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Absorptive capacity and R&D strategy in mixed duopoly with labor-managed and profit-maximizing firms

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ABSTRACT

In a mixed duopoly with a labor-managed firm and a profit-maximizing firm coexisting, this paper explores the effect of technology absorptive capacity on firms' output decision, R&D investment decision and social welfare. Firstly, we develop a two-stage R&D game model on the basis of cost-reducing R&D with spillover and absorptive capacity. Secondly, we explore the strategic interactions of output, R&D investment and social welfare respectively in the mixed duopoly with a labor-managed and a profit-maximizing firms. Finally we analyze the effects of absorptive capacity on output decision, strategic investment decision and social welfare respectively. The research suggests that labor-managed firms employ less workers and produce less outputs while they invest more in R&D than that of profit-maximizing firms. Whether the effect of absorptive capacity increases R&D investment of labor-managed firms or not depends on the returns to scale. However, it bears no relationship to the returns to scale of the profit-maximizing firm.

1. Introduction

An important effect of R&D activity is the externalities or R&D spillovers from one firm to another. However, a firm cannot benefit from other firms' R&D spillovers as "the pie falling from the sky". Growing empirical evidence strongly supports that a firm's R&D will contribute to realizing spillovers from other firms' R&D efforts as well as enhancing its innovative ability. This is the second face of R&D, namely, absorptive capacity, deriving from its own R&D efforts as a measure of its ability to benefit from other firms' R&D activity (Cohen and Levinthal, 1989). There have been significant advances in absorptive capacity by using empirical and theoretical study, respectively. On empirical aspect, many firms in pharmaceutical industry must invest in R&D in the form of in-house basic research, "pro-publication" internal incentives and extensive connections to the wider scientific community so as to be able to benefit from publicly funded basic research (Cockburn and Henderson, 1998). And the empirical evidence with a sample of 461 Greek enterprises participating in the third Community Innovation Survey demonstrates that absorptive capacity are directly related to external R&D knowledge and contributes to firms' innovation (Kostopoulos et al., 2011). Moreover, the degree of absorptive capacity influences positively both external and internal acquisition types of technology over 250 Spanish engineering consulting firms (del Carmen Haro-Domínguez et al., 2007). On theoretical aspect, Cohen and Levinthal (1990) explored the notion and firstly set up a model to confirm that absorptive capacity does have a direct effect on R&D spending and will provide a positive incentive to conduct R&D. And Kamien and Zang (2000) set up a three-stage game in which the absorptive capacity is influenced by both its R&D approach and R&D budget, and explored how to choose a R&D approach and R&D budget. Grunfeld (2003) probed into how R&D investment decision is affected by spillovers with absorptive capacity. Wiethaus (2005) explored how the firms choose R&D approach with absorptive capacity effects and found that competing firms can also adopt identical R&D approach. Leahy and Neary (2007) specified a general model of the absorptive capacity process and showed that costly absorptive capacity both raises the effectiveness of its own R&D and lowers the effective spillover coefficient.

However, all these contributions focus on profit-maximizing firms (henceforth PM firms, or PMF). There still exist some firms in Yugoslavia, America, England, France, Germany, China, and Italy etc, which do not aim at maximizing profit, but striving to maximize share-per-worker, namely labor-managed firms (henceforth LM firms, or LMF). The LM firms range from all kinds of cooperatives, stock cooperative enterprises, and some enterprises derived from state-owned enterprise reform, such as Plywood cooperatives, Spanish Mondragon cooperation complex, Muraton e Comentisi, and Employee stock ownership plans.

The pioneering work on a theoretical model of a LMF was conducted by Ward (1958). Thereafter, many economists have studied the behaviors of LMF, especially the mixed duopoly with LMF and PMF coexisting. Horowitz (1991) explored the effects of Cournot competition between a LMF and a PMF and showed that both firms' optimal output are affected by fixed costs and staff wages, in conflict with the tenets of classical theory. Okuguchi (1993) formulated a Cournot mixed model between LMF and PMF coexisting, and proved

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the existence and global stability of the unique Cournot equilibrium for duopoly. Lambertini and Rossini (1998) examined a two-stage Cournot duopoly model with strategic R&D investment and showed that the LMF always over-invested comparing to the PMF. Ireland (2003) examined a price-setting mixed model and showed that the average prices of all firms increased with the number of LM firms, but the price of LMF was lower than PMF. There are many other excellent studies in the mixed duopoly, such as Law and Stewart (1983), Cremer and Crémer (1992), Delbono and Rossini (1992), Stewart (1992), and Lambertini (1998), Lambertini (2001), Luo (2012).

In the aspect of technical innovation of the labor-managed firms, Goel and Haruna (2007) analyzed the decisions of outputs and R&D investments in the Cournot competition between two LMFs. Furthermore, we analyze how R&D investment decisions are affected by R&D spillovers between LMF and PMF, considering that R&D investment improves absorptive capacity.

2. The model

The framework in our model of cost-reducing R&D with spillovers follows D'Aspremont and Jacquemin (1988) and Goel (Goel and Haruna, 2007). Here the PMF and LMF choose their R&D investment levels in the first stage, and play a regular Cournot game in output in the second stage. The sub-game perfect equilibrium output and R&D investment levels are identified by using backward induction.

Let us consider the competitive duopoly producing a heterogeneous product, and a well-behaved production function such that output is a function of labor only: $q=f(l)$, where $f'(l)>0$ and $f''(l)\le 0$. Note that these restrictions on the production function imply that the average labor productivity is greater than or the same as its marginal product (for example, with a production function of the form $f=l^{\xi}$). The output elasticity of employment $\varepsilon = lf'/f$. If the production function exhibits increasing-return-to-scale (IRTS), then $\varepsilon>1$. And $\varepsilon=1$ when the production function is constant-returns-to-scale (CRTS), while $\varepsilon<1$ in decreasing-return-to-scale (DRTS). Based on the hypothesis of Bárcena-Ruiz and Espinosa, the product' market price p_i ($i=$L,P) is defined by the liner inverse demand function:

$$\begin{cases} p_P = a - f_P - df_L \\ p_L = a - f_L - df_P \end{cases} \tag{1}$$

where parameter a indicts market demand, and d denotes cross-price effects. We assume that products of the two firms are substitute so that $1\le d<0$.

The revenue of R&D investment of the ith firm is denoted by x_i ($i=$ L,P). R&D costs are given by $u_i(x_i)$, such that $u_i'(x_i)>0$ and $u_i''(x_i)>0$.

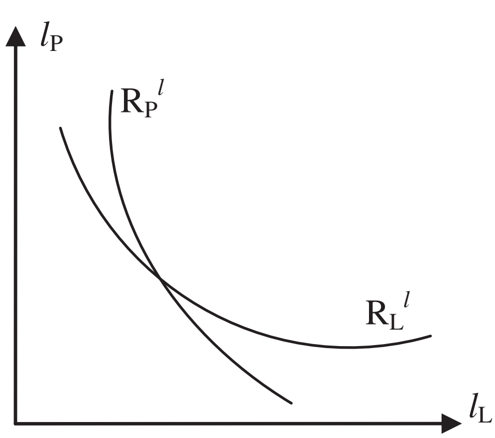

Fig. 1. Reaction curves of output with the LMF's production function being IRTS.

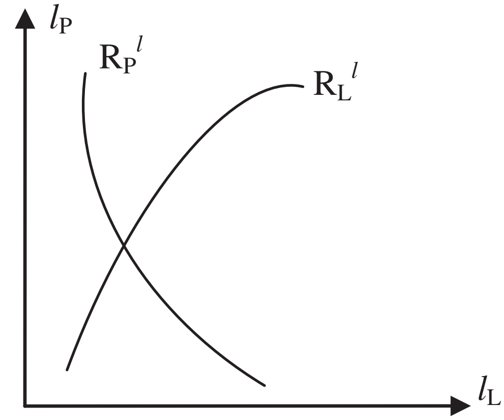

Fig. 2. Reaction curves of output with the LMF's production function being DRTS.

And the unit cost function has the following form,

$$\begin{cases} g_P(x_P, x_L) = c - x_P - \theta_P(x_P)x_L & 0 \le \theta_P(x_P) \le 1 \\ g_L(x_P, x_L) = c - x_L - \theta_L(x_L)x_P & 0 \le \theta_L(x_L) \le 1 \end{cases} \tag{2}$$

where c is the initial unit cost component. θ_i describes the proportion of R&D that spills over from firm j to firm i, contributing to a cost reduction. In the AJ approach (D'Aspremont and Jacquemin, 1988), this variable is treated as a linear exogenous parameter, namely, $\theta(x)=\beta$. Here, it is a function of its own R&D investment level.

Based on the Ward model (Ward, 1958), the LMF dedicates itself to maximizing share-per-worker by choosing R&D and output, while the objective of PMF is to maximize firm's total profits. Given this set, a LMF and a PMF choose R&D investments and employments (output) to maximize their objective respectively:

$$\begin{cases} \max\limits_{x_P, l_P} \pi_P = [p_P - g_P(x_P, x_L)]f_P(l_P) - w_P l_P - u_P(x_P) \\ \max\limits_{x_L, l_L} V_L = \dfrac{\pi_L}{l_L} + w_L = \dfrac{[p_L - g_L(x_P, x_L)]f_L(l_L) - u_L(x_L)}{l_L} \end{cases} \tag{3}$$

where w_i is the staff wages of the ith firm. And Eq. (3) can be reformulated Based on Eqs. (1)–(2) as follows:

$$\begin{cases} \max\limits_{x_P, l_P} \pi_P = [a - c - f_P - df_L + x_P + \theta_P(x_P)x_L)]f_P(l_P) - w_P l_P - u_P(x_P) \\ \max\limits_{x_L, l_L} V_L = \dfrac{\pi_L}{l_L} + w_L = \dfrac{[a - c - f_L - df_P + x_L + \theta_L(x_L)x_P)]f_L(l_L) - u_L(x_L)}{l_L} \end{cases} \tag{4}$$

The first-order conditions for optimal employment can be given by

$$\begin{cases} G_P = \dfrac{\partial \pi_P}{\partial l_P} = [a - c - 2f_P - df_L + x_P + \theta_P(x_P)x_L]f_P' - w_P = 0 \\ G_L = \dfrac{\partial V_L}{\partial l_L} = \dfrac{[a - c - 2f_L - df_P + x_L + \theta_L(x_L)x_P]f_L' - V_L}{l_L} = 0 \end{cases} \tag{5}$$

The PMF's marginal revenue $MR_P=(a\text{-}c\text{-}2f_P\text{-}df_L+x_P+\theta_P(x_P)f_P'$, and its marginal cost $MC_P=w_P$. While the LMF's marginal revenue $MR_L=(a\text{-}c\text{-}2f_L\text{-}df_P+x_L+\theta_L x_P)f_L'$, and its marginal cost $MC_L=V_L$. In particular, for LMF, MR_L can be explained as LMF's Competition Effect against PMF, and MC_L as Labor Effect of LMF. If the LMF strives to maximize its total profit, the Labor Effect will be switched to the fixed wage w_P, namely the LMF will convert to the traditional PMF.

Therefore, the stationary point in Eq. (5) is the equilibrium employment in Cournot, namely, $(l_P^*, l_L^*) = [l_L(x_P^*, x_L^*), l_L(x_P^*, x_L^*)]$. And the corresponding output $(f_P^*, f_L^*) = [f_P(l_P^*), f_L(l_L^*)]$. The corresponding price $(p_P^*, p_L^*) = (a - f_P^* - df_L^*, a - f_L^* - df_P^*)$.