Finnish Economic Papers – Volume 22 – Number 2 – Autumn 2009

STRATEGIC COMMITMENT AND THREE-STAGE GAMES WITH LABOR-MANAGED AND PROFIT-MAXIMIZING FIRMS*

KAZUHIRO OHNISHI

Osaka University, Tsugaryo 102, Hanjo 2-15-12, Minoo, Osaka, 562-0044, Japan; email: ohnishi@e.people.or.jp

This paper examines two three-stage games with a labor-managed income-per-worker-maximizing firm and a profit-maximizing firm. In the first stage, the labor-managed firm (resp. the profit-maximizing firm) decides whether to make a commitment to capacity. In the second stage, the other firm decides on a commitment to capacity. In the third stage, both firms non-cooperatively choose quantities. The paper shows the equilibrium outcomes of the two three-stage games. The paper then finds that the introduction of capacity commitment into the analysis of three-stage mixed market games is profitable for the labor-managed firm while it is not profitable for the profit-maximizing firm. (JEL: C72, D21, L20)

1. Introduction

The possibility of firms using excess capacity as a strategic instrument in duopolistic competition has been examined by many economists.[1] For example, this idea is presented in a two-stage model by Dixit (1980) and is extended to a three-stage model by Ware (1984). Dixit shows that an incumbent installing excess capacity in the first stage is able to deter a potential entrant in the second stage. Ware examines the three-stage model in which an incumbent installs capacity in the first stage, an entrant installs capacity in the second stage, and a quantity equilibrium is established in the third stage. He concludes that although his three-stage equilibrium is qualitatively similar to Dixit's two-stage equilibrium, it differs in that the strategic advantage available to the first mover is lessened. Furthermore, Poddar (2003) examines a two-stage model of strategic entry deterrence (*a la* Dixit 1980) under demand uncertainty and shows that to improve its strategic position in the product market competition an incumbent will choose a level of capacity that may remain idle in a low state of demand.

We study the behavior of labor-managed and profit-maximizing capitalist firms. Labor-managed firms have existed in Western economies since the advent of the factory system. The oldest surviving labor-managed firms in the United Kingdom and Italy appeared in the nineteenth century (Bonin, Jones, and Putterman, 1993). Furthermore, after the Second World War, the right to manage a firm in the former Yugoslavia was, within the limits determined by law, in the

* *The author would like to thank Andreas Wagener (the co-editor) and an anonymous referee for helpful comments and suggestions on earlier drafts of this paper.*

[1] *See Tirole (1988) and Gilbert (1989) for excellent surveys of strategic capacity investment.*

hands of its employees (Furubotn and Pejovich, 1970).

The labor-managed firm in all Western European countries grew significantly between the early 1970s and the early 1980s, for example, from 4,370 firms in 1970 to 11,203 in 1982 in Italy and from 522 to 933 firms in France over the same period. Furthermore, in the United Kingdom the number of labor-managed firms rose by almost 1,000% and employment by 133% between 1976 and 1981 (Estrin, 1985). In the United States, the most notable presence of labor-managed firms is in the plywood industry in the Pacific Northwest where they have been in existence since 1921, and during the 1950s, they contributed as much as 25 percent of the industry's total output (Bonin, Jones, and Putterman, 1993). In China, the market-oriented economic reform has given much greater autonomy to state and collective enterprises' managers to make production, investment and marketing decisions. Meng and Perkins (1998) find that the state and the collective sectors behave like labor-managed firms in their wage determination, while private-sector firms behave more like profit-maximizing firms.

Furthermore, the investment behavior of labor-managed firms has been empirically examined. For example, Berman and Berman (1989) examine marginal productivity in labor-managed and capitalist firms in the plywood industry of the United States and find that labor-managed firms fully exploit their capital stock while capitalist firms tend to be inefficiently overcapitalized. Bartlett et al. (1992) examine a sample of labor-managed and profit-maximizing firms in Italy and find that the labor-managed firms have a significantly lower ratio of fixed assets per head than the profit-maximizing firms. Podivinsky and Stewart (2007) examine a panel on the entry of labor-managed firms into UK manufacturing industries between 1981 and 1985 and find that there is a significant negative relationship between entry counts and the capital-labor ratio. Estrin and Jones (1998) test the view that labor-managed firms will invest less (underinvestment hypothesis) by using data on more than 300 French labor-managed firms from 1970–1979 and find no strong empirical support for the underinvestment hypothesis. Maietta and Sena (2008) test the underinvestment hypothesis by comparing the shadow price of capital and the capacity utilization indexes for a panel of Italian labor-managed and conventional firms over the period of 1996–2003 and find that the results do not support the underinvestment hypothesis. In addition, the underinvestment hypothesis has been widely studied in the empirical literature. Many empirical studies contain no econometric support for the underinvestment hypothesis.

In recent years, economic market models that incorporate labor-managed firms have been widely analyzed by many economists. The behavior of labor-managed firms is frequently encountered in the literature on economic theory. The pioneering work on a theoretical model of a labor-managed firm was conducted by Ward (1958). Thereafter, many economists have studied the behavior of labor-managed firms.[2] For example, Furubotn and Pejovich (1970) develop a theory of the labor-managed firm that takes into account the characteristic property rights structure and explain the pattern of behavior imposed on decision makers by this structure. Furubotn and Pejovich show that members of a labor-managed firm do not have an incentive to invest in capital equipment as they may not appropriate the increase in value of their ownership share following the investment when they decide to leave the labor-managed firm. Vanek (1977) shows a disincentive to finance capital with internal funds if workers do not have individual and transferable ownership rights in the firm's assets. The property rights approach indicates that labor-managed firms invest less in physical capital than profit-maximizing firms. Bonin, Jones, and Putterman (1993) state that the property rights approach predicts underinvestment in labor-managed firms relying on self-financing, but the empirical literature contains no economic support for this underinvestment hypothesis. Bonin, Jones, and Putterman point out that the property rights approach does not use the appropriate measure for labor-managed and conventional firms

[2] *See Ireland and Law (1982), Stephan (1982), Bonin and Putterman (1987), and Putterman (2008) for excellent surveys of labor-managed firms.*

(modeling problem). Tortia (2005) shows that the presence of underinvestment is due to a specific form of reinvestment, i.e., the reinvestment of self-financed capital funds in indivisible reserves.

Furthermore, Zhang (1993) and Haruna (1996) apply Dixit (1980) and Bulow, Geanakoplos, and Klemperer (1985a) frameworks of entry deterrence to labor-managed industries and show that labor-managed incumbents have greater incentive to hold excess capacity to deter entry than corresponding profit-maximizing incumbents. Goel and Haruna (2007) use a two-stage duopoly model of cost-reducing R&D investment with spillovers and examine different interactions between labor-managed firms. Goel and Haruna show that the effects of changes in research spillovers on employment (output) depend on the nature of the underlying production technology.

The following studies consider the strategic investment decisions in mixed market models with labor-managed and profit-maximizing firms. Stewart (1991) explores strategic entry interactions between profit-maximizing and labor-managed firms using a framework suggested by Dixit (1980) and shows that a labor-managed potential entrant is more likely to be accommodated into the industry than a profit-maximizing potential entrant. However, he considers the use of excess capacity to deter entry and examines mixed competition in which a labor-managed or profit-maximizing incumbent unilaterally chooses its pre-entry capacity level.

Futagami and Okamura (1996) examine a three-stage duopoly model in which a labor-managed firm and a profit-maximizing firm use investments as strategic variables and commit to investment levels and show that the labor-managed firm invests more capital and produces more than the profit-maximizing firm does. Neary and Ulph (1997) examine the relative profitability of profit-maximizing and labor-managed firms in a mixed duopoly equilibrium with strategic investment and show that there is no point in the wage/fixed-cost parameter set at which the two firms in a mixed equilibrium can simultaneously make zero profits. Furthermore, Lambertini and Rossini (1998) examine the behavior of labor-managed and profit-maximizing firms in a Cournot duopoly with capital strategic interaction and show that the labor-managed firm tends to over-invest while the opposite holds true for the profit-maximizing firm irrespective of the capital rental price. Each study examines mixed competition in which labor-managed and profit-maximizing firms simultaneously choose their capacity levels.

The problem with simultaneous capacity choice lies in the nature of strategic behavior. A firm may intend to adopt strategic behavior earlier than its rival. That is, it is thought that sequential capacity choice is an important element of the competition between firms. However, this analysis has been ignored in capacity choice competition with labor-managed and profit-maximizing firms. Therefore, we examine sequential capacity choice competition with a labor-managed income-per-worker-maximizing firm and a profit-maximizing firm. We consider two three-stage games. The first game runs as follows. In the first stage, the labor-managed firm decides whether to install capacity that cannot subsequently be reduced. At the end of the first stage, the profit-maximizing firm observes the behavior of the labor-managed firm. In the second stage, the profit-maximizing firm decides whether to install capacity that cannot subsequently be reduced. At the end of the second stage, the labor-managed firm observes the behavior of the profit-maximizing firm. In the third stage, both firms simultaneously and independently choose and sell quantities. The structure of the second game is nearly identical and differs only in the order in which the firms decide on the installation of capacity in the first two stages. If a firm produces within the limit of the capacity it has installed, then its marginal cost decreases because its capacity cost is sunk as a fixed cost. On the other hand, if it wishes to raise output above the capacity level in the third stage, then it must acquire additional capacity in the third stage and incurs the full marginal cost of producing any given quantity. That is, if capacity is expended as a flow simultaneously with production, then its cost is not sunk. We discuss the equilibrium outcomes of the two three-stage mixed games.

Our purpose is to analyze two three-stage games where a labor-managed income-per-worker-maximizing firm and a profit-maximizing firm can sequentially precommit to capacity levels before competing in quantities and to show the equilibrium outcomes of the three-stage games. We find that there exists an equilibrium that coincides with the Stackelberg solution where the labor-managed firm is the leader even in the game with the profit-maximizing firm moving first and the labor-managed firm moving second.

This paper is organized as follows. In Section 2, the basic model of the paper is presented. Section 3 derives both firms' reaction functions in quantities. Section 4 discusses the equilibrium outcomes of the model. Section 5 concludes the paper.

2. The Basic Model

The basic structure is from Dixit (1980) and Stewart (1991). We consider mixed duopoly competition with one labor-managed income-per-worker-maximizing firm (firm L) and one profit-maximizing firm (firm P), producing perfectly substitutable goods. For the remainder of this paper, when i and j are used to refer to firms in an expression, they should be understood to refer to L and P with $i \neq j$. There is no possibility of entry or exit. The market price is determined by the inverse demand function $p(Q)$, where $Q = q_L + q_P$. The subscripts L and P denote firm L and firm P, respectively. We assume that and $p' < 0$ and $p'' \leq 0$. The three stages run as follows. In the first stage, firm i decides whether to install capacity $k_i > 0$ that cannot subsequently be reduced. At the end of the first stage, firm j observes the behavior of firm i. In the second stage, firm j decides whether to install capacity $k_j > 0$ that cannot subsequently be reduced. At the end of the second stage, firm i observes the behavior of firm j. In the third stage, both firms simultaneously and independently choose and sell quantities $q_L \geq 0$ and $q_P \geq 0$.

Following Stewart (1991), firm L's income per worker is given by

$$(1)\quad \omega_L = \begin{cases} \dfrac{p(Q)q_L - rk_L - f}{l_L(q_L)} & \text{if } q_L \leq k_L, \\[2ex] \dfrac{p(Q)q_L - rq_L - f}{l_L(q_L)} & \text{if } q_L > k_L, \end{cases}$$

where $r > 0$ denotes the unit cost of capacity, $f > 0$ the fixed cost, and l_L the amount of labor in firm L. If firm L produces output q_L within the limit of the capacity it has installed (i.e., $q_L \leq k_L$), then its marginal capacity cost becomes zero because its capacity cost is sunk as a fixed cost. On the other hand, if firm L wishes to produce $q_L > k_L$ in the third stage, then it must acquire additional capacity to match its output in the third stage, and its marginal capacity cost rises to r.

Furthermore, following Dixit (1980) and Stewart (1991), firm P's profit is given by

$$(2)\quad \pi_P = \begin{cases} p(Q)q_P - rk_P - wl_P(q_P) - f & \text{if } q_P \leq k_P, \\ p(Q)q_P - rq_P - wl_P(q_P) - f & \text{if } q_P > k_P, \end{cases}$$

where $w > 0$ denotes the wage rate and l_P the amount of labor in firm P. If firm P produces output q_P within the limit of the capacity it has installed (i.e., $q_P \leq k_P$), then its marginal cost amounts to wl_P' because its capacity cost is sunk as a fixed cost. On the other hand, if firm P wishes to produce $q_P > k_P$ in the third stage, then it must acquire additional capacity to match its output in the third stage, and its marginal cost rises to $r + wl_P'$. That is, if capacity is expended as a flow simultaneously with production, then its cost is not sunk. Thus, each firm's marginal cost exhibits a discontinuity at $q_i = k_i$.

We assume that $l_i' > 0$ and $l_i'' > 0$. This assumption means that the marginal quantity of labor used is increasing. We use subgame perfection as an equilibrium concept. The fact that inverse demand is defined only for non-negative outputs ensures that all outputs obtained in equilibrium are non-negative.

3. Reaction Functions

In this section, we derive both firms' reaction functions in quantities. Stewart (1991) shows capacity reaction functions with linear demand. First, we derive firm L's best reaction function from (1). If firm L does not install k_L, then its reaction function is defined by

$$(3)\quad R_L(q_P) = \arg\max_{q_L}\left[\frac{p(Q)q_L - rq_L - f}{l_L(q_L)}\right],$$

and if firm L installs k_L and reduces its marginal cost, then its reaction function is defined by

$$(4)\quad R_L^r(q_P) = \arg\max_{q_L}\left[\frac{p(Q)q_L - rk_L - f}{l_L(q_L)}\right].$$

Therefore, if firm L installs k_L, then its best response is shown as follows:

$$(5)\quad R_L^k(q_P) = \begin{cases} R_L(q_P) & \text{if } q_L > k_L, \\ k_L & \text{if } q_L = k_L, \\ R_L^r(q_P) & \text{if } q_L < k_L. \end{cases}$$

The equilibrium occurs where each firm maximizes its objective with respect to its own output level, given the output level of its rival. Firm L aims to maximize its income per worker with respect to its own output level, given the output level of firm P. The equilibrium must satisfy the following conditions: If firm L does not install k_L, then the first-order condition is

$$(6)\quad (p'q_L + p - r)l_L - (pq_L - rq_L - f)l_L' = 0,$$

and the second-order condition is

$$(7)\quad (p''q_L + 2p')l_L - (pq_L - rq_L - f)l_L'' < 0.$$

If firm L installs and reduces its marginal cost, then the first-order condition is

$$(8)\quad (p'q_L + p)l_L - (pq_L - rk_L - f)l_L' = 0,$$

and the second-order condition is

$$(9)\quad (p''q_L + 2p')l_L - (pq_L - rk_L - f)l_L'' < 0.$$

Furthermore, we have

$$(10)\quad R_L'(q_P) = -\frac{p''q_L l_L + p'(l_L - q_L l_L')}{(p''q_L + 2p')l_L - (pq_L - rq_L - f)l_L''}$$

and

$$(11)\quad R_L^{r}{}'(q_P) = -\frac{p''q_L l_L + p'(l_L - q_L l_L')}{(p''q_J + 2p')l_L - (pq_L - rk_L - f)l_L''}.$$

Since $l_L'' > 0$, $l_L - q_L l_L' < 0$, so that $p''q_L l_L + p'(l_L - q_L l_L')$ is positive; that is, both $R_L(q_P)$ and $R_L'(q_P)$ are upward sloping. This means that firm L treats quantities as strategic complements. The concepts of strategic complements and substitutes were introduced by Bulow, Geanakoplos, and Klemperer (1985b). Stewart (1991) states that with linear demand, diminishing returns to labor produce a positive slope whereas increasing returns to labor generate a negative slope.[3]

Second, we derive firm P's best reaction function from (2). If Firm P does not install k_P, then its reaction function is defined by

$$(12)\quad R_P(q_L) = \arg\max_{q_P}[p(Q)q_P - rq_P - wl_P(q_P) - f],$$

and if firm P installs and reduces its marginal cost, then its reaction function is defined by

$$(13)\quad R_P^r(q_L) = \arg\max_{q_P}[p(Q)q_P - rk_P - wl_P(q_P) - f].$$

Therefore, if firm P installs k_P, then its best reaction function is shown as follows:

$$(14)\quad R_P^k(q_L) = \begin{cases} R_P(q_L) & \text{if } q_P > k_P, \\ k_P & \text{if } q_P = k_P, \\ R_P^r(q_L) & \text{if } q_P < k_P. \end{cases}$$

Firm P aims to maximize its profit with respect to its own output level, given the output level of firm L. The equilibrium must satisfy the following conditions: If firm P does not install k_P, then the first-order condition is

$$(15)\quad p'q_P + p - r - wl_P' = 0,$$

and the second-order condition is

$$(16)\quad p''q_P + 2p' - wl_P'' < 0.$$

[3] *See also Ireland and Law (1982), Delbono and Rossini (1992), Futagami and Okamura (1996), and Lambertini and Rossini (1998).*

If firm P installs k_P and reduces its marginal cost, then the first-order condition is

(17) $p'q_P + p - wl_P' = 0,$

and the second-order condition is

(18) $p''q_P + 2p' - wl_P'' < 0.$

Furthermore, we have

(19) $$R_P'(q_L) = R_P^{r}{}'(q_L) = -\frac{p''q_P + p'}{p''q_P + 2p' - wl_P''}.$$

Hence, both $R_P(q_L)$ and $R_P'(q_L)$ are downward sloping. This means that firm P treats quantities as strategic substitutes. Dixit (1980) suggests that the best reaction function creates kinks at the capacity level installed prior to production.

Third, we state the Cournot Nash equilibrium of the mixed market model. Firms L and P select their own outputs simultaneously and independently. Firm L maximizes its income per worker with respect to q_L, given q_P, while firm P maximizes its profit with respect to q_P, given q_L. The Cournot Nash equilibrium is a pair (q_L^n, q_P^n) of output levels and is derived from $q_L^n \in R_L^k(q_P^n)$ and $q_P^n \in R_P^k(q_L^n)$. From (5), (10) and (11), we see that the optimal output q_L^* is nondecreasing in q_P. Furthermore, from (14) and (19), we see that the optimal output q_P^* is nonincreasing in q_L. Hence, the existence and the uniqueness of the Cournot Nash equilibrium are guaranteed.

4. *Equilibrium Outcomes*

In this section, we begin by presenting the following two lemmas.

Lemma 1 If firm i installs capacity k_i and an equilibrium is achieved, then in equilibrium $q_i = k_i$.

Proof First, we prove that if firm L installs k_L, then in equilibrium $q_L = k_L$. Consider the possibility that $q_L < k_L$ in equilibrium. From (1), if $q_L < k_L$, firm L installs extra capacity. That is, firm L can increase its income per worker by reducing k_L, and the equilibrium point does not change in $q_L \le k_L$. Hence, $q_L < k_L$ does not result in an equilibrium.

Consider the possibility that $q_L > k_L$ in equilibrium. From (1), we see that firm L has to incur the marginal capacity cost of producing any given quantity. It is impossible for firm L to change its output in equilibrium because such a strategy is not credible. That is, if $q_L > k_L$, capacity investment does not function as a strategic commitment.

Next, we prove that if firm P installs k_P, then in equilibrium $q_P = k_P$. Consider the possibility that $q_P < k_P$ in equilibrium. From (2), if $q_P < k_P$, firm P installs extra capacity. That is, firm P can increase its profit by reducing k_P, and the equilibrium point does not change in $q_P \le k_P$. Hence, $q_P < k_P$ does not result in an equilibrium.

Consider the possibility that $q_P > k_P$ in equilibrium. From (2), we see that firm P has to incur the full marginal costs of producing any given quantity. It is impossible for firm P to change its output in equilibrium because such a strategy is not credible. That is, if $q_P > k_P$, capacity investment does not function as a strategic commitment. Q.E.D.

Lemma 2 Firm ’s optimal output is higher when it installs k_i than when it does not.

Proof First, we prove that firm L’s income-per-worker-maximizing output is higher when it installs k_L than when it does not. If firm L does not install k_L, then the first-order condition is (6), and if firm L installs k_L and reduces its marginal cost, then the first-order condition is (8). Here, r is positive. Furthermore, Lemma 1 shows that if firm L installs k_L and maximizes its income per worker, then $q_L = k_L$. To satisfy (6), $(p'q_L + p)l_L - (pq_L - rq_L - f)l_L'$ must be positive. Thus, firm L’s optimal output is higher when it installs k_L than when it does not.

Next, we prove that firm P’s profit-maximizing output is higher when it installs k_P than when it does not. If firm P does not install k_P, then the first-order condition is (15), and if firm P installs k_P and reduces its marginal cost, then the first-order condition is (17). Here, r is positive. To satisfy (15), $p'q_P + p - wl_P'$ must be positive. Thus, firm P’s optimal output is higher when it installs k_P than when it does not. Q.E.D.

These lemmas provide characterizations of capacity investment as a strategic commitment. Lemma 1 means that in equilibrium firm *i* does not install extra capacity. Lemma 2 means that if firm *i* installs capacity in advance of production, then its optimal output increases.

For the remainder of this section, we discuss the equilibrium outcomes of two three-stage games.

Game 1

In this game, first firm L moves, then firm P observes firm L's move, and subsequently firm P moves. That is, the three stages of the game run as follows. In the first stage, firm L decides whether to install capacity that cannot subsequently be reduced. At the end of the first stage, firm P observes the behavior of firm L. In the second stage, firm P decides whether to install capacity that cannot subsequently be reduced. At the end of the second stage, firm L observes the behavior of firm P. In the third stage, the firms simultaneously and independently choose quantities, and both firm L's income per worker and firm P's profit are decided. The equilibrium outcome can be stated as follows.

Proposition 1 In the three-stage capacity choice game with firm L moving first and firm P moving second, there exists an equilibrium where: (i) firm L installs capacity in the first stage, (ii) firm P does not install capacity in the second stage, (iii) the equilibrium solution occurs at the Stackelberg point with firm L leading and firm P following, (iv) firm L's income per worker is higher than in the Cournot equilibrium with no capacity installed, and (v) firm P's profit is lower than in the Cournot equilibrium with no capacity installed.

Proof See Appendix.

Proposition 1 means that capacity investment is an effective strategy only for firm L in Game 1. The intuition behind Proposition 1 is as follows. In the first stage, if firm L installs capacity, then its marginal cost decreases and thus it increases its output (Lemma 2). Given the output level of firm P, increasing firm L's output increases the total market output and lowers the market price. Hence, firm P's profit decreases. Furthermore, firm P decreases its output because of strategic substitutes. Firm L's capacity investment increases its income per worker. Therefore, firm L installs capacity in the first stage. In the second stage, if firm P installs capacity, then its marginal cost decreases and thus it increases its output (Lemma 2). Given the output level of firm L, increasing firm P's output increases the total market output and lowers the market price. From (5), (10) and (11), we see that increasing firm P's output never decreases firm L's output. Even though firm L's output is constant, both firm L's income per worker and firm P's profit decrease. If firm L increases its optimal output because of strategic complements, then firm P's profit decreases further, and thus firm P does not install capacity in the second stage.

Game 2

In this game, firm P moves first intertemporally. That is, the three stages of the game run as follows. In the first stage, firm P decides whether to install capacity that cannot subsequently be reduced. At the end of the first stage, firm L observes the behavior of firm P. In the second stage, firm L decides whether to install capacity that cannot subsequently be reduced. At the end of the second stage, firm P observes the behavior of firm L. In the third stage, the firms simultaneously and independently choose quantities, and both firm L's income per worker and firm P's profit are decided. The equilibrium outcome can be stated as follows.

Proposition 2 In the three-stage capacity choice game with firm P moving first and firm L moving second, there exists an equilibrium where: (i) firm P does not install capacity in the first stage, (ii) firm L installs capacity in the second stage, (iii) the equilibrium solution occurs at the Stackelberg point with firm L leading and firm P following, (iv) firm L's income per worker is higher than in the Cournot equilibrium with no capacity installed, and (v) firm P's profit is lower than in the Cournot equilibrium with no capacity installed.

Proof See Appendix.

Proposition 2 means that capacity investment is an effective strategy only for firm L even in Game 2. The intuition behind Proposition 2 is as follows. In the first stage, if firm P installs capacity, then its marginal cost decreases and thus it increases its output (Lemma 2). Given the output level of firm L, increasing firm P's output increases the total market output and lowers the market price. Furthermore, firm L increases its output because of strategic complements. Given the output level of firm P, increasing firm L's output increases the total market output and lowers the market price. Both firm L's income per worker and firm P's profit decrease. Hence, firm P does not install capacity in the first stage. In the second stage, if firm L installs capacity, then its marginal cost decreases and thus it increases its output (Lemma 2). Given the output level of firm P, increasing firm L's output increases the total market output and lowers the market price. Hence, firm P's profit decreases. Furthermore, firm P decreases its output because of strategic substitutes. Firm L's capacity investment increases its income per worker. Therefore, firm L installs capacity in the second stage. Since firm P does not install capacity, firm L chooses capacity corresponding to its Stackelberg leader solution. That is, the equilibrium of Game 2 coincides with that of Game 1. Consequently, we see that the introduction of capacity investment into the analysis of three-stage mixed market games is profitable for firm L while it is not profitable for firm P.[4]

[4] *The advantage of being a first-mover in profit-maximizing quantity competition is very well known. We briefly examine the analysis for mixed competition with sequential output choice and compare its equilibrium outcome with that of sequential capacity choice competition. There are a profit-maximizing firm (firm P) and a labor-managed firm (firm L). In the first stage of the game, firm P chooses an output level. At the end of the first stage, firm L observes the behavior of firm P. In the second stage, firm L chooses an output level.*

Firm L moving second will choose an output along its reaction function. Firm P moving first is aware that its output choice influences that of firm L. Therefore, in the first stage, firm P picks the output level that maximizes its profit in the reaction function of firm L. In the second stage, firm L responds by picking the expected output level. Thus, it is clear that the equilibrium of the sequential output choice game coincides with the Stackelberg solution where firm P is the leader. In the equilibrium, firm P's profit and firm L's income per worker both are higher than in the Cournot equilibrium because of the upward-sloping reaction function of firm L as shown in Section 3. This result differs notably from that of the sequential capacity choice competition shown in Proposition 2.

5. Concluding Remarks

We have examined two three-stage games, where a labor-managed income-per-worker-maximizing firm and a profit-maximizing firm can make a commitment to capacity. First, we have examined the three-stage game with the labor-managed firm moving first and the profit-maximizing firm moving second and have shown that there is an equilibrium in which the labor-managed firm installs capacity in the first stage and the profit-maximizing firm does not install capacity in the second stage. Second, we have examined the three-stage game with the profit-maximizing firm moving first and the labor-managed firm moving second and have shown that there is an equilibrium in which the profit-maximizing firm does not install capacity in the first stage and the labor-managed firm installs capacity in the second stage. We have found that there exists an equilibrium that coincides with the Stackelberg solution where the labor-managed firm leads and the profit-maximizing firm follows even in the game with the profit-maximizing firm moving first and the labor-managed firm moving second. Furthermore, we have found that the introduction of capacity investment into the analysis of three-stage mixed competition is profitable for the labor-managed firm while it is not profitable for the profit-maximizing firm. The results of this study indicate that labor-managed firms should act more aggressively against profit-maximizing firms.

The property rights approach originating with the work of Furubotn and Pejovich (1970) and Vanek (1977) shows a disincentive to finance capital with internal funds if workers do not have individual and transferable ownership rights in the firm's assets and indicates that labor-managed firms invest less in physical capital than profit-maximizing firms. The underinvestment hypothesis has been widely studied in the empirical literature, such as Jones and Backus (1977), Zevi (1982), Berman and Berman (1989), Bartlett et al. (1992), Estrin and Jones (1998), and Maietta and Sena (2008). Many empirical studies contain no econometric support for the underinvestment hypothesis. Bonin, Jones, and Putterman (1993) state that the property rights approach predicts underinvestment in labor-managed firms relying on self-financing but it does not use the appropriate measure for labor-managed and conventional firms (modeling problem). In the real world, labor-managed and profit-maximizing firms do not always simultaneously choose their capacity levels. A labor-managed firm may be able to play the role of Stackelberg leader, or a profit-maximizing firm may be able to do so. In both cases, the results of this study agree with many empirical findings.

Stewart (1991) considers the use of capacity precommitment by incumbents to deter entry. He analyzes strategic entry interactions between profit-maximizing and labor-managed firms and shows that a labor-managed potential entrant is more likely to be accommodated into the industry than a profit-maximizing potential entrant. Futagami and Okamura (1996) examine simultaneous capital choice competition with a labor-managed firm and a profit-maximizing firm and show that the labor-managed firm invests more capital and produces more than the profit-maximizing firm does. Lambertini and Rossini (1998) examine the behavior of labor-managed and profit-maximizing firms in a Cournot duopoly with capital strategic interaction and show that the labor-managed firm over-invests while the profit-maximizing firm under-invests. We have examined sequential capacity choice competition with a labor-managed firm and a profit-maximizing firm and have found that the labor-managed firm unilaterally installs capacity even in the game with the profit-maximizing firm moving first and the labor-managed firm moving second. These theoretical studies show that the labor-managed firm can enter the market more easily than the profit-maximizing firm does and even after entry the labor-managed firm is not attacked as much. That is, it can be said that although many of the firms that exist in the real world are profit-maximizing firms, there is a large possibility that labor-managed firms will increase in the future.

References

Bartlett, W., J. Cable, S. Estrin, D. Jones, and S. Smith (1992). "Labor-managed Cooperatives and Private Firms in North Central Italy: An Empirical Comparison." *Industrial and Labor Relations Review* 46, 103–118.

Ben-Ner, A. (1988). "The Life Cycle of Worker-owned Firms in Market Economies: A Theoretical Analysis." *Journal of Economic Behavior and Organization* 10, 287–313.

Berman, K.V., and M.D. Berman (1989). "An Empirical Test of the Theory of the Labor-managed Firm." *Journal of Comparative Economics* 13, 281–300.

Bonin, J.P., D.C. Jones, and L. Putterman (1993). "Theoretical and Empirical Studies of Producer Cooperatives: Will Ever the Twain Meet?" *Journal of Economic Literature* 31, 1290–1320.

Bonin, J.P., and L. Putterman (1987). *Economics of Cooperation and the Labor-managed Economy.* Chur, Switzerland: Harwood Academic Publisher.

Bulow, J., J. Geanakoplos, and P. Klemperer (1985a). "Holding Idle Capacity to Deter Entry." *Economic Journal* 95, 178–182.

Bulow, J., J. Geanakoplos, and P. Klemperer (1985b). "Multimarket Oligopoly: Strategic Substitutes and Complements." *Journal of Political Economy* 93, 488–511.

Cooper, T.E. (1986). "Most-favored-customer Pricing and Tacit Collusion." *Rand Journal of Economics* 17, 377–388.

Craig, B., and J. Pencavel (1992). "The Behavior of Worker Cooperatives: The Plywood Companies of the Pacific Northwest." *American Economic Review* 82, 1083–1105.

Delbono, F., and G. Rossini (1992). Competition Policy vs Horizontal Merger with Public, Entrepreneurial, and Labor-managed Firms." *Journal of Comparative Economics* 16, 226–240.

Dixit, A.K. (1980). "The Role of Investment in Entry-deterrence." *Economic Journal* 90, 95–106.

Estrin, S. (1985). "The Role of Producer Co-operatives in Employment Creation." *Economic Analysis and Workers' Management* 19, 345–384.

Estrin, S., and D.C. Jones (1998). "The Determinants of Investment in Employee Owned Firms: Evidence from France." *Economic Analysis* 1, 17–28.

Estrin, S., D.C. Jones, and J. Svejnar (1987). "The Productivity Effects of Worker Participation: Producer Cooperative in Western Economies." *Journal of Comparative Economics* 11, 40–61.

Furubotn, E. G., and S. Pejovich (1970). "Property Rights and the Behavior of the Firm in a Social State: The Example of Yugoslavia." *Zeitschrift für Nationalökonomie* 30, 431–454.

Futagami, K., and M. Okamura (1996). "Strategic Investment: The Labor-managed Firm and the Profit-maximizing Firm." *Journal of Comparative Economics* 23, 73–91.

Gilbert, R. J. (1989). "Mobility Barriers and the Value of Incumbency." In *Handbook of Industrial Organization.* Vol. 1, 475–535. Eds. R. Schmalensee and R.D. Willig. Amsterdam: North-Holland.

Goel, R.K., and Haruna, S. (2007). "Cooperative and Noncooperative R&D with Spillovers: The Case of Labor-managed Firms." *Economic Systems* 31, 423–440.

Haruna, S. (1996). "A Note on Holding Excess Capacity to Deter Entry in a Labour-managed Industry." *Canadian Journal of Economics* 29, 493–499.

Horowitz, I. (1991). "On the Effects of Cournot Rivalry between Entrepreneurial and Cooperative Firms." *Journal of Comparative Economics* 15, 115–121.

Ireland, N.J., and P.J. Law (1982). *The Economics of Labour-managed Enterprises.* London: Croom Helm.

Jones, D.C., and D.K. Backus (1977). "British Producer Cooperatives in the Footware Industry: An Empirical Evaluation of the Theory of Financing." *Economic Journa*l 87, 488–510.

Lambertini, L. (1997). "Cournot vs Stackelberg Equilibria with Entrepreneurial and Labour Managed Firms." *Journal of International and Comparative Economics* 5, 31–43.

Lambertini, L., and G. Rossini (1998). "Capital Commitment and Cournot Competition with Labour-managed and Profit-maximising Firms." *Australian Economic Papers* 37, 14–21.

Law, P.J., and G. Stewart (1983). "Stackelberg Duopoly with an Illyrian and Profit-maximising Firm." *Recherches Economiques de Louvain* 49, 207–212.

Maietta, O.W., and V. Sena (2008). "Shadow Price of Capital and the Furubotn–Pejovich Effect: Some Empirical Evidence for Italian Wine Cooperatives." *Applied Stochastic Models in Business and Industry* 24, 495–505.

Marshall, A. (1920). *Principles of Economics.* 8th ed. London: Macmillan.

Marshall, R.C. (2003). "The Culture of Cooperation in Three Japanese Worker Cooperatives." *Economic and Industrial Democracy* 24, 543–572.

Matsumura, T. (2003). "Stackelberg Mixed Duopoly with a Foreign Competitor." *Bulletin of Economic Research* 55, 275–287.

Meng, X., and F. Perkins (1998). "Wage Determination Differences between Chinese State and Non-state Firms." *Asian Economic Journal* 12, 295–316.

Moretto, M., and G. Rossini (2003). "Labour Participation." In *Technology, Information and Market Dynamics: Topics in Advanced Industrial Organization.* 81–118. Eds. P. Bianchi, and L. Lambertini. Cheltenham, UK: Edward Elgar.

Mosheim, R. (2002). "Organizational Type and Efficiency in the Costa Rican Coffee Processing Sector." *Journal of Comparative Economics* 30, 296–316.

Neary, H.M., and D. Ulph (1997). "Strategic Investment and the Co-existence of Labour-managed and Profit-maximising Firms." *Canadian Journal of Economics* 30, 308–328.

Neilson, W.S., and H. Winter (1992). "Unilateral Most-favored-customer Pricing: A Comparison with Stackelberg." *Economics Letters* 38, 229–232.

Ohnishi, K. (2000). "A Two-stage Price-setting Equilibrium Designed in Consideration of Goods Relevance and Strategic Relevance." *Australian Economic Papers* 39, 173–183.

Ohnishi, K. (2006). "A Mixed Duopoly with a Lifetime Employment Contract as a Strategic Commitment." *FinanzArchiv* 62, 108–123.

Pejovich, S. (1969). "The Firm, Monetary Policy and Property Rights in a Planned Economy." *Western Economic Journal* 7, 193–200.

Poddar, S. (2003)." Excess Capacity: A Note." *Keio Economic Studies* 40, 75–83.

Podivinsky, V.K., and G. Stewart (2007). "Why is Labour-managed Firm Entry so Rare? An Analysis of UK Manufacturing Data." *Journal of Economic Behaviour and Organisation* 63, 177–192.

Putterman, L. (2008). "Labour-managed Firms." In *The New Palgrave Dictionary of Economics.* Vol. 4, 791–795. Eds. S.N. Durlauf and L.E. Blume. Basingstoke, Hampshire: Palgrave Macmillan.

Stehmann, O. (1992). "Entry Deterrence and Excess Capacity in a Stackelberg Game." *Economic Notes* 21, 450–467.

Stephan, F.H. (Ed.) (1982). *The Performance of Labour-managed Firms.* London: Macmillan Press.

Stewart, G. (1991). "Strategic Entry Interactions Involving Profit-maximising and Labour-managed Firms." *Oxford Economic Papers* 43, 570–583.

Stewart, G. (1992). "Management Objectives and Strategic Interactions among Capitalist and Labour-managed Firms." *Journal of Economic Behavior and Organization* 17, 423–431.

Tirole, J. (1988). *The Theory of Industrial Organization.* Cambridge, MA: MIT Press.

Tortia, E. (2005). "The Accumulation of Capital in Labour-managed Firms: Divisible Reserves and Bonds.", Department of Economics Working Paper No. 23, November 2005, University of Trento.

Vanek, J. (1977). *The Labor-managed Economy.* Ithaca, NY: Cornell University Press.

Ward, B. (1958). "The Firm in Illyria: Market Syndicalism." *American Economic Review* 48, 566–589.

Ware, R. (1984). "Sunk Costs and Strategic Commitment: A Proposed Three-stage Equilibrium." *Economic Journal* 94, 370–378.

Wills, J., and A. Lincoln (1999). "Filling the Vacuum in New Management Practice? Lessons from US Employee-owned Firms." *Environment and Planning A* 31, 1497–1512.

Zevi, A. (1982). "The Performance of Italian Producer Cooperatives." In *Participatory and Self-Managed Firms: Evaluating Economic Performance.* 239–251. Eds. D.C. Jones and J. Svejnar. Lexington, MA: Lexington Books.

Zhang, J. (1993). "Holding Excess Capacity to Deter Entry in a Labour-managed Industry." *Canadian Journal of Economics* 26, 222–234.

Appendix

We begin by presenting the following two supplementary lemmas in order to prove the propositions.

Lemma 3 Suppose the quantity-setting mixed game with no capacity installed. Then firm L's Stackelberg leader output q_L^s is higher than its Cournot output q_L^c.

Proof Firm L selects q_L, and firm P selects q_P after observing q_L. When firm L is the Stackelberg leader, it maximizes its incomer per worker $\omega_L(q_L, R_P(q_L))$ with respect to q_L. Therefore, firm L's Stackelberg leader output satisfies the first-order condition:

(20) $(p'q_L + p - r)l_L - (pq_L - rq_L - f)l_L' + p'q_L R_P' l_L = 0.$

From $p' < 0$ and $R_P' < 0$, to satisfy (20), $(p'q_L + p - r)l_L - (pq_L - rq_L - f)l_L'$ must be negative. Thus, Lemma 3 follows. Q.E.D.

Lemma 4 Suppose the quantity-setting mixed game with no capacity installed. Then firm P's Stackelberg leader output q_P^s is lower than its Cournot output q_P^c.

Proof Firm P selects q_P, and firm L selects q_L after observing q_P. When firm P is the Stackelberg leader, it maximizes its profit $\pi_P(q_P, R_L(q_P))$ with respect to q_P. Therefore, firm P's Stackelberg leader output satisfies the first-order condition:

(21) $p'q_P + p - r - wl_P' + p'q_P R_L' = 0.$

From $p' < 0$ and $R_L' > 0$, to satisfy (21), $p'q_P + p - r - wl_P'$ must be positive. Thus Lemma 4 follows. Q.E.D.

Now, we prove the propositions.

Proof of Proposition 1

First, we prove (i). Lemma 3 shows that $q_L^s > q_L^c$. Furthermore, $\omega_L = [p(Q)q_L - rq_L - f]/l_L(q_L)$ is continuous and concave. $R_P(q_L)$ gives firm P's profit-maximizing output for each output of firm L. In R_P, ω_L is highest at firm L's Stackelberg leader point, and the further the point on R_P gets from firm L's Stackelberg leader point, the more ω_L decreases. By Lemmas 1 and 2, if firm L installs k_L, then its income per worker becomes higher than in the Cournot equilibrium with no capacity installed, and thus (i) is derived.

Next, we prove (ii). Lemma 2 shows that firm P's profit-maximizing output is larger when firm P installs k_P than when it does not, whereas Lemma 4 shows that $q_P^s < q_P^c$. $R_P(q_L)$ gives firm P's profit-maximizing output for each output of firm L. $\pi_P = p(Q)q_P - rq_P - wl_P(q_P) - f$ is continuous and concave. From (5), (10) and (11), we see that increasing firm P's output never decreases firm L's output. Firm P's capacity investment decreases its profit, and thus (ii) is derived.

At equilibrium, firm L unilaterally makes a commitment to capacity. Lemma 2 shows that firm L's income-per-worker-maximizing output is higher when firm L installs k_L than when it does not. Since firm L can choose q_L^c, its Stackelberg income per worker must equal or exceed its Cournot income per worker. Lemma 3 shows that $q_L^s > q_L^c$. Furthermore, $\omega_L = [p(Q)q_L - rq_L - f]/l_L(q_L)$ is continuous and concave. Lemma 1 shows that in equilibrium $q_L = k_L$. Thus, firm L's Stackelberg income per worker exceeds its Cournot income per worker, and (iii) and (iv) follow.

Firm L installs capacity in the first stage, and firm P does not install capacity in the second stage. Lemma 2 shows that firm L's income-per-worker-maximizing output is higher when firm L installs k_L than when it does not. Furthermore, $\pi_P = p(Q)q_P - rq_P - wl_P(q_P) - f$ is continuous and concave. Since $\partial\pi_P / \partial q_L = p'q_P < 0$, increasing q_L decreases π_P given q_P, and thus (v) follows. Q.E.D.

Proof of Proposition 2

(i) Lemma 4 shows that $q_P^s < q_P^c$. Furthermore, $\pi_P = p(Q)q_P - rq_P - wl_P(q_P) - f$ is continuous and concave. In R_L, π_P is highest at firm L's Stackelberg leader point, and the further the point on R_L gets from firm P's Stackelberg leader point, the more π_P decreases. By Lemma 2, if firm P installs k_P, then its profit becomes lower than in the Cournot equilibrium with no capacity installed, and thus (i) follows.

(ii) Lemma 3 shows that $q_L^s < q_L^c$. Furthermore, $\omega_L = [p(Q)q_L - rq_L - f] / l_L(q_L)$ is continuous and concave. In R_L, ω_L is highest at firm L's Stackelberg leader point, and the further the point on R_P gets from firm L's Stackelberg leader point, the more ω_L decreases. By Lemmas 1 and 2, if firm L installs k_L, then its income per worker becomes higher than in the Cournot equilibrium with no capacity installed, and thus (ii) follows.

The proofs of (iii), (iv) and (v) are omitted, since they are the same as the proofs of (iii), (iv) and (v) of Proposition 1. Q.E.D.