality spectrum *à la* Beath et al. (1987). This is because our focus is on product innovation adoption and the resulting dynamic efficiency. Thus, just like Beath et al. (1987), we impose an upper bound on the feasible quality spectrum to represent the state-of-the-art quality, for if an infinitely high quality level is already technologically feasible, then there is no point to talk about product innovation adoption (instead, it might make more sense to consider process innovations in this latter setting). I would like to thank an anonymous referee for drawing my attention to this clarification and discussion.

10 Our vertical differentiation model with zero costs of production and a closed quality spectrum can be seen as a variation of Motta (1993). If we assume zero fixed costs of quality improvement in Motta (1993) (i.e., letting $F(u_i) = u_i^2/2 = 0$) and impose an upper limit, $\overline{u}$, on his quality spectrum, then the last terms in (5), (5'), (15) and (15') of Motta (1993) disappear. Thus, his (5) and (5') yield $((4/7)\overline{u},\overline{u})$, while (15) and (15') yield $(\overline{u},\overline{u})$ as the optimal qualities under Bertrand and Cournot competition, respectively. Note that these solutions are exactly the same as ours. As for profits, letting the upper bound of his taste parameter $\overline{v}=1$, then Motta's (4) and (4') respectively yield Bertrand profits $\pi_1^B = \overline{u}/48$ and $\pi_2^B = 7\overline{u}/48$, while (14) and (14') yield Cournot profits $\pi_1^C = \pi_2^C = \overline{u}/9$, which are also the same as ours (refer to the proof of our Lemma 4). Given these modifications, Motta (1993) also yields that industry profits are higher under Cournot competition.

We next consider region I where global adoption of a large innovation prevails under both competition regimes. The subsequent equilibrium qualities are given by $(\bar{\bar{q}}, \bar{\bar{q}})$ under Cournot and by $((4/7)\bar{\bar{q}}, \bar{\bar{q}})$ under Bertrand competition. These equilibrium qualities (and thus all other associated equilibrium values) are similar to those for regions IIIa and IIIb, except that $\bar{q}$ is replaced by $\bar{\bar{q}}$. Hence, results for this case are similar to those in Lemma 4. We lastly consider regions IIc and IId where partial adoption (e.g., only firm 2 adopts) prevails under both competition regimes. The equilibrium quality under Cournot competition is given by $(\bar{q}, \bar{\bar{q}})$. The equilibrium qualities under Bertrand competition are given by $((4/7)\bar{\bar{q}}, \bar{\bar{q}})$ and $(\bar{q}, \bar{\bar{q}})$ for small and large innovations, respectively. Straightforward analysis shows that the conventional results again hold in this case, since adoption patterns are the same under both regimes. We then have the following proposition.

Proposition 3. *When Cournot and Bertrand competition lead to the same innovation adoption patterns, the conventional results that industry profits are greater, consumer surplus is smaller, and social welfare is lower under Cournot competition hold in our model. In addition, when partial adoption of a large innovation prevails under both competition regimes, equilibrium qualities and the degree of vertical product differentiation are identical under both competition regimes, with both firms producing the upper bounds of their respective quality spectrums.*

6.2 Stronger incentives for innovation under Cournot competition

In regions IIa and IIb, we see global adoption under Cournot and partial adoption under Bertrand competition, such that incentives for product innovation are stronger under Cournot competition. We will show that the static efficiency of Bertrand competition may not hold in this situation. Using the relevant equilibrium outcomes (and their associated equilibrium values) described in the preceding subsection (and related proofs), we obtain the following.

Proposition 4. *When Cournot competition leads to stronger incentives for product innovation (i.e., regions IIa and IIb), we have the following.*

(1) *For* $\Delta q \leq 1.14\overline{q}$ *, the conventional results that gross industry profits are greater, consumer surplus is smaller, and social welfare is lower under Cournot competition hold.*
(2) *For* $1.14\overline{q} < \Delta q \leq 1.70\overline{q}$ *, gross industry profits are greater, consumer surplus is smaller, but social welfare turns out to be higher under Cournot competition.*
(3) *For* $1.70\overline{q} < \Delta q \leq 2.50\overline{q}$ *, gross industry profits and consumer surplus are both higher under Cournot competition, such that social welfare is also higher.*
(4) *For* $2.50\overline{q} < \Delta q$ *, gross industry profits are smaller but consumer surplus is larger under Cournot competition, with social welfare higher under Cournot competition.*

We consider gross (instead of net) industry profits in this proposition, because when computing social welfare we need not subtract adoption costs, for these costs are transfers from innovation adopting firms to the owner of the product innovation. Hence, social welfare is the sum of consumer surplus and gross industry profits. Note that in the novel case where gross industry profits are *smaller* under Cournot competition (i.e., part (4)), net industry profits are also smaller, as we subtract adoption costs twice under Cournot, but only once under Bertrand competition for net profits.

Proposition 4 shows that when Cournot competition leads to stronger incentives for product innovation adoption, social welfare is *higher* under Cournot competition when the innovation size is sufficiently large (in particular, if $\Delta q > 1.14\overline{q}$ as shown in parts (2)-(4)). Interestingly, we encompass three different combinations of forces behind the result that social welfare is higher under Cournot competition. Specifically, we see industry profits and consumer surplus rank in opposite directions in part (2), with the effect of profits dominating. This case occurs in former studies regarding the dynamic efficiency of Cournot competition with process innovations, including Delbono and Denicolò (1990), Qiu (1997), Pal (2010), and Mukherjee (2011). Next, we see industry profits and consumer surplus rank in the same direction in part (3), with both higher under Cournot competition. This case is emphasized by Symeonidis (2003) in that it cannot arise in models with process innovations, but does arise in his quality-augmented horizontal product differentiation model with product innovation. Furthermore, our part (4) presents an entirely novel case in which industry profits are *lower* but consumer surplus is *higher* under Cournot competition, with the effect of consumer surplus dominating such that social welfare is also *higher*. In this novel case, a switch from Bertrand to Cournot competition enhances social welfare, because the increase in consumer surplus outweighs the decrease in industry profits. The intuitions for our novel results are as follows.

We first consider industry profits. In the case of large innovations, Cournot firms produce $(\bar{\bar{q}}, \bar{\bar{q}})$ under global adoption, while Bertrand firms produce $(\bar{q}, \bar{\bar{q}})$ under partial adoption. Hence, the magnitude of Δq is not only the innovation size, but also the extent of product differentiation under Bertrand competition (noting that Cournot firms have zero product differentiation). Due to the benefit of product differentiation, the high-quality Bertrand firm's profit is higher than that of each Cournot firm, whose profit is in turn greater than the low-quality Bertrand firm's profit. In a standard vertical differentiation model (e.g., Shaked and Sutton (1982) and Beath et al. (1987)), *both* the high- and low-quality Bertrand firms' profits *increase* in the extent of product differentiation. Thus, when the value of Δq is sufficiently large (i.e., $\Delta q > 2.5\bar{q}$ in part (4)), the high-quality Bertrand firm's profit is so much higher whereas the low-quality Bertrand firm's profit is not too much lower than that of a Cournot firm, such that the duopoly's total profits are *greater* under Bertrand competition.

We next discuss the intuition for the novel result that consumer surplus is *higher* under Cournot competition when the innovation size is large enough (i.e., $\Delta q > 1.70\overline{q}$ in both parts (3) and (4)). Under Cournot competition, all consumers purchase the product of the highest quality, $\overline{\overline{q}}$, from the Cournot duopoly, whereas under Bertrand competition, only those who value quality highly (with high values of θ) enjoy $\overline{\overline{q}}$ while others buy $\overline{q}$. Interestingly, when Δq is sufficiently large (i.e., $\Delta q > 1.5\overline{q}$), the great extent of product differentiation allows the high-quality Bertrand firm to raise its price so much that its price is even *higher* than the market price under Cournot competition. Thus, all the consumers (with high values of θ) who buy $\overline{\overline{q}}$ under both competition regimes are better off under Cournot competition since price is lower. Next, the group of consumers (with moderate values of θ) who buy $\overline{\overline{q}}$ under Cournot, but switch to $\overline{q}$ under Bertrand competition (due to the higher price for $\overline{\overline{q}}$ under Bertrand competition), is also better off under Cournot competition. Finally, the group of consumers (with low values of θ) who buy $\overline{q}$ under Bertrand, but do not consume the product under Cournot competition, is better off under Bertrand competition. However, the gains of the consumers who value quality more (i.e., those with high and moderate values of θ) obviously outweigh the loss of the consumers who value quality less (i.e., those with low values of θ), such that the aggregate consumer surplus is unambiguously higher under Cournot competition.

Note that when innovation sizes are very large (i.e., $\Delta q > 2.50\overline{q}$ as in part (4)), the extent by which consumer surplus under Cournot exceeds that under Bertrand competition is so large that it even dominates the profit effect. This is because when Δq increases, industry profits increase under both competition modes, such that the extent by which Bertrand profits exceed Cournot profits increases in a relative sense. By contrast, under Bertrand competition the high-θ group of consumers who buy $\bar{\bar{q}}$ at a higher price and the middle-θ group who are forced to consume $\bar{q}$ instead of $\bar{\bar{q}}$ both suffer in an absolute sense. Thus, social welfare turns out to be lower under Bertrand competition.

6.3 Weaker incentives for innovation under Cournot competition

In regions IIe and IIf neither Cournot firm adopts, but one Bertrand firm is still adopting, such that incentives for innovations are weaker under Cournot competition. The equilibrium quality under Cournot competition is $(\bar{q}, \bar{q})$, while Bertrand firms produce $((4/7)\bar{\bar{q}}, \bar{\bar{q}})$ and $(\bar{q}, \bar{\bar{q}})$ for small and large innovations, respectively. Through direct computations and comparisons, we have the following.

Proposition 5. *When Cournot competition leads to weaker incentives for product innovation (i.e., in regions IIe and IIf), consumer surplus and social welfare are lower under Cournot competition. The industry's gross profits are higher (lower) under Bertrand competition when* $\Delta q > (1/3)\bar{q}$ *(*$\Delta q < (1/3)\bar{q}$*).*

It is not surprising that consumer surplus and social welfare are lower under Cournot competition, because there is no positive force added to Cournot competition for the conventional results to be reversed. As for profits, it is now even easier to see Bertrand firms earn greater gross industry profits (i.e., we require $\Delta q > (1/3)\bar{q}$ here in Proposition 5, while requiring $\Delta q > 2.5\bar{q}$ in part (4) of Proposition 4), because both Bertrand firms benefit from the adoption and the resulting increase in product differentiation, especially the innovating firm whose quality is now much higher than that of each non-innovating Cournot firm.

7. Conclusion

We compare incentives for product innovation adoption under Cournot and Bertrand competition and evaluate the resulting dynamic efficiency of these two competition modes in a standard vertical differentiation model *à la* Shaked and Sutton (1982). Regarding the notion of a product innovation, we follow Beath et al. (1987) to model a product innovation as an extension of the upper bound of the adopting firm's technologically feasible quality spectrum. We have the following findings.

First, we find a non-monotone relation between intensity of competition and incentives for product innovations. When adoption costs are relatively low, incentives for product innovations are stronger under Cournot competition, while the opposite result holds when adoption costs are relatively high. The distribution of innovation adoption patterns differs under both competition regimes. In particular, we are more likely to observe global and no adoption of a product innovation under Cournot and partial adoption under Bertrand competition.

Second, when Cournot competition leads to stronger incentives for product innovations, the static efficiency of Bertrand competition no longer holds if the innovation size is sufficiently large. Unlike earlier studies with process innovations (which find that social welfare may be higher under Cournot competition, though consumer surplus is still lower), we find conditions under which both consumer surplus and social welfare are higher under Cournot competition, whereas industry profits may be lower.

Third, regarding the forces behind the result that social welfare is higher under Cournot competition, we present new insights. Our model not only encompasses the two cases identified in the existing literature (i.e., in models with process innovations as described above and Symeonidis's (2003) product innovation model where consumer surplus and industry profits rank in the same direction), but also finds an entirely novel case in which consumer surplus is higher, industry profits are lower, but social welfare is still higher under Cournot competition.

Fourth, while Bertrand firms tend to differentiate their qualities more in order to soften price competition, in our vertical differentiation model with product innovation adoption we show that in one instance (i.e., partial adoption of a large innovation prevailing under both competition regimes) equilibrium qualities and the degree of vertical product differentiation are identical under both competition regimes.

Throughout our analysis we have assumed zero costs of production as other vertical differentiation models do (e.g., Shaked and Sutton (1982), Beath et al. (1987), and Choi and Shin (1992)). However, one should ask: what happens if we consider alternative cost functions? An earlier version of this paper shows that our results remain true if we consider a linear cost function of quality. Alternatively, if we have a quadratic cost function of quality as is considered in Motta (1993), then as Motta (1993) argues, in the presence of an upper bound on the quality spectrum, if the quadratic costs do not increase too fast in quality such that when evaluated at this upper bound marginal costs are not as high as marginal revenues of quality, then both Cournot firms choose the highest possible quality. As such, our main point remains valid-while both Cournot firms choose their best possible qualities, only one Bertrand firm chooses the top quality, with the other firm refraining from getting too close so as to avoid fierce price competition. Such contrasting concerns regarding quality choice under both competition regimes then lead to different incentives for product innovation adoption, and hence, the possibility of the dynamic efficiency of Cournot competition. Nevertheless, it is still interesting to consider alternative definitions of product innovations and different specifications of cost functions. This is a direction that may be worthwhile pursuing in the future.

Appendix

Proof of Lemma 1: We consider each of the four parts, respectively.

(1) If neither firm adopts the innovation, then $q_1 \in [0, \overline{q}]$ and $q_2 \in [0, \overline{q}]$. We first derive firm 2's best-response function (in quality) for each possible value of q_1 as follows.

(i) If $q_1 = 0$, then firm 2's best response is to choose $q_2 = \overline{q}$, because $q_2 = 0$ yields zero profits (from equation (8)) and $q_2 = \overline{q}$ dominates all other choices of $q_2 > 0$ (from equation (12)).

(ii) If $q_1 = \overline{q}$, then choosing $q_2 = \overline{q}$ yields $\pi_2^C(q_1 = q_2 = \overline{q}) = \overline{q}/9$ from (8), while choosing $q_2 < \overline{q}$ yields $\pi_2^C(q_1 = \overline{q}, q_2 < \overline{q}) = \overline{q}^2 q_2/(4\overline{q} - q_2)^2$ from (6). It is straightforward to show that $\overline{q}/9 > \overline{q}^2 q_2/(4\overline{q} - q_2)^2$ for all q_2, such that $\overline{q}$ is firm 2's best response to $q_1 = \overline{q}$.

(iii) If $0 < q_1 < \overline{q}$, then firm 2 may respond from *above* (with $q_2 > q_1$), respond from *below* (with $q_2 < q_1$), or respond with $q_2 = q_1$. The best choice for responding from above is to select $\overline{q}$, which yields $\pi_2^C(0 < q_1 < \overline{q}, q_2 = \overline{q}) = \overline{q}(2\overline{q} - q_1)^2/(4\overline{q} - q_1)^2$. The best choice for responding from below is to have q_2 as close to $\overline{q}$ as possible, which yields a supremum, $\sup \pi_2^C(0 < q_1 < \overline{q}, q_2 < q_1) = q_1/9$. Responding with $q_2 = q_1$ yields $q_1/9$. We have $\pi_2^C(0 < q_1 < \overline{q}, q_2 = \overline{q}) > q_1/9 \Leftrightarrow (\overline{q} - q_1)(5\overline{q} - 2q_1) > 0$, which is true for all $0 < q_1 < \overline{q}$. Thus, $\overline{q}$ is firm 2's best response to any $q_1 \in (0, \overline{q})$.

The results in (i) to (iii) together imply that $\overline{q}$ is firm 2's best response to all possible values of $q_1 \in [0, \overline{q}]$. Similarly, we can show that choosing $q_1 = \overline{q}$ is firm 1's best response to each possible value of $q_2 \in [0, \overline{q}]$. This completes our proof for part (1).

(2) If only firm 1 adopts the innovation, then $q_1 \in [0, \overline{\overline{q}}]$ and $q_2 \in [0, \overline{q}]$. We first derive firm 2's best-response function as follows.

(i) If $q_1 > \overline{q}$, then firm 2 can only respond from below with $q_2 < q_1$. The best choice is to have $q_2 = \overline{q}$.

(ii) If $q_1 = \overline{q}$, then firm 2 can either respond from below with $q_2 < \overline{q}$ or respond with $\overline{q}$. Responding from below yields $\sup \pi_2^C(q_1 = \overline{q}, q_2 < \overline{q}) = \overline{q}/9$. Responding with $q_2 = \overline{q}$ yields $\overline{q}/9$. Thus, $\overline{q}$ is firm 2's best response to $q_1 = \overline{q}$.

(iii) If $q_1 < \overline{q}$, then using the same proof as in (1)-(iii), we can show that $\overline{q}$ is firm 2's best response.

The results in (i)-(iii) show that choosing $q_2 = \overline{q}$ is firm 2's unique best response to all values of $q_1 \in [0, \overline{\overline{q}}]$. We next derive firm 1's best-response function.

(iv) If $q_2 = 0$, then firm 1's best response is to choose $q_1 = \overline{\overline{q}}$ (similar to (1)-(i)).

(v) If $q_2 = \overline{q}$, then firm 1 may respond from above with $q_1 > \overline{q}$, respond from below with $q_1 < \overline{q}$, or respond with $q_1 = \overline{q}$. The best choice for responding from above is to select $\overline{\overline{q}}$, which yields $\pi_1^C(q_1 = \overline{\overline{q}}, q_2 = \overline{q}) = \overline{\overline{q}}(2\overline{\overline{q}} - \overline{q})^2 / (4\overline{\overline{q}} - \overline{q})^2$. Responding from below yields $\sup \pi_1^C(q_1 < \overline{q}, q_2 = \overline{q}) = \overline{q}/9$, while responding with $q_1 = \overline{q}$ yields $\overline{q}/9$. Using algebraic manipulations similar to those in (1)-(iii) (in particular, replacing $\overline{q}$ and q_1 by $\overline{\overline{q}}$ and $\overline{q}$, respectively), we can show that $\pi_1^C(q_1 = \overline{\overline{q}}, q_2 = \overline{q}) > \overline{q}/9$, such that $q_1 = \overline{\overline{q}}$ is firm 1's best response to $q_2 = \overline{q}$.

(vi) If $0 < q_2 < \overline{q}$, then choosing $q_1 = \overline{\overline{q}}$ is still firm 1's best response. The proof is similar to (1)-(iii) and thus omitted.

The results in (iv) to (vi) together show that choosing $q_1 = \overline{\overline{q}}$ is firm 1's unique best response to all values of $q_2 \in [0, \overline{q}]$. This completes our proof for part (2).

(3) The proof is similar to (2) (with 1 and 2 reversed) and is thus omitted.

(4) The proof is similar to (1) (with $\bar{q}$ replaced by $\bar{\bar{q}}$) and is thus omitted.

$\square$

Proof of Proposition 1: From (8), we have $\pi_i^C(\bar{q},\bar{q}) = \bar{q}/9$ and $\pi_i^C(\bar{\bar{q}},\bar{\bar{q}}) = (\bar{q}+\Delta q)/9$, where i = 1, 2. From (6) we have $\pi_1^C(\bar{q},\bar{\bar{q}}) = \pi_2^C(\bar{\bar{q}},\bar{q}) = \bar{q}(\bar{q}+\Delta q)^2/(3\bar{q}+4\Delta q)^2$ and $\pi_1^C(\bar{\bar{q}},\bar{q}) = \pi_2^C(\bar{q},\bar{\bar{q}}) = (\bar{q}+\Delta q)(\bar{q}+2\Delta q)^2/(3\bar{q}+4\Delta q)^2$.

The strategy profile (adopt, adopt) is a Nash equilibrium iff $\pi_1^C(\bar{\bar{q}},\bar{\bar{q}}) - k \geq \pi_1^C(\bar{q},\bar{\bar{q}})$ and $\pi_2^C(\bar{\bar{q}},\bar{\bar{q}}) - k \geq \pi_2^C(\bar{\bar{q}},\bar{q})$, both of which hold iff $k \leq (\bar{q}+\Delta q)/9 - \bar{q}(\bar{q}+\Delta q)^2/(3\bar{q}+4\Delta q)^2$, where the RHS is defined as $k_1(\Delta q)$.

The strategy profile (not, adopt) is a Nash equilibrium iff $\pi_1^C(\bar{\bar{q}},\bar{\bar{q}}) - k \leq \pi_1^C(\bar{q},\bar{\bar{q}})$ and $\pi_2^C(\bar{q},\bar{\bar{q}}) - k \geq \pi_2^C(\bar{q},\bar{q})$. The first inequality holds iff $k \geq k_1(\Delta q)$. The second inequality holds iff $(\bar{q}+\Delta q)(\bar{q}+2\Delta q)^2/(3\bar{q}+4\Delta q)^2 - k \geq \bar{q}/9$, which after rearranging becomes $k \leq (21\bar{q}^2 + 56\bar{q}\Delta q + 36\Delta q^2)\Delta q/9(3\bar{q}+4\Delta q)^2 \equiv k_2(\Delta q)$. It can be easily verified that $k_2(\Delta q) > k_1(\Delta q)$ for all $\Delta q > 0$. Thus, (not, adopt) is a Nash equilibrium iff $k_1(\Delta q) \leq k \leq k_2(\Delta q)$. Similarly, (adopt, not) is a Nash equilibrium iff $k_1(\Delta q) \leq k \leq k_2(\Delta q)$.

The strategy profile (not, not) is a Nash equilibrium iff $\pi_1^C(\bar{\bar{q}},\bar{q}) - k \leq \pi_1^C(\bar{q},\bar{q})$ and $\pi_2^C(\bar{q},\bar{\bar{q}}) - k \leq \pi_2^C(\bar{q},\bar{q})$, both of which hold iff $k \geq k_2(\Delta q)$.

$\square$

Derivations for Curves in Figure 1: We have

$k_1' = (45\bar{q}^3 + 126\bar{q}^2\Delta q + 144\bar{q}\Delta q^2 + 64\Delta q^3)/9(3\bar{q}+4\Delta q)^3 > 0$,

$k_1'' = -2(9\bar{q}^3 + 8\bar{q}^2\Delta q)/(3\bar{q}+4\Delta q)^4 < 0$,

$k_2' = (7\bar{q}^3 + 28\bar{q}^2\Delta q + 36\bar{q}\Delta q^2 + 16\Delta q^3)/(3\bar{q}+4\Delta q)^3 > 0$, and

$k_2'' = -8\bar{q}^2\Delta q/(3\bar{q}+4\Delta q)^4 < 0$. We also have $k_3' = 7/48 > 0$, $k_3'' = 0$,

$k_4{}' = (4\Delta q - 3\overline{q})(39\overline{q}^2 + 48\overline{q}\Delta q + 16\Delta q^2)/48(3\overline{q} + 4\Delta q)^3 > 0$ for $\Delta q > 0.75\overline{q}$, $k_4{}'' = (39\overline{q}^2 + 48\overline{q}\Delta q + 16\Delta q^2)/12(3\overline{q} + 4\Delta q)^3$ $-(4\Delta q - 3\overline{q})(9\overline{q} + 4\Delta q)^2/12(3\overline{q} + 4\Delta q)^4 > 0$,
$k_5{}' = 4(\overline{q} + \Delta q)(3\overline{q}^2 + 5\overline{q}\Delta q + 4\Delta q^2)/(3\overline{q} + 4\Delta q)^3 > 0$, and
$k_5{}'' = -8(6\overline{q}^3 + 5\overline{q}^2\Delta q)/(3\overline{q} + 4\Delta q)^4 < 0$.

□

Proof of Lemma 4: Under Cournot competition, we have $x_1^C = x_2^C = 1/3$ and $p^C = \overline{q}/3$ from(8). The marginal buyer is given by $\theta^C = p^C/q^C = 1/3$. Thus, we have consumer surplus $CS^C = \int_{\theta^C}^1 (\theta\overline{q} - p^C)d\theta = 2\overline{q}/9$, industry profits $\Pi^C = 2\pi_i^C = 2\overline{q}/9$, and social welfare $W^C = 4\overline{q}/9$. Under Bertrand competition, we have $p_1^B = \overline{q}/14$, $p_2^B = \overline{q}/4$, $x_1^B = 7/24$, and $x_2^B = 7/12$ from (10). Thus, marginal buyers are given by $\theta_m^B = 5/12$ and $\theta_1^B = 1/8$. We hence have $CS^B = \int_{\theta_m^B}^1 (\theta\overline{q} - p_2^B)d\theta + \int_{\theta_1^B}^{\theta_m^B} [(4/7)\theta\overline{q} - p_1^B]d\theta$ $= 7\overline{q}/24$, industry profits $\Pi^B = \pi_1^B + \pi_2^B = \overline{q}/48 + 7\overline{q}/48 = \overline{q}/6$, where $\pi_1^B < \pi_i^C < \pi_2^B$, and social welfare $W^B = 11\overline{q}/24$. Given these equilibrium values, the lemma can be proved by inspection.

□

Proof of Proposition 3: Under global adoption, the values of θ^C, θ_1^B, and θ_m^B remain the same as those in Lemma 4. The expressions for consumer surplus, industry profits, and social welfare all scale up from their counterparts in Lemma 4 with $\overline{q}$ replaced by $\overline{\overline{q}}$, such that the rankings shown above still hold here.

We next consider the case of partial adoption. Under Cournot competition, from (6) we have $x_1^C = \overline{\overline{q}}/(3\overline{q} + 4\Delta q)$, $x_2^C = (\overline{q} + 2\Delta q)/(3\overline{q} + 4\Delta q)$, $p_1^C = \overline{q}\overline{\overline{q}}/(3\overline{q} + 4\Delta q)$, $p_2^C = \overline{\overline{q}}(\overline{q} + 2\Delta q)/(3\overline{q} + 4\Delta q)$, $\pi_1^C = \overline{q}\overline{\overline{q}}^2/(3\overline{q} + 4\Delta q)^2$, and $\pi_2^C = \overline{\overline{q}}(\overline{q} + 2\Delta q)^2/(3\overline{q} + 4\Delta q)^2$. The marginal buyers are given by $\theta_m^C = 2\overline{\overline{q}}/(3\overline{q} + 4\Delta q)$ and

$\theta_1^C = \overline{\overline{q}}/(3\overline{q}+4\Delta q)$. With these, it is straightforward to obtain that $CS^C = (4\overline{q}^2+9\overline{q}\Delta q+4\Delta q^2)\overline{\overline{q}}/2(3\overline{q}+4\Delta q)^2$, $\Pi^C = \overline{\overline{q}}(2\overline{q}^2+5\overline{q}\Delta q+4\Delta q^2)/(3\overline{q}+4\Delta q)^2$, and $W^C = (8\overline{q}^2+19\overline{q}\Delta q+12\Delta q^2)\overline{\overline{q}}/2(3\overline{q}+4\Delta q)^2$.

Under Bertrand competition, in the case of small innovations, given $((4/7)\overline{\overline{q}},\overline{\overline{q}})$, we have $p_1^B = \overline{\overline{q}}/14$, $p_2^B = \overline{\overline{q}}/4$, $x_1^B = 7/24$, $x_2^B = 7/12$, $\pi_1^B = \overline{\overline{q}}/48$, and $\pi_2^B = 7\overline{\overline{q}}/48$ from (10). Thus, we also have $\theta_m^B = 5/12$, $\theta_1^B = 1/8$, $CS^B = 7\overline{\overline{q}}/24$, $\pi_1^B = \overline{\overline{q}}/48$, $\pi_2^B = 7\overline{\overline{q}}/48$, $\Pi^B = \overline{\overline{q}}/6$, and $W^B = 11\overline{\overline{q}}/24$. In the case of large innovations, given $(\overline{q},\overline{\overline{q}})$, we have $p_1^B = \overline{q}\Delta q/(3\overline{q}+4\Delta q)$, $p_2^B = 2\overline{q}\Delta q/(3\overline{q}+4\Delta q)$, $x_1^B = \overline{\overline{q}}/(3\overline{q}+4\Delta q)$, $x_2^B = 2\overline{\overline{q}}/(3\overline{q}+4\Delta q)$, $\pi_1^B = \overline{q}\overline{\overline{q}}\Delta q/(3\overline{q}+4\Delta q)^2$, and $\pi_2^B = 4\overline{\overline{q}}^2\Delta q/(3\overline{q}+4\Delta q)^2$ from (10). Marginal buyers are given by $\theta_m^B = (\overline{q}+2\Delta q)/(3\overline{q}+4\Delta q)$ and $\theta_1^B = \Delta q/(3\overline{q}+4\Delta q)$. We then have $CS^B = (9\overline{q}+4\Delta q)\overline{\overline{q}}^2/2(3\overline{q}+4\Delta q)^2$, $\Pi^B = \overline{\overline{q}}(5\overline{q}+\Delta q)\Delta q/(3\overline{q}+4\Delta q)^2$, and $W^B = (9\overline{q}^2+23\overline{q}\Delta q+12\Delta q^2)\overline{\overline{q}}/2(3\overline{q}+4\Delta q)^2$.

Straightforward computations show that $\Pi^C > \Pi^B$ in the case of small innovations. For the case of large innovations, we can see by inspection that $\pi_1^C > \pi_1^B$ and $\pi_2^C > \pi_2^B$, such that $\Pi^C > \Pi^B$ holds. It is straightforward to show that $CS^B > CS^C$ holds true for both innovation cases. Lastly, regarding social welfare, we can prove that $W^B > W^C$ in the case of small innovations by direct computations, while proving by inspection that $W^B > W^C$ in the case of large innovations.

□

Proof of Proposition 4: In the case of small innovations, the expressions of gross profits, consumer surplus, and social welfare under both competition regimes remain the same as those under global adoption, such that the proof is the same as that in Lemma 5. In the case of large innovations, we have $\Pi^C = 2\overline{\overline{q}}/9$ and $\Pi^B = \Delta q(5\overline{q}+4\Delta q)\overline{\overline{q}}/(3\overline{q}+4\Delta q)^2$. Direct computations yield that $\Pi^C > (=,<)\ \Pi^B$ iff $\Delta q < (=,>)\ 2.5\overline{q}$. Given $CS^C = 2\overline{\overline{q}}/9$ and $CS^B = (9\overline{q}+4\Delta q)\overline{\overline{q}}^2/2(3\overline{q}+4\Delta q)^2$, it is straightforward to show that $CS^C < CS^B$ if $\Delta q < 1.70\overline{q}$ and $CS^C > CS^B$ if $\Delta q > 1.70\overline{q}$. Given $W^B = \overline{\overline{q}}(9\overline{q}^2 + 23\overline{q}\Delta q + 12\Delta q^2)/2(3\overline{q} + 4\Delta q)^2$ and $W^C = 4(\overline{q} + \Delta q)/9$, direct computations show that $W^C < W^B$ if $\Delta q < 1.14\overline{q}$ and $W^C > W^B$ if $\Delta q > 1.14\overline{q}$.

□

Proof of Proposition 5: We first compare gross profits. In the case of small innovations, we have $\Pi^C = 2\overline{q}/9$ and $\Pi^B = \overline{\overline{q}}/6$. Straightforward computations yield that $\Pi^C > (=,<)\ \Pi^B$ iff $\Delta q < (=,>)\ \overline{q}$. In the case of large innovations, we have $\Pi^B = \Delta q(5\overline{q} + 4\Delta q)\overline{\overline{q}}/(3\overline{q} + 4\Delta q)^2$, which is greater than Π^C iff $(36\Delta q^3 + 45\overline{q}\Delta q^2 - 18\overline{q}^3) + (4\overline{q}\Delta q^2 - 3\overline{q}^2\Delta q) > 0$. Given $\Delta q > (3/4)\overline{q}$, it is easy to see that both sets of parentheses are positive.

We next consider consumer surplus. In the case of small innovations, it is easy to see that $CS^B = 7\overline{\overline{q}}/24 > CS^C = 2\overline{q}/9$. In the case of large innovations, we have $CS^B = (9\overline{q} + 4\Delta q)(\overline{q} + \Delta q)^2/2(3\overline{q} + 4\Delta q)^2$, which can be shown to be greater than CS^C by direct computations. Finally, for social welfare, in the case of small innovations, we have $W^B = 11\overline{\overline{q}}/24 > W^C = 4\overline{q}/9$ obviously. In the case of large innovations, we have $W^B = (9\overline{q}^2 + 23\overline{q}\Delta q + 12\Delta q^2)\overline{\overline{q}}/2(3\overline{q} + 4\Delta q)^2$, which can be shown to be greater than W^C by direct computations.

□

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競爭強度與產品創新：比較 Cournot 與 Bertrand 競爭下之創新意願與社會福利

謝 修

摘 要

本文在產品創新的脈絡中探討 Cournot 競爭優於 Bertrand 競爭的可能性。研究發現，競爭強度與創新意願並非單調相關，Cournot 競爭下的社會福利與消費者剩餘都可能高於 Bertrand 競爭，而產業利潤反而可能較低。除刻劃研究結果成立的條件，本文也對研究結果的成因提出新的洞見。

關鍵詞：產品創新、創新意願、Cournot 競爭、Bertrand 競爭、福利分析
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