# R&D in a Mixed Duopoly in China

## 中国混合複占市場におけるＲ＆Ｄ

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**Abstract**：We provide a simple model to investigate the incentive of investing in R&D in a mixed duopoly market. We assume that the public firm has higher extent of research inefficiency, and the result shows that the public firm's level of R&D is negatively correlated to the extent of privatization and research inefficiency. When the extent of privatization and the public firm's R&D inefficiency level is relatively low, the public firm engage in more R&D compared with the private firm, and vice versa. This research is closely related to the policy of extensive industry transition of privatization in China.

**Keywords**：R&D, Mixed duopoly, China

### 1　Introduction

We consider a duopoly market in which a partial privatization firm competes with a private firm in a homogeneous good. We compared the level of R&D (research and development) between the two firms. Heywood and Ye (2009) discussed the same problem and they showed that the public firm (partial privatization firm) invests more in R&D than its private rival, by assuming the research inefficiency is same for both firms. However, we assume that the public firm has higher extent of research inefficiency, which is common assumption. And this phenomena that a public is more inefficient than a private firm in China is obvious. In such assumption, we find that only when the extent of privatization and the public firm's R&D inefficiency level is relatively low, the public firm engage in more R&D compared with the private firm, and vice versa. This result can be explained by the empirical previous research of Wu (2012), where he proved that state owned enterprises have greater incentives for more R&D investment. According to his words, the reason could be explained that large public firms often have easy access to resources such as physical assets, human capital, availability of finance and connections with various government departments.

However, keeping on of the two factors, either the extent of privatization or the public firm's R&D inefficiency level constant, increasing the other factor will cause the private firm to invest more than the public firm. Hence, the relatively high level of the extent of privatization or the public firm's R&D inefficiency would weaken the incentive of the public firm to invest more in R&D. This result has not been touched on in the existing researches.

The result suggests that if the public firm has less R&D inefficiency level, the policy in China of industry transition, which targets for extensive privatization should be reconsidered. For example, in China the information technology industry is a mixed oligopoly market with Lenovo, Huawei and TCL. According to Heywood and Ye (2009), Lenovo is a public firm, Huawei is a private firm and TCL is partially privatized. R&D investment for Lenovo was the biggest in 2006. Lenovo has been mentioned its high efficiency for countless times in media. In such case, the privatization policy might need be reconsidered.

We discuss our topic in 5 sections. In the first section, we provide an introduction. We then give the

model and analysis in the second and third section, respectively. Then we offer an extension.
Finally, we present a conclusion.

## 2 The Model

We consider a duopoly market consisting of a private firm ($F_1$) and a public firm (state-owned firm $F_2$) producing a homogeneous product. Firms produce with the same constant unit cost $c$ of production, which is equal or greater than 0. Each firm $i$ ($i$ = 1,2) sets its sales $q_i$ and thus the inverse demand function is given by $p = 1 - Q$, where $p$ denotes price and $Q$ is the total production level, i.e., the sum of both firms' outputs ($Q = q_1 + q_2$). Each firm engages in R&D, saying $x_i$ ($i$ = 1,2), respectively.

Firms' profit functions are represented as:

$$\pi_i = (1 - q_1 - q_2 - c + x_i) q_i - A_i x_i^2 \quad i \in \{1,2\} \tag{1}$$

where $A_i$ is the inefficiency parameter of R&D for firms.

The social welfare $W$ is as following:

$$W = \frac{(q_1 + q_2)^2}{2} + \pi_1 + \pi_2 \tag{2}$$

Firm 1 intends to maximize the profit. However, firm 2 which is a public or partially privatized firm intends to maximize the following:

$$G = (1 - \lambda) W + \lambda \pi_2 \tag{3}$$

Where $0 < \lambda < 1$ and represents the extent of privatization. As $\lambda$ increases, firm 2 is more willing to maximize the profit rather than the social welfare.

We consider a four-stage game. In the first stage, the public firm 2 chooses the extent of privatization, $\lambda$, to maximize its G. In the second stage, firm 1 chooses its level of R&D as a Stackelberg leader. In the third stage, firm 2 decides its level of R&D as a Stackelberg follower. In the last stage, firms compete in quantities.

## 3 Analysis

We start our analysis from the last stage, the profit maximization for the firms are as follows:

$$\max_{q_1} \ (1 - q_1 - q_2 - c + x_1) q_1 - A_1 {x_1}^2 \tag{4}$$

$$\max_{q_2} \ (1 - q_1 - q_2 - c + x_2) q_2 - A_2 {x_2}^2 \tag{5}$$

We obtain the outcome as following:

$$q_1 = \frac{x_1 - x_2 + \lambda - c\lambda + x_1\lambda}{1 + 2\lambda} \tag{6}$$

$$q_2 = \frac{1 - c - x_1 + 2x_2}{1 + 2\lambda} \tag{7}$$

As regards R&D setting of firm 2 at stage 3, by substituting of (6) (7), then we have:

$$x_2 = \frac{(1+\lambda)^2 - c(1+\lambda)^2 + x_1(-2 - 3\lambda + \lambda^2)}{-3 - 5\lambda + 2A_2(1 + 2\lambda)^2} \tag{8}$$

At stage 2, by substituting of (6) (7) (8), after maximization, we obtain as:

$$x_1 = \frac{(1-c)(-2A_2(1+2\lambda)^2(1+3\lambda) + (1+3\lambda)^2 + 4\lambda(1+\lambda)A_2 + 2A_2\lambda)^2)}{A_1(3 + 5\lambda - 2A_2(1+2\lambda)^2)^2 - (1 + 3\lambda - 2A_2(1 + 3\lambda + 2\lambda^2))^2} \tag{9}$$

For simplicity of calculation, we assume $A_1 = 1$, $c = 0$. Then we obtain the equilibriums:

$$q_1 = \frac{3 + 14\lambda + 15\lambda^2 + 4A_2^2\lambda(1+2\lambda)^3 - 2A_2(1 + 10\lambda + 27\lambda^2 + 22\lambda^3)}{4(1+2\lambda)(2(1+\lambda) + A_2^2\lambda(2 + 7\lambda + 6\lambda^2) - A_2(2 + 7\lambda + 7\lambda^2))} \tag{10}$$

$$q_2 = \frac{3 + 2\lambda - 5\lambda^2 + 4\lambda(A_2 + 2A_2\lambda)^2 + 2A_2(-3 - 9\lambda - 4\lambda^2 + 4\lambda^3)}{4(1+2\lambda)(2(1+\lambda) + A_2^2\lambda(2 + 7\lambda + 6\lambda^2) - A_2(2 + 7\lambda + 7\lambda^2))} \tag{11}$$

$$x_1 = \frac{-2A_2(1+2\lambda)^2(1+3\lambda) + (1+3\lambda)^2 + 4\lambda(1+\lambda)(A_2 + 2A_2\lambda)^2}{(3 + 5\lambda - 2A_2(1+2\lambda)^2)^2 - (1 + 3\lambda - 2A_2(1 + 3\lambda + 2\lambda^2))^2} \tag{12}$$

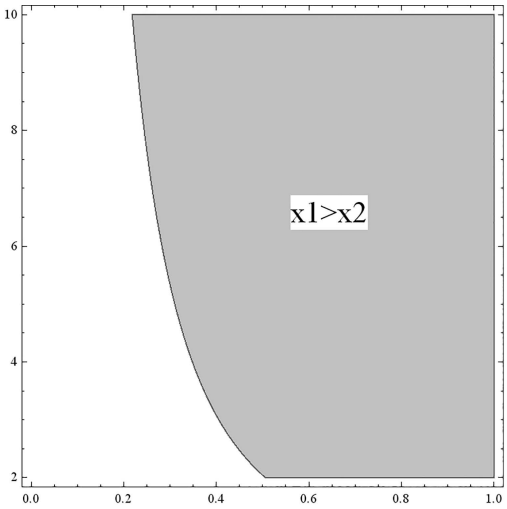
$$x_2 = \frac{-2 - 5\lambda + 4(-1 + A_2)\lambda^2 + (-5 + 12A_2)\lambda^3 + 8A_2\lambda^4}{4(1+2\lambda)(2(1+\lambda) + A_2^2\lambda(2 + 7\lambda + 6\lambda^2) - A_2(2 + 7\lambda + 7\lambda^2))} \tag{13}$$

$$p = \frac{-1 + (-3 + 2A_2)\lambda + 4A_2\lambda^2}{2(1+2\lambda)(-2 + A_2(2 + 3\lambda))} \tag{14}$$

$$\pi_1 = \frac{(-1 + (-3 + 2A_2)\lambda + 4A_2\lambda^2)^2}{4(1+2\lambda)(-1 + (-1 + A_2)\lambda + 2A_2\lambda^2)(-2 + A_2(2 + 3\lambda))} \tag{15}$$

$$\pi_2 = \frac{(16\lambda^3(A_2 + 2A_2\lambda)^4 + \lambda(3 + 2\lambda - 5\lambda^2)^2 - 16A\frac{3}{2}\lambda^2(1+2\lambda)^2(3 + 9\lambda + 5\lambda^2 - 2\lambda^3 + \lambda^4) + 4A\frac{2}{2}\lambda(9 + 64\lambda + 155\lambda^2 + 124\lambda^3 - 26\lambda^4 - 26\lambda^4 - 26\lambda^5 + 36\lambda^6) - A_2(4 + 56\lambda)}{(16(1+2\lambda)^2(-1 + (-1 + A_2)\lambda + 2A_2\lambda^2)^2(-2 + A_2(2 + 3\lambda))^2} \tag{16}$$

To ensure all equilibriums to be positive, we found the area where $x_2 < x_1$ as Fig. 1




(Figure 1)

## 4 Extension

We next consider firms choose the the level of R&D simultaneously. Then the two firms engage in a three-stage game. At stage 1, the public firm 2 chooses the extent of privatization, $\lambda$, to maximize its G. At stage 2, firm 1 and firm 2 chooses its level of R&D simultaneously. At the last stage, firms set outputs quantities simultaneously in a Cournot competition.

In the last stage, the profit maximization for the firms are same in the last section. Therefore we consider form stage 2. By substituting of (6) (7), then we have:

$$x_1 = \frac{(1-c)(1+\lambda)(-1+(-3+2A_2)\lambda+4A_2\lambda^2)}{A_1(1+2\lambda)(-3-5\lambda+2A_2(1+2\lambda)^2)-(1+\lambda)(-1-3\lambda+A_2(2+6\lambda+4\lambda^2))} \quad (17)$$

$$x_2 = \frac{(1-c)(1+\lambda)(-1+A_1-3\lambda+3A_1\lambda+2A_1\lambda^2)}{A_1(1+2\lambda)(-3-5\lambda+2A_2(1+2\lambda)^2)-(1+\lambda)(-1-3\lambda+A_2(2+6\lambda+4\lambda^2))} \quad (18)$$

For simplicity of calculation, we assume $A_1 = 1$, $c = 0$. Then we obtain the equilibriums:

$$q_1 = \frac{(1+2\lambda)(-1+(-3+2A_2)\lambda+4A_2\lambda^2)}{-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3} \quad (19)$$

$$q_2 = \frac{(1+2\lambda)(-1+\lambda+2A_2\lambda)}{-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3} \quad (20)$$

$$x_1 = \frac{(1+\lambda)(-1+(-3+2A_2)\lambda+4A_2\lambda^2)}{-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3} \quad (21)$$

$$x_2 = \frac{2\lambda^2(1+\lambda)}{-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3} \quad (22)$$

$$p = \frac{\lambda(-1+(-3+2A_2)\lambda+4A_2\lambda^2)}{-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3} \quad (23)$$

$$\pi_1 = \frac{\lambda(2+3\lambda)(-1+(-3+2A_2)\lambda+4A_2\lambda^2)^2}{(-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3)^2} \quad (24)$$

$$\pi_2 \frac{(\lambda(1+(2-4A_2)\lambda+(-3-12A_2+4A_2^2)\lambda^2+4(-1-A_2+4A_2^2)\lambda^3+4(1+2A_2+4A_2^2)\lambda^4-4A_2\lambda^5))}{(-2+(-7+4A_2)\lambda+7(-1+2A_2)\lambda^2+12A_2\lambda^3)^2} \quad (25)$$

To ensure all equilibriums to be positive, we find that $x_1 < x_2$ if $(1 + 3\lambda) / (2\lambda + 4\lambda^2) < A_2 < (1 + \lambda) / (2\lambda)$ and $x_2 < x_1$ if $A_2 > (1 + \lambda) / (2\lambda)$.

## 5 Conclusion

Our results show that the public firm's level of R&D is negatively correlated to the extent of privatization and research inefficiency. When the extent of privatization and the public firm's R&D inefficiency level is relatively low, the public firm engage in more R&D compared with the private firm, and vice versa. This theoretical analysis is a correspondence of the current situation of some Chinese industries such as information technology. And our results question the Chinese policy about the transition of the industry targeting for extensive privatization.

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