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INNOVATION UNDER SPATIAL DUOPOLY

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Abstract:

Innovation is an important topic in economics. This paper highlights duopoly innovation under the Hotelling model with game theory approaches. This paper argues that market power, as measured by the cost advantage of a dominant firm over its rival, serves to enhance the incentive to innovate in a Hotelling model of spatial competition. This result implies that a firm with cost advantage will have a larger incentive than its rivals to further its cost advantage as new opportunities for innovation arise thereby implying that innovation increases concentration. This result is in contrast to the result obtained by Holmes *et al.* (2012) who use the Betrand model to show that "market power" lowers the incentive to innovate. We think that the inelastic demand causes this economic phenomenon.

Keywords: innovation, spatial duopoly, game theory, case study.

JEL Classification: C61, C72, D4, L1

1. Introduction

Arrow (1962) initially proposed that monopolistic industries would be less innovative than competitive ones. This proposal has been intensely debated for many years. Perhaps the most famous critique came from Demsetz (1969) and Yi (1999). Demsetz (1969) and Yi (1999) proposed that according to Arrow's idea, antitrust should be pursued less diligently than is dictated by considerations of output restrictions only, for, at least in the linear model of two industries of equal output size, the more monopolistic would give the greatest encouragement to invention. Another important critique is laid out by Gilbert and Newbery (1982), in which Arrow's assumptions were changed and it showed that a monopolist has a greater incentive to adopt new technologies.

Practically, the relationship between innovation and competition is considerably complex. In empirical aspect, Tang (2006) showed that the relationship could be positive or negative depending on specific competition perception and specific innovation activity. Patel and Ward (2011) recently estimated competition in innovative market based on the patent citation patterns.

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Vives (2008) and Schmutzler (2007) reviewed literature on both innovation and competition. Aghion, Bloom, Blundell, Griffith and Howitt (2006) confirmed an inverted-U relationship between competition and innovation. With linear demand function, Sacco and Schmutzer (2011) further examined the U-shaped relation between competition and innovation with numerical simulation. Narajabad and Watson (2011) addressed innovation in a dynamic stochastic discrete-time duopoly with endogenous horizontal differentiation under Hotelling. Sawng *et al*. (2011) examined the assumption of innovative technology in mobile service in Korea. Recently, Holmes, Levine and Schmitz, Jr. (2012) explored switchover disruptions in the monopoly market structure, and their conclusions support Arrow's idea.

The relationship between innovation and competition is widely explored, while the transportation costs are always neglected in the extant literature. Actually, transportation costs have heavy effects on both competition and innovation. This motivates us to further focus on the effects of transportation costs on the relationship between innovation and competition. This study shows that a firm with cost advantage will have a larger incentive than its rivals to further its cost advantage as new opportunities for innovation arise thereby implying that innovation increases concentration. This result is in stark contrast to the result obtained by Holmes *et al.* (2012) and Arrow's idea (1962).

This paper aims to explore the effects of spatial competition on innovation using industrial organization theory. This study combines spatial competition (Hotelling, 1929) with innovation of Holmes, Levine and Schmitz, Jr. (2012). Compared with the model of Holmes, Levine and Schmitz, Jr. (2012), transportation costs are introduced and switchover disruptions are not remarked in this work. The main result is that market power has positive effects on innovation under spatial competition. The main conclusion is contrary to that in Holmes, Levine and Schmitz, Jr. (2012) or the idea of Arrow (1962) and a rational explanation is offered.

Here we introduce some related literature about spatial competition. Hotelling's model was initially established by Hotelling in 1929 to originally analyze spatial competition (see, *e.g*., Hotelling (1929), Fudenberg and Tirole (1991)). There further exists extensive research on Hotelling model recently (see in Greenhut and Ohta (1972, 1975), Armstrong and Vickers (2010), Loginova and Wang (2011), Nie (2010), Nie (2011)). Larralde, H., Stehlé, J. and Jensen, (2009) recently address spatial competition with quadratic transportation cost function. In the recent paper, Vogel (2008) derived interesting results of product differentiations in Hotelling model. Vogel found that a firm's price, market share and profit were all independent of its neighbors' marginal costs, conditional on the average marginal cost in the market. Vogel also proved that more productive firms were more isolated, all else equal.

This paper is organized as follows. The model of spatial duopoly with innovation is established in the next section. In this model, Arrow's (1962) baseline model of

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innovation is combined with the classical Hotelling´s model. The game theory model of innovation under spatial competition is analyzed in Section 3. The equilibrium price and the equilibrium output are all outlined and discussed. Furthermore, the relationships between transportation costs along with market power and net profits are examined in this section. An example and a case study are outlined in Section 4. Example and cases all support the above conclusions. Some remarks are given and some further research is discussed in the final section.

2. Game Theory Model

The model with duopoly innovation under spatial duopoly is formally established here. Consumers are uniformly distributed in the linear city: $z \in [0,1]$. We assume that there exists no difference between consumers. Two producers in the linear city, producing products without differentiation in quality, are introduced in this industry. Two firms locate at z_1 and z_2, respectively. To simplify the model, we assume that $z_1 = 0$ and $z_2 = 1$.

Consumers. The transportation costs are fully undertaken by consumers in this model. Two firms price p_1 and p_2, respectively. Denote the utility of the consumer to consume a unit good to be u_0. The consumer lying in is inclined to buy the product of the first producer if and only if the following inequality holds[1]:

$$u_0 - [p_1 + tD(z, z_1)] \geq u_0 - [p_2 + tD(z, z_2)], \tag{1}$$

where $t > 1$ represents the transportation cost for a unit product and $D(z, z_i)$ denotes the distance between the firm i and this consumer for $i = 1, 2$. The variable t heavily depends on transport technologies and other factors, such as management. Otherwise, this consumer is likely to buy the second producer's product.

The distance function previously mentioned needs some further discussion. We also note that this distance may be geographic, or related to differences in beliefs and cultures, and so on. In this paper, we always use the distance function $D(z, z_i) = |z - z_i|$ for $i = 1, 2$.

Based on the prices p_1 and p_2 along with locations $z_1 = 0$, and $z_2 = 1$ the demand function is addressed here. Market clearing conditions yield that the demands of two firms are

$$q_1 = 1 - q_2 = \frac{p_2 - p_1 + t}{2t}, \tag{2}$$

$$q_2 = 1 - q_1 = \frac{p_1 - p_2 + t}{2t}. \tag{3}$$

(2) and (3) is reaction function of firms. Denote z^* to be the solution of $u_0 - [p_1 + tD(z, z_1)] = u_0 - [p_2 + tD(z, z_2)]$. In Figure 1, the first firm's price is p_1, and

1 The utility of the consumer is assumed to be large enough such that the market is fully covered. Or u_0 is large enough.

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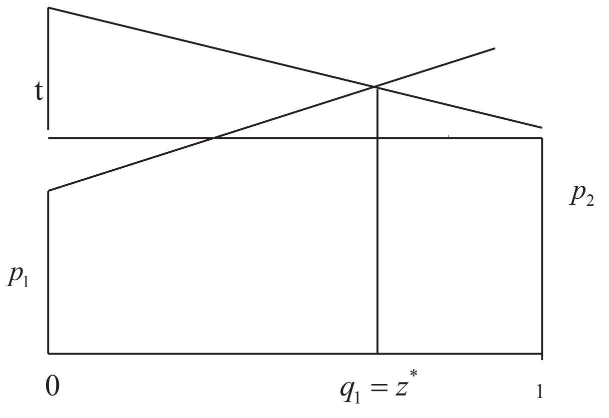
the second firm's price is p_2. The consumers in [0, z^*] choose the first firm's product because (3) is met. Other consumers buy the products from the second firm, and the market is fully covered. We further point out that the total demand in this work is inelastic.

Figure 1
Two Producers Pricing in the Linear City



Two producers without innovation. The constant marginal cost incurred by the first firm is c_1 and $c_2 = c_1 + \tau$ ($\tau > 0$) for the second producer. The parameter τ governs the degree of market power that the first firm exerts on its rivals, which means the cost advantage of the first firm. One interpretation is that there exist a domestic incumbent and a rival foreign firm with the same production cost, c_1. The foreign firm incurs an additional cost $\tau > 0$ *per* unit, which could be a tariff or a transportation cost.[2] Given price p_1 and quantity q_1, the first firm maximizes the following profit function:

$$\pi_1 = (p_1 - c_1)q_1 . \tag{4}$$

Given price p_2 and quantity q_2, the second firm maximizes the following profit function:

$$\pi_2 = (p_2 - c_2)q_2 . \tag{5}$$

Two firms with innovation. The innovation in Arrow's pattern (1962) is then introduced and used as the baseline approach in this paper. Of the above two firms, the first firm (incumbent) alone has the choice to adopt a new technology or not. If the first firm pays the fixed cost $F \geq 0$ to adopt the new technology, the second firm's marginal cost remains constant and the first firm's marginal cost changes with time.[3] If a new technology is

2 This explanation appeared in Holmes *et al.* (2012).

3 These notations are the same as that in Holmes, Levine and Schmitz, Jr. (2012) so that we can compare the results in spatial competition with the situation without spatial competition.

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adopted, the marginal cost of the first firm varies over time. We denote the cost path to be $c(T)$.

The cost path $c(T)$. over time T is continuous and decreasing. At time $T = 0$, a new technology becomes available. We denote $\overline{c} = c_1 = c(0)$ and the cost ultimately attained as $\underline{c} = c(1)$ with $\underline{c} < \overline{c}$ .We define $0 \leq G(c) \leq 1$ to be how much time remains when marginal cost equals c for $c \in [\underline{c}, \overline{c}]$. It is therefore rational that $G(\overline{c}) = 1$ and $G(\underline{c}) = 0$ simultaneously hold. We also define $g(c) = G^{'}(c)$ to be the density of marginal cost, and ρ to be the discount factor. Finally, we define $h(c)$ as follows:

$$h(c) \equiv e^{-\rho(1-G(c))} g(c). \tag{6}$$

If the first firm adopts the new technology, the net return is given as follows:

$$W = \int_{\underline{c}}^{\overline{c}} h(c)(p_1(c) - c) q_1(c) dc - \int_{\underline{c}}^{\overline{c}} h(c) dc [p_1(\overline{c}) - \overline{c}] q_1(\overline{c}) - F. \tag{7}$$

For the above model, (4) is concave in p_1, and (5) is concave in p_2 because of

$$D(z, z_i) = | z - z_i | \quad \text{for } i = 1, 2.$$

Timing of this game is outlined as follows: Firstly, two firms with costs c_1 and $c_2 = c_1 + \tau$ in some industry compete in a Hotelling Betrand. Then, given the fixed costs $F \geq 0$ and the cost path $c(T)$ along with $0 \leq G(c) \leq 1$, the first firm determines to adopt new technology or not. Finally, if the first firm adopts new technology, the second firm's marginal cost remains unchanged and the first firm's marginal cost path is $c(T)$. Two firms compete under a new spatial Betrand. Otherwise, two firms' marginal costs remain constant and the spatial Betrand competition remain unchanged.

3. Equilibrium Analysis

The above model is considered in this section. The equilibrium state is analyzed, which is described as follows. Given the locations of two firms, the two firms compete in price until a Nash equilibrium is attained. That is, any firm that changes the price will undertake a loss or see a decrease in profits. The Nash equilibrium, with demand, price and profits for the above model is analyzed in the rest of this paper. We first consider demand in the spatial duopoly, then, the equilibrium.

The price under equilibrium is considered. The prices, based on (2)–(3) along with (4)-(5), are given here. In this case, the existence and the uniqueness of the solution to the system (4)-(5) are obvious according to the concavity of profit functions. The solution is determined by the first-order derivatives of (4) and (5). The first-order optimal conditions of (4) indicate

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$$p_1 = \frac{c_1}{2} + \frac{t}{2} + \frac{p_2}{2}. \tag{8}$$

Similarly, (5) implies the following conclusion:

$$p_2 = \frac{c_2}{2} + \frac{t}{2} + \frac{p_1}{2}. \tag{9}$$

From (8)-(9), we have the following formulation:

$$p_1 = \frac{2}{3}c_1 + \frac{c_2}{3} + t.$$

$$p_2 = \frac{2}{3}c_2 + \frac{c_1}{3} + t.$$

When innovation is introduced, the price depends on the cost change of the first firm. With $c \in [\underline{c}, \overline{c}]$, the prices are given by the following formulations:

$$p_1 = \frac{2}{3}c + \frac{c_2}{3} + t. \tag{10}$$

$$p_2 = \frac{2}{3}c_2 + \frac{c}{3} + t. \tag{11}$$

The corresponding demands for the two firms are:

$$q_1 = \frac{c_2 - c + 3t}{6t}. \tag{12}$$

$$q_2 = \frac{c - c_2 + 3t}{6t}. \tag{13}$$

The static equilibrium price is given from the above model. According to the technique of comparative static analysis, we find that the rising marginal cost of the first firm results in the increase of the prices of both firms. Higher marginal cost of the first firm results in a lower quantity produced by the first firm and a higher quantity produced by the second firm.

Based on the above analysis, (7) is replaced by the following formulation because of the hypothesis $c_2 = c_1 + \tau$.

$$\begin{aligned} W &= \int_{\underline{c}}^{\overline{c}} h(c)(p_1(c) - c)q_1(c)dc - \int_{\underline{c}}^{\overline{c}} h(c)dc[p_1(\overline{c}) - \overline{c}]q_1(\overline{c}) - F \\ &= \int_{\underline{c}}^{\overline{c}} h(c)\frac{(3t + c_2 - c)^2}{18t}dc - \int_{\underline{c}}^{\overline{c}} h(c)dc\frac{(3t + c_2 - c_1)^2}{18t} - F \\ &= \int_{\underline{c}}^{\overline{c}} h(c)\frac{(3t + c_1 + \tau - c)^2}{18t}dc - \int_{\underline{c}}^{\overline{c}} h(c)dc\frac{(3t + \tau)^2}{18t} - F. \end{aligned} \tag{14}$$

In the above formulation, the first term represents returns under innovation, and the second term stands for profits without innovation. The third term is the fixed cost of the innovation.

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The equilibrium state is considered here, and the factors that affect the net return of the first firm are analyzed. Here, we consider the relationship between the transportation cost and the net return. Furthermore, by virtue of $c_1 = \overline{c}$ and $c \in [\underline{c}, \overline{c}]$, we have $c_1 - c > 0$.

$$\begin{aligned} \frac{\partial W}{\partial t} &= \partial[\int_{\underline{c}}^{\overline{c}} h(c)\frac{(c_1-c)^2+2(c_1-c)(3t+\tau)}{18t}dc - F]/\partial t \\ &= \partial[\frac{1}{18t}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)^2dc + \frac{1}{3}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)dc + \frac{1}{9t}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)\tau dc]/\partial t \\ &= -\frac{1}{18t^2}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)^2dc - \frac{1}{9t^2}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)\tau dc < 0. \end{aligned} \tag{15}$$

Thus, increasing transportation cost decreases the net return of the first firm when there is innovation.

According to (14), the following conclusions hold.

Proposition If $W > 0$, higher market power results in more active innovation.

Proof. Further considering equation (14), simple calculations yield the following formulation:

$$\begin{aligned} W &= \int_{\underline{c}}^{\overline{c}} h(c)(p_1(c)-c)q_1(c)dc - \int_{\underline{c}}^{\overline{c}} h(c)dc[p_1(\overline{c})-\overline{c}]q_1(\overline{c}) - F \\ &= \int_{\underline{c}}^{\overline{c}} h(c)\frac{(3t+c_1+\tau-c)^2}{18t}dc - \int_{\underline{c}}^{\overline{c}} h(c)dc\frac{(3t+\tau)^2}{18t} - F \\ &= \int_{\underline{c}}^{\overline{c}} h(c)\frac{(c_1-c)^2+2(c_1-c)(3t+\tau)}{18t}dc - F. \end{aligned} \tag{16}$$

If $W > 0$, this innovation is worth adopting. We further note that $h(c) > 0$ for any $c \in [\underline{c}, \overline{c}]$ according to the definition $g(c)$ of and (6). The relationship between net profits and monopoly power is analyzed and the following conclusion holds:

$$\frac{\partial W}{\partial \tau} = \frac{1}{9t}\int_{\underline{c}}^{\overline{c}} h(c)(c_1-c)dc > 0. \tag{17}$$

Therefore, increments in the tariff increase the innovation of the incumbent. The results are therefore obtained and the proof is complete.

Remarks: (15) implies that transportation technology is a major factor in stimulating innovation. Consequently, many districts in China have improved infrastructure to enhance innovation. In this proposition, we also find that firms with higher market power are more innovative, which is contrary to the conclusion obtained by Holmes, Levine and Schmitz, Jr. (2012). Transportation cost and inelastic demand yield this interesting phenomenon. This result is consistent with that in Gilbert and Newbery (1982).

Because of spatial competition, there exist four differences from Holmes, Levine and Schmitz, Jr. (2012). The first, in Holmes, Levine and Schmitz, Jr., the price of the

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products was always fixed, while in this paper, the price of the products is determined by the instant cost. The second, because of transportation, the prices of two firms are not identical in this paper. The third, in Holmes, Levine and Schmitz, Jr., the switchover disruption is considered, whereas these phenomena are neglected in this paper. Finally, the total demand in Holmes, Levine and Schmitz, Jr. (2012) and Arrow (1962) is elastic while is inelastic in this paper. Below is an explanation of these differences.

It is surprising that market power increases innovation if spatial competition is introduced. From (15), we argue that transportation cost deters innovation. It is hence rational to think that the inelastic demand causes this economic phenomenon, in which higher market power yields more active innovation.

The important implication of the market power result is that markets will tend to become more concentrated as new opportunities for innovation arise. Specifically, the results in this paper imply that a firm with a cost advantage has a greater incentive to take advantage of new innovation, thereby furthering their cost advantage and increasing market concentration by either increasing the variance in market share or by inducing the exit of non-innovators.

According to the relationship between τ and W, for the fixed positive cost F, there exists a threshold value τ_0 where the incumbent adopts this innovation if $\tau > \tau_0$ and it does not if $\tau < \tau_0$. This is rational because of the inequality $\partial W / \partial \tau > 0$. The threshold value τ_0 satisfies:

$$W = \int_{\underline{c}}^{\overline{c}} h(c) \frac{(c_1 - c)^2 + 2(c_1 - c)(3t + \tau)}{18t} dc - F = 0. \tag{18}$$

By direct calculation, we immediately have the formulation $\partial W / \partial F = -1 < 0$. (17) suggests that $\partial W / \partial \tau > 0$. By virtue of the implicit function theorem, there exists a unique solution $\tau_0(F)$, which is differential, and the following is satisfied:

$$\frac{d\tau_0(F)}{dF} = -\frac{\partial W}{\partial F} / \frac{\partial W}{\partial \tau_0} > 0. \tag{19}$$

The above analysis is summarized, and we have that the threshold value of the tariff or the incentive to innovate increases with the fixed cost $F > 0$.

Remarks: The above conclusion illustrates that higher fixed cost results in less incentive to innovate, which is observed in practice. This result is also contrary to that obtained in the recent paper of Holmes, Levine and Schmitz, Jr. (2012).

The discount factor is further considered in the above model. For $\rho_1 > \rho_2 > 0$, according to (6), we immediately obtain the relationship $e^{-\rho_1(1-G(c))} g(c) < e^{-\rho_2(1-G(c))} g(c)$ because of $g(c) > 0$ and $1 \geq G(c) \geq 0$. Combining (7) and (15), we have that monotonically decreases in discount factor ρ. Thus, we have the relationship $\partial W / \partial \rho < 0$ if W is

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continuously differential. By virtue of (18), from $\partial W / \partial \tau > 0$ and the implicit function theorem, there exists a unique solution $\tau_0(\rho)$, which is differential, and the following is satisfied:

$$\frac{\partial \tau_0}{\partial \rho} = -\frac{\partial W}{\partial \rho} / \frac{\partial W}{\partial \tau_0}. \tag{20}$$

Based on the above analysis, we find that a more patient firm seems more innovative, whereas a firm focused on short-term profit seems less innovative. This is also empirically observed in society. The above analyses are summarized as follows. The net profits of the first firm to innovate decrease with the discount factor and the threshold value of the tariff, or the incentive to innovate monotonically increases with the discount factor ρ.

Remarks: The above result implies that more patient firms are more innovative. A firm anxious for success has no strong incentive to innovate in practice. This conclusion also seems rational in society.

In this section, price and profits in equilibrium are all captured. The main conclusions are contrary to those in Holmes, Levine and Schmitz, Jr. (2012) because the spatial competition is introduced, which is interesting.

4. Example and Case Study

Here is an example outlined to illustrate the above conclusion. Then, a case study is outlined to illustrate the above conclusions.

Example We consider a case with uniform distribution. Assume $c_1 = \overline{c} = 2$, $c_2 = 2 + \tau$ and $\underline{c} = 1$. $G(c) = c - 1$, $g(c) = 1$ and $h(c) \equiv e^{-\rho(2-c)}$. Then, we have $p_1 = \dfrac{2c + 2 + \tau + 3t}{3}$, $p_2 = \dfrac{4 + 2\tau + c + 3t}{3}$. The corresponding demands for the two firms are $q_1 = \dfrac{2 + \tau - c + 3t}{6t}$ and $q_2 = \dfrac{c - 2 - \tau + 3t}{6t}$.

The net return is given by

$$W = \int_1^2 h(c) \frac{2 + \tau + 3t - c}{3} \frac{2 + \tau - c + 3t}{6t} dc - \int_1^2 h(c) dc \frac{\tau + 3t}{3} \frac{\tau + 3t}{6t} - F$$

$$= \int_1^2 h(c) \frac{(2-c)^2 + 2(2-c)(\tau + 3t)}{18t} dc - F = \int_1^2 e^{-\rho(2-c)} \frac{(2-c)^2 + 2(2-c)(\tau + 3t)}{18t} dc - F.$$

Apparently, $\dfrac{\partial W}{\partial t} = -\dfrac{1}{18t^2} \displaystyle\int_1^2 e^{-\rho(2-c)} (2-c)^2 dc - \dfrac{1}{9t^2} \int_1^2 e^{-\rho(2-c)} (2-c)\tau dc < 0.$

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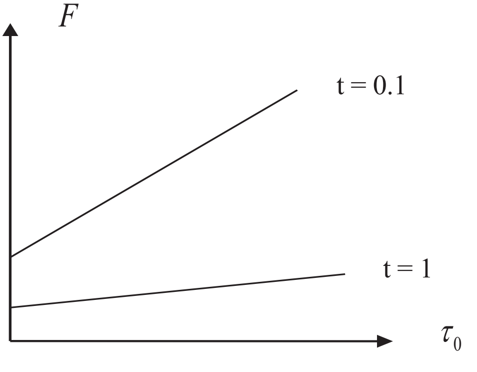
Since the term $e^{-\rho(2-c)}\dfrac{(2-c)^2+2(2-c)(\tau+3t)}{18t}$ is increased in ρ, we have the relationship $\partial W/\partial\rho > 0$. Moreover, we examine the conclusions with $\rho = 1$.

$$\frac{\partial W}{\partial \tau} = \frac{1}{9t}\int_1^2 e^{-\rho(2-c)}(2-c)dc = \frac{1}{9t}\int_1^2 e^{-(2-c)}(2-c)dc$$
$$= \frac{1}{9t}(2-c)e^{c-2}\Big|_1^2 + \frac{1}{9t}e^{c-2}\Big|_1^2 = \frac{1}{9t}(1-2e^{-2}) > 0.$$

τ_0 is determined by the equation $\int_1^2 e^{-\rho(2-c)}\dfrac{(2-c)^2+2(2-c)(\tau+3t)}{18t}dc - F = 0.$ For $\rho = 1$, we immediately obtain that $\tau_0 = \dfrac{9t}{1-2e^{-2}}F-(3t+4)+\dfrac{2e^{-1}}{1-2e^{-2}}$. Obviously, $\dfrac{d\tau_0}{dF} > 0$ because of $\dfrac{9t}{1-2e^{-2}} > 0$. The relationship between τ_0 and the fixed cost F is illustrated in Figure 2 with $t = 1$ and $t = 0.1$. All conclusions meet the above Proposition.

Figure 2

The Relationship between τ_0 and the Fixed Cost F under $t = 1$ and $t = 0.1$



Case Study There exist many cases supporting conclusions in this study. For example, Huawei Technologies Co., Ltd, as a leading global information and communications technology (ICT) solution provider, is a very famous firm in China and its income tax in 2010 is RMB 3,672 million. Judging from the annual report of Huawei Technologies Co., Ltd from 2006 to 2010, the market share of this firm (or the market power) is promoted and the innovative investment is corresponding increased (See Table 1). The revenue is

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RMB 185,176 million in 2010 while RMB 149,059 million in 2009. The corresponding R&D investment is RMB 16,556 million in 2010 while RMB 13,340 million in 2009. This is consistent with conclusion in this work. In fact, the increase in demand is not large enough and we neglect the increase in demands in this case.

Table 1
Data from Annual Reports of Huawei Technologies Co., Ltd

Year	Revenue (Million RMB)	R&D (Million RMB)
2006	66,365	6,637
2007	93,792	9,379
2008	125,217	10,469
2009	149,059	13,340
2010	185,176	16,556

Table 2
Net Return Based on Technology Innovation and R&D Investment In Huawei Technologies Co., Ltd

Year	Net return of technology innovation (Million RMB)
2007	27,427
2008	31,525
2009	23,842
2010	36,117

Source: http://www.huawei.com/en/ucmf/groups/public/documents/annual_report/092576.pdf

We list the net return based on technology innovation. The net return of innovation in 2010 is RMB 36,117 million, RMB 23,842 million in 2009. We find that the relationship of net return of technology innovation and technology innovation meets the above conclusion in Section 3.We also neglect the increase in demands in this case.

Table 3
Data from Annual Reports of ZTF Corporation

Year	Revenue (Million RMB)	R&D (Million RMB)
2006	23,214.6	2,832
2007	34,777.2	3,210
2008	44,293.4	3,994
2009	60,272.6	5,781
2010	70,263.9	7,092

Table 4
Net Return Based on Technology Innovation and R&D Investment of ZTF Corporation

Year	Net return of technology innovation (Million RMB)
2007	11,562.6
2008	9,516.2
2009	15,979.2
2010	9,991.3

Source: http://wwwen.zte.com.cn/en/about/investor_relations/corporate_report/

Another typical example lies in ZTE Corporation, which is also a very famous firm in China and its income tax in 2010 is RMB 883.7 million. According to the annual report of ZTE Corporation from 2006 to 2010, the market share of this firm (or the market power) is continuously promoted and the innovative investment is corresponding increased (See in Table 2). This is highly consistent with conclusions in this work.

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We also list the net return based on technology innovation. The net return of innovation in 2010 is RMB 9,991.3 million, RMB 15,979.2 million in 2009. We confirm that the relationship of net return of technology innovation and technology innovation satisfies the above conclusion in Section 3.

Example and many cases all highly support the theoretic results in this paper.

5. Conclusions

Innovation under duopoly is addressed in a spatial situation in this work, where we have extended Arrow's model for innovation to spatial competition. This study argues that market power, services to enhance the incentive in a Hotelling model of spatial competition. The conclusions in Holmes, Levine and Schmitz, Jr. do not hold if spatial competition is introduced. It is a surprising conclusion, and a rational explanation is offered. Therefore, under spatial competition, this study also overturns the conclusions of Vives in 2008. Apparently, without switchover disruption, the conclusions in this paper also hold. To compare with that in Homes *et al*. (2012), this study also introduces switchover disruption.

Without spatial competition, the relationship between competitive pressure and innovation is addressed by Vives. There are several further research topics related to this topic. In many cases, transportation cost is not linear function. Under spatial models with non-linear transportation cost, the situation seems more complicated, and it is very difficult to guarantee the concavity of the object functions. When vertical product differentiation is introduced, the situation becomes more complex. It is also interesting to consider multiple firms. Furthermore, we just consider innovation by the first firm, and it is also important to extend it. For example, since there exist various types of innovation in practice. For example, the innovation proposed by Gibert and Newbery. It would be interesting to extend innovation in Gibert and Newbery; in fact, we are currently pursuing this research topic. Moreover, we consider firms living from $T = 0$ to $T = 1$ such that $\overline{c} = c_1 = c(0)$. If firms continue to live after $T = 1$, it is interesting to address it. This is also our further researching topic.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P. (2006), "Competition and Innovation: An inverted-U Relationship." *Quarterly Journal of Economics*, 120(2): pp. 701-728.

Armstrong, M., Vickers, J. (2010), "Competitive Non-linear Pricing and Bundling." *The Review of Economic Studies*, 77(1): pp. 30-60.

Arrow, K. (1962), "Economic Welfare and the Allocation of Resources for Inventions." In *The Rate and Direction of Inventive Activity*, R. Nelson, ed., Princeton, N. J.: Princeton University Press.

Demsetz, H. (1969), "Information and Efficiency: Another Viewpoint." *Journal of Law and Economics*, 12(1): pp.1-22.

Fudenberg, D., Tirole, J. (1991), *Game Theory*. Cambridge, Massachusetts: MIT Press.

DOI: 10.18267/j.pep.463

Gibert, R. J., Newbery, D. M. G. (1982), "Preemptive Patenting and the Persistence of Monopoly." *American Economic Review*, 72(3): pp. 514-526.

Greenhut, M. L., Ohta, H. (1975), *Theory of Spatial Pricing and Market Areas*, Duke Press, 1975.

Greenhut, M. L., Ohta, H. (1972), "Monopoly Output under Alternative Spatial Pricing Techniques." *American Economic Review*, 62(4): pp. 705-13.

Holmes, T. J., Levine, D. K., Schmitz, Jr., J. A. (2012), "Monopoly and the Incentive to Innovate when Adoption Involves Switchover Disruptions." *American Economic Journal: Microeconomics*, 4(3): pp.1–33.

Hotelling, H. (1929), "Stability in Competition." *The Economic Journal*, 39(1): pp. 41-57.

Larralde, H., Stehlé, J., Jensen, P. (2009), "Analytical Solution of a Multi-dimensional Hotelling Model with Quadratic Transportation Costs." *Regional Science and Urban Economics*, 39(3): pp. 343-349.

Loginova, O., Wang X. H. (2011), "Customization with Vertically Differentiated Products." *Journal of Economics & Management Strategy*, 20(2): pp. 475-515.

Narajabad, B., Watson, R. (2011), "The Dynamics of Innovation and Horizontal Differentiation." *Journal of Economic Dynamics and Control*, 35(6): pp. 825-842.

Nie, P. Y. (2010), "Spatial Technology Spillover." *Economic Computation and Economic Cybernetics Studies and Research*, 44(4): pp. 213-223.

Nie, P. Y. (2011), "Spatial Maintenance Goods under Monopoly." *Ekonomska Istrazivanja - Economic Research*, 24(4), pp. 16-26.

Patel, D., Ward, M. R. (2011), "Using Patent Citation Patterns to Infer Innovation Market Competition." *Research Policy*, 40(6): pp. 886-894.

Sacco, D., Schmutzer, A. (2011), "Is there a U-shaped Relation between Competition and Investment?" *International Journal of Industrial Organization*, 29(1): pp. 65-73.

Sawng Y. W., Kim, S. H., Lee, J., Oh, Y. S. (2011), "Mobile Service Usage Behavior in Korea: An Empirical Study on Consumer Acceptance of Innovative Technologies." *Technological and Economic Development of Economy*, 17(1): pp. 151-173.

Schmutzler, A. (2007), "The Relation between Competition and Innovation- Why Is It such a Mess?" University of Zurich, Mimeo, Nov. 2007.

Tang, J. M. (2006), "Competition and Innovation Behavior." *Research Policy*, 35(1): pp. 68-82.

Vives, X. (2008), "Innovation and Competitive Pressure." *Journal of Industrial Economics*, 56(3): pp. 419-469.

Vogel, J. (2008), "Spatial Competition with Heterogeneous Firms." *Journal of Political Economy*, 116(3): pp. 423-466.

Yi, S. S. (1999), "Market Structure and Incentives to Innovate: The Case of Cournot Oligopoly." *Economic Letters*, 65(3): pp. 379-388.