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Full Length Research Paper

Entry deterrence with human capital

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This paper focuses on human capital in the economy and entry deterrence when human capital is captured by a firm. A dynamic game theory model about one firm and a potential entrant is established to characterize entry deterrence with human capital. This study first argues that higher fixed set-up and transfer costs deter entrants. Second, to efficiently deter the entrants, the firm is inclined to contract workers with high contract termination compensation requirements. Finally, contracts with high termination compensation can accommodate monopolization and reduce competition for skilled labor.

Key words: Entry deterrence, commitment, trained workers, human capital, game theory.

INTRODUCTION

After a firm establishes an industry, many firms try to enter this industry. Bain (1956) first defined an entry barrier as anything that allows incumbents to earn above-normal profits without encouraging competitors. Entry deterrence launched by the incumbent seems crucial to industrial organization theory as initially discussed by Dixit (1980). This brought many extensions; see the paper and the references mentioned therein (Park and Seo, 2008). Marelli and Pastore (2010) introduced the relationship between labor and growth. Karakaya and Stahl (1989) discussed the effects of barriers on the timing of market entry of 49 firms delivering industrial goods and consumer goods. Goolsbee and Syverson (2008) examined how airline incumbents respond to the threat of entry by competitors.

Calzada and Valletti (2008) investigated network competition to a multi-firm industry. Creane and Miyagiwa (2009) developed a theory of invention as an important measure to deter entrants. Granier and Trinquard (2010) studied pharmaceutical markets under entry deterrence and discussed incumbents' various strategies. Arping and Diaw (2008) discussed how sunk costs affect a financially constrained incumbent's ability to deter entry into its market. Furthermore, Jain (2009) found that if learning does not deter entry, the monopolist incumbent learns less. Utaka (2008) investigated a pricing strategy that is aimed at deterring entry for a two-period model of a durable goods monopolist. Entry deterrence of product qualities was recently addressed by Chen and Ma (2010).

Many types of entry deterrence have been elaborately explored and characterized. Despite the practical and theoretical importance of the matter, we have little understanding of the impact of entry deterrence on human capital. In many industries, human capital acts as important entry deterrence because human capital is a crucial element in many industries, which motivates further research on this topic by highlighting human capital in entry deterrence theory.

Recently, Almazan et al. (2007) addressed firm location based on human capital. Gerlach et al. (2009) significantly discussed the relation between firms' R&D decisions and local labor market competition. The theory of human capital has been established by many interesting papers (Becker, 1964; Mincer, 1974; Nie, 2012; García-Gómez et al., 2010). Gathmann and Schönberg (2010) confirmed portable skills accumulated in the labor market. Education, training, and health are regarded as the most important investments in the human capital community (Becker, 1964). Almeida and Carneiro (2009) studied the investment in human capital. Rotemberg and Saloner (2000) established the model of human capital in which contracting can accommodate monopolization. Hannah (2010) examined the criteria that courts in the United States have considered in balancing

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employers' legitimate economic interests against labor market efficiency and workers' post-employment freedom and mobility. Acemoglu (2010) addressed innovation under labor scarcity.

In terms of practicality, in many industries, it was exceedingly expensive to move people and human capital (Glaeser and Kohlhase, 2004). During the late 19th and early 20th centuries, human capital in the United States became significantly more valuable as the need for skilled labor came with new found technological advancement. In developing countries, human capital plays crucial roles in many industries.

The extant papers primarily focused on human capital in the management field. This paper discusses the entry deterrence with human capital. We show that both higher fixed set-up costs and higher transfer costs deter entrants. This article examines the roles of contracts with high compensation requirements for leaving the firm. We develop a three-stage model to investigate entry deterrence with human capital. This article studies specific human capital (one obtained via training) rather than general human capital (one provided via formal education). Therefore, a special production function with only human capital input is employed.

Many industries and companies, such as Boeing (the sole manufacturer of commercial aircraft in Washington state) and Hershey (the sole chocolate manufacturer in Hershey, Pennsylvania), play the monopolization roles partially because of human capital. The conclusions in this work are consistent with many social phenomena. The entry deterrence model of Dixit (1980) is extended to human capital in theory.

THE MODEL

Here the model is formally established. To simplify the problem, we discuss an incumbent and a potential entrant in this industry. When a firm enters into the market, $F \geq 0$ is the fixed set-up cost to establish a firm. The model is composed by three stages. At the first stage, the first firm trains some workers and establishes this industry. At the second stage, the second firm decides whether to enter or not. At the final stage, if the second firm enters in this market, the corresponding market is in duopoly. Otherwise, the first firm is still in monopolization. $N = \{1, 2\}$ is the set of the firms in this model. Furthermore, two firms produce products without differentiations;

Consumers

We outline here the quasi-linear utility function for consumers with positive constant A.

$$u(q, p) = Aq - \frac{1}{2}q^2 - pq, \qquad (1)$$

where p is the price of the product and q is the quantity to consume by consumers. The above utility function is strictly concave to guarantee the existence of the unique solution. Furthermore, the quadratic function is employed to simplify the problem so that the demand function is linear as follows:

$$q = A - p. \qquad (2)$$

We point out that this demand function is induced by the above utility function (1). Because the function in (1) is concave, the first order optimal conditions of (1) immediately yield (2).

Firms

At the first stage, the first firm trains similar workers and establishes this industry. The training expenses are undertaken by the first firm, which is different from that of Rotemberg and Saloner (2000). Rotemberg and Saloner (2000) ruled out arrangements if the firm trains workers at its own expense. With the fixed set-up cost $F \geq 0$, the price p_1 and the quantity to produce $q_1^{(1)}$, the profit function of the first firm at the first stage is outlined as follows:

$$\pi_1^{(1)} = p_1 q_1^{(1)} - \varpi_1 h_{1,1} - F, \qquad (3)$$

where $h_{1,1}$ is the number of trained workers and ϖ_1 is the reservation wages for trained workers in the first firm. The second term of (3) is the wages to trained workers and the third term manifests the set-up cost. Market clear conditions $q_1^{(1)} = A - p_1$ are met and $q_1^{(1)}$ with the marginal product $\alpha > 0$ and the marginal costs $\tau > 0$ satisfy the following conditions. This production function is similar to that in Almazan et al. (2007), which is a special type of Cobb-Douglas function.

$$q_1^{(1)} = \alpha h_{1,1} - \tau h_{1,1} \qquad (4)$$

The first term plus the second term equals the quantity produced by the trained workers. In fact, we assume that $\alpha > \tau$ or the profits of trained workers are higher than the cost to train workers. If this assumption is not satisfied, no firms are willing to train workers. This assumption is rational according to social observation. Furthermore, the first firm contracts with trained workers to prevent trained workers from leaving this firm. If a trained worker violates this contract or this worker leaves the first firm, this worker has to pay c_2 to the first firm as compensation. This is a type of transferring cost from the second firm to the first firm at the third stage of each trained worker. Moreover, this contract acts as an important type of commitment of the workers of the first firm to deter other firms to enter in this industry.

At the second stage, the second firm determines whether to enter this industry. Two firms all receive no profits at this stage.

For the first firm at the third stage, given the price p_3, the number of trained workers $h_{3,1}$, the quantity to produce $q_1^{(3)}$ and the reservation wages of trained worker ϖ_1, the corresponding profits are below.

$$\pi_1^{(3)} = p_3 q_1^{(3)} - \varpi_1 h_{3,1}, \qquad (5)$$

where $q_1^{(3)} = \alpha h_{3,1}$. The second term is the wages for trained workers and no set-up cost for the first firm is happened at the third stage. Furthermore, the discount factor is always assumed to be 1 to simplify the problem. For the workers in the first firm, the reservation wages at the first stage is equal to that at the third stage.

At the third stage, the second firm may enter into this industry with price p_3, trained workers $h_{3,2}$, fixed set-up cost $F \geq 0$, quantity to produce $q_2^{(3)}$ and marginal cost for each worker c_2, which comes from remedy to destroy contract for the first firm, to join this industry. The corresponding profit function of the second firm is given as follows.

$$\pi_2^{(3)} = p_3 q_2^{(3)} - (c_2 + \varpi_2) h_{3,2} - F . \qquad (6)$$

ϖ_2 is the reservation wages of the second firm and $q_2^{(3)} = \alpha h_{3,2}$. The second term implies the transferring cost and the wages for trained workers. The third term is set-up cost for an establishing firm. Market clear conditions $q_1^{(3)} + q_2^{(3)} = A - p_3$ are also met. Furthermore, $h_{3,2} + h_{3,1} \leq h_{1,1}$. No workers are trained at the third stage. When the second firm does not enter into this industry, the corresponding profits of the second firm are exactly equal to 0.

The above model with three stages details human capital competition with entry deterrence of two firms. This model is different from that of Dixit (1980) because the competition in this paper highlights the human capital. To simplify the model, the product capacity commitment, which appeared in the paper of Dixit (1980), is not applied in this paper. The commitment of cost to transfer workers is applied in this work. The demand function is continuously differentiable. For the above model, we always assume that all firms are rational. That is, when firms make decisions, they aim to maximize their profits.

RESULTS

The above model is addressed here by backward induction. All stages are elaborately discussed, respectively. We investigate this model from the third stage to the first stage.

The third stage

At the final stage, there are two types of situations. In one situation, the second firm enters into this industry and in the other situation; the first firm is still in monopolization at this stage.

The second firm enters into this industry

At this stage, we further assume that the solution is an interior point and the concave function (5) is rewritten as follows;

$$\pi_1^{(3)} = (A - \alpha h_{3,1} - \alpha h_{3,2}) \alpha h_{3,1} - \varpi_1 h_{3,1} . \qquad (7)$$

The first-order optimal conditions of (7) suggest the following relationship;

$$\frac{\partial \pi_1^{(3)}}{\partial h_{3,1}} = A\alpha - 2\alpha^2 h_{3,1} - \alpha^2 h_{3,2} - \varpi_1 = 0 . \qquad (8)$$

The concave function (6) is written as follows;

$$\pi_2^{(3)} = (A - \alpha h_{3,1} - \alpha h_{3,2}) \alpha h_{3,2} - (c_2 + \varpi_2) h_{3,2} . \qquad (9)$$

The first-order optimal conditions of (9) indicate the following relationship;

$$\frac{\partial \pi_2^{(3)}}{\partial h_{3,2}} = A\alpha - 2\alpha^2 h_{3,2} - \alpha^2 h_{3,1} - (\varpi_2 + c_2) = 0 , \qquad (10)$$

(8) and (10) manifest the following formulations. The coefficient matrix of (8) and (10) is denoted as follows;

$$D = \begin{bmatrix} -2\alpha^2 & -\alpha^2 \\ -\alpha^2 & -2\alpha^2 \end{bmatrix} . \qquad (11)$$

We have $\det D = 3\alpha^4 > 0$ and the above systems of equations accordingly have the following unique solution. Further denote;

$$D_1 = \begin{bmatrix} \varpi_1 - A\alpha & -\alpha^2 \\ \varpi_2 + c_2 - A\alpha & -2\alpha^2 \end{bmatrix} , \qquad (12)$$

$$D_2 = \begin{bmatrix} -2\alpha^2 & \varpi_1 - A\alpha \\ -\alpha^2 & \varpi_2 + c_2 - A\alpha \end{bmatrix} . \qquad (13)$$

The solution for the above system is given as follows;

$$h_{3,1} = \frac{\det D_1}{\det D} = \frac{A\alpha + \varpi_2 + c_2 - 2\varpi_1}{3\alpha^2} , \qquad (14)$$

$$h_{3,2} = \frac{\det D_2}{\det D} = \frac{A\alpha - 2\varpi_2 - 2c_2 + \varpi_1}{3\alpha^2} . \qquad (15)$$

For (14)-(15), according to comparative static analysis technique, the following conclusions immediately hold.

Proposition 1: For the above system, if the second firm enters into this industry, we have the following formulations.

$$\frac{\partial h_{3,1}}{\partial \varpi_1} < 0, \frac{\partial h_{3,1}}{\partial \varpi_2} > 0, \frac{\partial h_{3,1}}{\partial c_2} > 0 , \quad \frac{\partial h_{3,2}}{\partial \varpi_1} > 0, \quad \frac{\partial h_{3,2}}{\partial \varpi_2} < 0 \text{ and } \frac{\partial h_{3,2}}{\partial c_2} < 0 .$$

Remarks: The improvement of reservation wages brings about a decrease of the corresponding human capital. Higher transfer cost keeps trained workers from transferring.

These conclusions are consistent with social observations. In reality, because of higher reservation wages in recent years, firms hire less human capital in China. Moreover, high housing prices in China prevent workers from transferring. By envelop theorem, for the profit functions we further have the following conclusions at the third stage.

Proposition 2: For profit functions of two firms, if the second firm enters into this industry, we have the following relationships.

$\frac{\partial \pi_1^{(3)}}{\partial \varpi_1} < 0, \frac{\partial \pi_1^{(3)}}{\partial \varpi_2} > 0, \frac{\partial \pi_1^{(3)}}{\partial c_2} > 0$,
$\frac{\partial \pi_2^{(3)}}{\partial F} < 0$, $\frac{\partial \pi_2^{(3)}}{\partial \varpi_1} > 0, \frac{\partial \pi_2^{(3)}}{\partial \varpi_2} < 0$ and $\frac{\partial \pi_2^{(3)}}{\partial c_2} < 0$.

Proof: Details are shown in the Appendix section.

Remarks: The above conclusions illustrate the relationship between profit functions and some parameters. Larger c_2 (higher transferring cost) reduces profits of the second firm. This conclusion illustrates that higher cost to transfer significantly deter potential entrants. Set-up cost also deters entrants $\frac{\partial \pi_2^{(3)}}{\partial F} < 0$. Both higher set-up costs and higher transfer costs deter entrants. These conclusions fit with economic observations.

The second firm does not enter into this industry

Here, we consider the case wherein the second firm does not enter this industry at the third stage. In this case, this industry is in monopolization and the second firm obtains zero profits. The profit function of the first firm is;

$$\pi_1^{(3,m)} = (A - \alpha h_{3,1})\alpha h_{3,1} - \varpi_1 h_{3,1}. \qquad (16)$$

If the solution is a strict interior-point, the solution is outlined by the following first-order optimal conditions.

$$\frac{\partial \pi_1^{(3,m)}}{\partial h_{3,1}} = A\alpha - 2\alpha^2 h_{3,1} - \varpi_1 = 0. \qquad (17)$$

The solution is outlined as follows;

$$h_{3,1}^m = \frac{A\alpha - \varpi_1}{2\alpha^2}. \qquad (18)$$

If the solution lies at the corner, $h_{3,1}^m = h_{1,1}$.

The second stage

At this stage, according to profits achieved at the third stage, the second firm determines whether to enter into this industry or not. No profits are obtained for two firms at this stage. The second firm enters into this industry if $\pi_2^{(3)} \geq 0$. In this case, strategies to enter this industry dominate to keep away from this industry. Otherwise, the second firm is always shut out of this industry. There exists a threshold value for the solution. Given $\varpi_1, \varpi_2, \alpha$ and optimal human capital $h_{3,2}^*$, the threshold value is given by the following equation;

$$\pi_2^{(3)}(h_{3,2}^*(c_2), c_2) = 0. \qquad (19)$$

According to Proposition 2, $\pi_2^{(3)}(h_{3,2}^*(c_2), c_2)$ is decreasing in c_2.Thus, according to the value of c_2 along with profits the second firm determines whether to join this industry or not. This is consistent with the conclusions of Rotemberg and Saloner (2000). Furthermore, for higher damages remedy, the following conclusion holds

Proposition 3: Higher damages remedy causes reduction of occupation for trained workers.

Proof: From (14) and (15) we have $h_{3,1} + h_{3,2} = \frac{2A\alpha - \varpi_2 - c_2 - \varpi_1}{3\alpha^2}$. When c_2 increases, the value of $h_{3,1} + h_{3,2}$ decreases. Therefore, the conclusion is achieved and the proof is complete.

Remark: From the above analyses, we find that the higher damages remedy reduces the move of human capital and reduces occupation.

The first stage

At the first stage, the first firm is in monopolization and launches a commitment about c_2. The solution to (19) is denoted c_2^*. When $c_2 > c_2^*$, no other firms enter into this industry. When $c_2 < c_2^*$, there are firms to enter into this industry. On the other hand, by virtue of $\frac{\partial h_{3,2}}{\partial c_2} < 0$, the value c_2 can efficiently deter the trained workers to move.

In this stage, the profits of the first firm are given as follows;

$$\pi_1^{(1)} = [A - (\alpha h_{1,1} - \tau h_{1,1})](\alpha h_{1,1} - \tau h_{1,1}) - \varpi_1 h_{1,1} - F. \quad (20)$$

The solution is determined by the following first-order optimal conditions.

$$\frac{\partial \pi_1^{(1)}}{\partial h_{1,1}} = A(\alpha-\tau) - 2(\alpha-\tau)^2 h_{1,1} - \varpi_1 = 0 . \quad (21)$$

The solution is;

$$h_{1,1} = \frac{A(\alpha-\tau)-\varpi_1}{2(\alpha-\tau)^2} . \quad \text{p} \quad (22)$$

Three stages are analyzed by backward induction and we find that the transferring cost, from the incumbent to entrants, deters the potential entrants. Here we compare $h_{1,1} = \frac{A(\alpha-\tau)-\varpi_1}{2(\alpha-\tau)^2}$ and $h_{3,1}^m = \frac{A\alpha-\varpi_1}{2\alpha^2}$ and the following conclusion holds.

Proposition 4: If $A(\alpha-\tau)-2\varpi_1 > 0$ and the second firm keeps away from this industry, we have;

$$h_{1,1} > h_{3,1}^m .$$

Proof: Here we consider the function $f(x) = \frac{Ax-\varpi_1}{2x^2}$ and we have;

$$\frac{df(x)}{dx} = \frac{A}{2x^2} - \frac{Ax-\varpi_1}{x^3} = \frac{-Ax+2\varpi_1}{2x^3} .$$

If $A(\alpha-\tau)-2\varpi_1 > 0$, we have $f(x) = \frac{Ax-\varpi_1}{2x^2}$ is monotonically decreasing in $x \in [\alpha-\tau, \alpha]$. Accordingly, if $A(\alpha-\tau)-2\varpi_1 > 0$ and the second firm keeps away from this industry, we achieve $h_{1,1} > h_{3,1}^m$ and the proof is complete.

Remark: The conclusion in Proposition 3 illustrates that the number of trained workers is more than the optimal human capital at the third stage if no firms enter at the third stage. This conclusion outlines a condition of potential entrants to enter this industry.

Conclusions

In this paper, the model of Dixit (Dixit, 1980) is extended to human capital competitions. We address human capital for entry deterrence because many industries in developing countries, such as China, Vietnam et al., are intensive of human capital. The conclusions in this paper seem useful for developing countries.

This paper shows that higher transferring costs and set-up costs all deter potential entrants. Moreover, we find that if no other firms enter this industry, the number of trained workers is not optimal for the incumbent. We assume that the solution is an interior point at the third stage. In fact, for larger damage remedy, this hypothesis is realized. When $c_2 > 2A\alpha - \varpi_2 - \varpi_1 - \frac{3\alpha^2[A(\alpha-\tau)-\varpi_1]}{2(\alpha-\tau)^2}$, we have the relation $h_{3,1} + h_{3,2} = \frac{2A\alpha - \varpi_2 - c_2 - \varpi_1}{3\alpha^2} < \frac{A(\alpha-\tau)-\varpi_1}{2(\alpha-\tau)^2} = h_{1,1}$. In this case, the solution is exact an interior point at the third stage.

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APPENDIX

Proof of Proposition 2

We first argue $\frac{\partial \pi_1^{(3)}}{\partial \varpi_1} < 0$ and $\frac{\partial h_{3,1}}{\partial \varpi_2} > 0$. According to the profit function of the first firm, by envelop theorem we immediately have;

$$\begin{aligned}\frac{\partial \pi_1^{(3)}}{\partial \varpi_1} &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_1} + \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_1} - h_{3,1} \\ &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_1} - h_{3,1} = -\alpha^2 h_{3,1}\frac{\partial h_{3,2}}{\partial \varpi_1} - h_{3,1} = -\frac{4h_{3,1}}{3} < 0\end{aligned}.$$

$$\begin{aligned}\frac{\partial \pi_1^{(3)}}{\partial \varpi_2} &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_2} + \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_2} \\ &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_2} = -\alpha^2 h_{3,1}\frac{\partial h_{3,2}}{\partial \varpi_2} = \frac{2h_{3,1}}{3} > 0.\end{aligned}$$

We then show $\frac{\partial \pi_1^{(3)}}{\partial c_2} > 0$. (7) suggests;

$$\begin{aligned}\frac{\partial \pi_1^{(3)}}{\partial c_2} &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial c_2} + \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial c_2} \\ &= \frac{\partial \pi_1^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial c_2} = -\alpha^2 h_{3,1}\frac{-2}{3\alpha^2} = \frac{2}{3}h_{3,1} > 0.\end{aligned}$$

Therefore, $\frac{\partial \pi_1^{(3)}}{\partial \varpi_1} < 0$, $\frac{\partial h_{3,1}}{\partial \varpi_2} > 0$ and $\frac{\partial \pi_1^{(3)}}{\partial c_2} > 0$ simultaneously hold.

Apparently, we directly have $\frac{\partial \pi_2^{(3)}}{\partial F} < 0$ from (9). We further show $\frac{\partial \pi_2^{(3)}}{\partial \varpi_1} > 0$, $\frac{\partial \pi_2^{(3)}}{\partial \varpi_2} < 0$ and $\frac{\partial \pi_2^{(3)}}{\partial c_2} < 0$.

$$\begin{aligned}\frac{\partial \pi_2^{(3)}}{\partial \varpi_1} &= \frac{\partial \pi_2^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_1} + \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_1} \\ &= \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_1} = \frac{2}{3}h_{3,2} > 0.\end{aligned}$$

$$\begin{aligned}\frac{\partial \pi_2^{(3)}}{\partial \varpi_2} &= \frac{\partial \pi_2^{(3)}}{\partial h_{3,2}}\frac{\partial h_{3,2}}{\partial \varpi_2} + \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_2} - h_{3,2} \\ &= \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}}\frac{\partial h_{3,1}}{\partial \varpi_2} - h_{3,2} = -\frac{h_{3,2}}{3} - h_{3,2} = -\frac{4}{3}h_{3,2} < 0.\end{aligned}$$

We therefore obtain the solution $\frac{\partial \pi_2^{(3)}}{\partial \varpi_1} > 0$ and $\frac{\partial \pi_2^{(3)}}{\partial \varpi_2} < 0$. We further argue the conclusion $\frac{\partial \pi_2^{(3)}}{\partial c_2} < 0$ by envelop theorem directly.

$$\frac{\partial \pi_2^{(3)}}{\partial c_2} = \frac{\partial \pi_2^{(3)}}{\partial h_{3,2}} \frac{\partial h_{3,2}}{\partial c_2} + \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}} \frac{\partial h_{3,1}}{\partial c_2} - h_{3,2}$$
$$= \frac{\partial \pi_2^{(3)}}{\partial h_{3,1}} \frac{\partial h_{3,1}}{\partial c_2} - h_{3,2} = -\frac{1}{3} h_{3,2} - h_{3,2} = -\frac{4}{3} h_{3,2} < 0.$$

The results $\frac{\partial \pi_1^{(3)}}{\partial \varpi_1} < 0, \frac{\partial \pi_1^{(3)}}{\partial \varpi_2} > 0, \frac{\partial \pi_1^{(3)}}{\partial c_2} > 0$, $\frac{\partial \pi_2^{(3)}}{\partial \varpi_1} > 0$, $\frac{\partial \pi_2^{(3)}}{\partial \varpi_2} < 0$ and $\frac{\partial \pi_2^{(3)}}{\partial c_2} < 0$ are accordingly achieved and the proof is complete.