Team Incentives and Efficient Referrals*

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Very preliminary, please do not quote.

Abstract

We consider a principal-agent model in which referrals play a role in production. We study both an individual-based (IBIS) and a team-based incentive schemes (TBIS). We establish a necessary and sufficient condition on "position-specific productivity" for the TBIS to be more profitable for a class of specifications of "team-specific productivity". Our results are supported with empirical evidences.

Keywords: Incentive Schemes, backward induction, referrals.

JEL Classification: D86, J33, L22, M52.

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1 Introduction

In the last several years, there has been a sharp increase in the use of teamwork in organizations. *Fortune* magazine estimated that half of America's largest companies are experimenting with teams (Dumaine, 1990). Gross and Safier (1995) reported that as many as 80% or more of companies in the U.S. use teams in some of their critical transformation processes. Teams have become popular for redesigning organizational structures as a mean of increasing productivity, improving flexibility, and raising employee involvement and reciprocal learning. Moreover, social psychology literature on teams advises that teamwork is a good mechanism for increasing communication, helping, information-sharing, and other forms of cooperation. For all these reasons, one of the more perplexing challenges facing human resource professionals today involves finding ways to compensate teams and team members fairly and efficiently, while providing incentives to enhance productivity and performance (Howard et al. 2002).

For instance, teamwork is a major characteristic of the legal services industry. Garicano and Hubbard (2003) argued that a central problem within a law firm is the allocation of opportunities to partners with different specializations. As specializations between lawyers further diversified, the ability of clients to identify the right expert for their needs may decrease. In that case, a client may hire the wrong lawyer. Once the lawyer realizes that he is not best qualified to deal with the client's problem, he can refer the client to another lawyer or he can opt to extract some rents. It follows that referrals play a key role in efficient allocation of opportunities to partners (Garicano and Santos 2004). An individual-based incentive scheme (hereafter IBIS) that links payments to lawyers with individual performance would exclude any referral and hence, it would cause a problem of miss match between client's needs and lawyer's specialization. A team-based incentive scheme (hereafter TBIS) that rewards each lawyer with a bonus in case of success can avoid this miss match problem. However, this incentive scheme increases the free-riding problem.

In this paper we establish the dominance of TBIS over IBIS for a principal when referrals play a key role in efficiently allocating opportunities among agents. Our model is a simple principal-agent model with two agents resembling the teamwork structure of a law firm. The model has three stages. In stage one the principal designs an incentive contract. In stage two the agents individually decide effort levels to exert in production. In stage three nature first selects an agent to move first. The first mover can either "serve" or "refer" to the other agent. If he serves, the game ends; if he refers, then the other agent has the opportunity to serve after which the game ends. An agent's productivity depends on two components. One component is common to both agents, which is referred to as the "team-specific component". Another component is "position specific", which depends on whether the agent is the first or the second mover.

We solve the game by backward induction: (i) find the agents' optimal actions in stage three taking incentive contract and effort choices as given; (ii) determine agents' optimal effort levels in stage two taking incentive contract choice and decisions in the third stage as given; and (iii) determine the optimal incentive contract choices in the stage one taking choices in stage two and stage three as given. We compare the expected profits generated by IBIS and TBIS for the principal. We show that IBIS can never be more profitable than TBIS. We establish a necessary and sufficient condition on position-specific productivity for the TBIS to be more profitable than IBIS for the principal, for a class specifications of team-specific productivity.

Garicano and Santos (2004) consider a model of referrals. In their model, two agents can deal with an opportunity (e.g. to serve a prospective client), but one agent is more skilled than the other, in the sense that he can add more value to the opportunity. The agent who receives the opportunity must undertake a costly diagnosis in order to learn whether he or the other agent is more skilled for the opportunity. He may then deal with the opportunity himself by exerting costly effort or let the other agent deal with it by referral. The central issue investigated in their paper is on what institutions that can result in efficient referrals (Garicano and Santos, 2004, pp. 500-501). The agents are independent in the sense that they are not hired by the same principal. In comparison, the agents in our model work for the same principal. Thus referrals in our paper can be seen as between members of the same organization while those in Garicano and Santos (2004) are between organizations. In addition, while an agent exerts effort only when it is certain that he will deal with the opportunity in their paper, the agents in the present paper exert costly efforts before any opportunity arrives in order to develop their team's skills as well as their individual skills. Furthermore, the agent who receives the opportunity knows who is the right to deal with it without undertaking any costly diagnosis. This is justifiable if the opportunity is to meet a specific need.

The rest of this paper is organized as follows. Section 2 introduces the model and analyzes the choice problems for the agents and principal. Section 3 compares the TBIS with IBIS. Section 4 discusses the empirical implications of the model and Section 5 concludes the paper.

2 Model

Consider a situation in which a senior member, the principal, offers contracts to two new partners A and B, the agents, who in turn may provide services called for by prospective clients. When a partner is contacted by a client, there are three possible outcomes: A wins the client's case, B wins, and neither A nor B wins. Set $G = \{\text{No One Wins, A Wins, B Wins}\}$. Profit for the principal is as follows: she receives (a prize) x_S amount of payment when winning takes places and $x_F < x_S$ amount otherwise. We normalize the payoffs so as to make the reservation payoff level equal to zero for both agents.

The model involves sequential moves. The principal specifies contract first. Next, observing the incentive contract specified by the principal, the agents individually decide how much effort $e_i \in [a, b]$, $i = A, B$, to exert in production. Finally, nature selects an agent with equal probability to move first.[1] The first mover can either "serve" himself or "refer" to the other agent. If he serves the game ends; otherwise, if he refers, the second mover then has the opportunity to serve after which the game ends. Nature also selects from a joint probability distribution $Z(\lambda_1, \lambda_2)$ a "position-specific component" of productivity λ_1 for the first mover and λ_2 for the second mover. Given e and λ, the "winning probability" is [2]

$$\lambda_1 f(e) \tag{1}$$

if the first mover serves and

$$\lambda_2 f(e), \tag{2}$$

if the first mover refers. Here, $f(e)$ is the common component in the first and second movers' winning probabilities. Thus, it can be regarded as the "team-specific" productivity at effort choices $e = (e_A, e_B)$. We assume that f is differentiable with $f_A(e_A, e_B) = f_B(e_A, e_B)$ whenever $e_A = e_B$.

Due to the lack of observability of e and λ, the principal can only link payments to the agents with outcomes in G. A contract is thus characterized by a triplet $w = (w_0, w_1, w_2)$, where w_0 is the wage for every agent when nobody wins, w_1 is the wage for an agent who wins, and w_2 is the wage for an agent when his partner wins. Table 2 summarizes the contingent payments to the agents and the prize for the principal.

Outcome (G)	Wage for agents (A, B)	Prize for principal
Nobody wins	(w_0, w_0)	x_F
A wins	(w_1, w_2)	x_S
B wins	(w_2, w_1)	x_S

Table 1: Contingent Wages and Prizes

[1] In case of a law firm, to move first means that a lawyer is contacted first by a client.

[2] The situation in which lawyers have the same specialization in our model corresponds to $\lambda_1 = \lambda_2$.

We assume $w_1 \geq w_2 \geq w_0 \geq 0$. This assumption implies that the principal can use only positive rewards and not penalties. By a IBIS, we mean a wage structure $w^I = (w_0, w_1, w_2)$ with $w_0 = w_2$ and a TBIS, we mean a wage structure $w^T = (w_0, w_1, w_2)$ with $w_1 = w_2$.

We assume the principal and the agents are all risk-neutral. Agent i has the following utility function

$$U_i(m, e_i) = m - C(e_i), \tag{3}$$

where m denotes income and $C(e_i)$ is the cost of effort with $C'(e_i), C_i''(e_i) > 0$.

2.1 Agents' Choice Problem

We begin the analysis with agents' decisions in the third stage. The choice problem of the second mover is trivial, because the wage structure implies that it is optimal to always serve whenever he gets the opportunity.

2.1.1 Optimal Choice under IBIS

Suppose that the principal offers a IBIS. Given w, e, and λ, from (1) the first mover's income from serving is given by

$$\lambda_1 f(e) w_1 + [1 - \lambda_1 f(e)]\, w_0.$$

If the first mover refers, his income would be w_0 with probability 1. But, since $w_1 \geq w_0$, serving is always better than referring. It follows that an IBIS induces agents to serve even if referring is better from the principal's point of view. This contract thus distorts the optimal action, in that the first mover will never refer even if the second mover has a higher probability to win.

At this point, one can objects that the first mover will always have a probability of winning greater than the second mover since it is in client's interest to hire a lawyer with a specialization in the field client needs. However, as a leading Boston lawyer[3] wrote in a classic 1940 article on the organization of the law firm:

> "[...] most clients do not go to lawyers because they are specialists in a given field; they generally are not even aware of it. They go to a given lawyer because they know, like and trust him. The client with a tax case is just as likely to go to the real estate expert and the client with a land problem to go to the tax expert."

[3] Reginald Heber Smith, American Bar Association Journal, 1940.

Moreover, many lawyers during their studies can specialize in one or more areas of the law (for instance corporate law, criminal law, environmental law, family law, patent law, real estate law, tax law, and many others). In their career lawyers can also specialize further into even more specialized doctrines. For example, many specialists in corporate law specialize further in specific areas of corporate law (mergers and acquisitions, joint ventures, securities law, and so on). This strong specialization makes complicated for a client to hire the "right" lawyer.

Since each agent is selected with equal probability to move first, it follows from the preceding analysis that given w, e, and λ, agent A's income is

$$P^I(w,e,\lambda) = \frac{1}{2}\lambda_1 f(e)[w_1 - w_0] + w_0. \tag{4}$$

Taking expectations over λ, (4) implies that A's expected payoff will be

$$P^I(w,e,\bar{\lambda}) = \frac{1}{2}\bar{\lambda}_1 f(e)[w_1 - w_0] + w_0. \tag{5}$$

where

$$\bar{\lambda}_1 = \int \lambda_1 dZ(\lambda) \tag{6}$$

is the mean of the position-specific component of productivity for the first mover. Given w and given B's effort level e_B, it follows from (3) and (5) that agent A's effort choice problem can be formulated as

$$\max_{e_A} \frac{1}{2}\bar{\lambda}_1 f(e)[w_1 - w_0] + w_0 - C(e_A). \tag{7}$$

The FOC for the above problem is:

$$\bar{\lambda}_1 f_A(e)\,(w_1 - w_0) = 2C'(e_A^I). \tag{8}$$

Agent B's effort choice problem can be similarly formulated. Since $f_A(e) = f_B(e)$ when $e_A = e_B$, (8) implies that symmetric optimal effort levels exit. Let $e^I(w) = (e_A^I(w), e_B^I(w))$ denote the pair of symmetric optimal effort levels at wage structure w.

2.1.2 Optimal Choice under TBIS

With a TBIS, it is not always in the first mover's best interest to always serve himself, because they will receive the same wage regardless of who wins. The first mover's optimal choice is therefore to maximize the probability of winning for the whole team. Specifically, Given w, e, and λ, from (1) and (2) the first mover receives

$$\lambda_1 f(e) w_1 + (1 - \lambda_1 f(e))\, w_0 \tag{9}$$

by serving himself and

$$\lambda_2 f(e) w_1 + (1 - \lambda_2 f(e))\, w_0 \tag{10}$$

by referring to the other agent. By (9) and (10), serving is at least as good as referring for the first mover if and only if:

$$\lambda_1 \geq \lambda_2.$$

Correspondingly, a TBIS enables the principal to align the agents' objectives with her own.

The agents receive the same income under TBIS. We denote the common income at effort levels $e = (e_A, e_B)$, wage structure $w = (w_1, w_0)$, and position-specific productivity $\lambda = (\lambda_A, \lambda_B)$ by $P^T(w, e, \lambda)$. Then,

$$P^T(w, e, \lambda) = \begin{cases} \lambda_1 f(e) w_1 + (1 - \lambda_1 f(e))\, w_0 & \text{if} \quad \lambda_1 \geq \lambda_2 \\ \lambda_2 f(e) w_1 + (1 - \lambda_2 f(e))\, w_0 & \text{if} \quad \lambda_2 \geq \lambda_1 \end{cases} \tag{11}$$

Taking expectations with respect to λ, it follows

$$P^T(w, e, \underline{\lambda}) = E_\lambda \left[P^T(e, \lambda, w) \right] = \left(\underline{\lambda}_1 + \underline{\lambda}_2 \right) f(e) \left(w_1 - w_0 \right) + w_0 \tag{12}$$

where

$$\underline{\lambda}_1 = \int_{\lambda_1 \geq \lambda_2} \lambda_1 dZ(\lambda) \tag{13}$$

and

$$\underline{\lambda}_2 = \int_{\lambda_1 \leq \lambda_2} \lambda_2 dZ(\lambda) \tag{14}$$

represent the means of λ_1 conditional on $\lambda_1 \geq \lambda_2$ and λ_2 conditional on $\lambda_1 \leq \lambda_2$, respectively.

Given w, by (3) and (12), agent A's effort choice problem can be formulated as

$$\max_{e_A} (\underline{\lambda}_1 + \underline{\lambda}_2)\, f(e)\, (w_1 - w_0) + w_0 - C(e_A^T) \tag{15}$$

The FOC for the above problem is

$$(\underline{\lambda}_1 + \underline{\lambda}_2)\, f_A(e)\, (w_1 - w_0) = C'(e_A^T). \tag{16}$$

Agent B's choice problem can be similarly formulated. Since $f_A(e) = f_B(e)$ when $e_A = e_B$, (16) implies that there exist symmetric optimal effort levels. We denote by $e^T(w) = (e_A^T(w), e_B^T(w))$ the pair of symmetric optimal effort levels at wage structure w.

2.2 Principal's Choice Problem

We now turn to the principal choice problem. Her objective is to maximize total payment less payments to the agents. Observe that from (8) and (16) it follows that the agents' optimal effort choices depend only on the wage differential $\Delta w = (w_1 - w_0)$ under either scheme. We write agents' effort functions as $e_i(\Delta w)$ instead of $e(w)$. Thus, to specify the contracts can be regarded as specifying w_0 and Δw.

2.2.1 Optimal Choice with IBIS

As argued before, the first mover will always serve himself under IBIS. Accordingly, given wage structure $(w_0, \Delta w)$, the (expected) probability of winning is $\bar{\lambda} f(e^I(\Delta w))$. Thus, taking the agents' responses into consideration, the principal's expected profit at $(w_0, \Delta w)$ is:

$$\bar{\lambda}_1 f(e^I(\Delta w))\,[x_S - \Delta w] + \left[1 - \bar{\lambda}_1 f(e^I(\Delta w))\right] (x_F - 2w_0)$$

if the agents participate and x_F if they do not participate. We consider solutions with participation by the agents. It follows that the principal's choice problem can be formulated as

$$\begin{aligned} &\max\nolimits_{\Delta w} \bar{\lambda}_1 f(e^I(\Delta w))[\Delta x_S - \Delta w] + x_F - 2w_0 \\ &\text{subject to} \\ &w_0 = C(e^I(\Delta w)) - \tfrac{1}{2}\bar{\lambda}_1 f(e^I(\Delta w))\Delta w \end{aligned} \tag{17}$$

where $\Delta x_S = x_S - x_F$. The FOC for the preceding problem is

$$\bar{\lambda}_1 f_A(e^I(\Delta w))\Delta x_S = C'^I(\Delta w)). \tag{18}$$

In deriving (18), we applied the identity $f_A(e^I(\Delta w)) = f_B(e^I(\Delta w))$.

2.2.2 Optimal Choice with TBIS

With TBIS, our previous analysis shows that the first mover serves if and only if $\lambda_1 \geq \lambda_2$. Thus, given e, and λ, the probability of winning is $\lambda_1 f(e)$ when $\lambda_1 \geq \lambda_2$ and $\lambda_2 f(e)$ when $\lambda_1 \leq \lambda_2$. Taking the agents' responses into consideration, the principal's expected profit at w will be

$$\underline{\lambda} f(e^T(\Delta w))\,(x_S - 2w_1) + [1 - \underline{\lambda} f(e^T(\Delta w))](x_F - 2w_0)$$

where $\underline{\lambda} = \underline{\lambda}_1 + \underline{\lambda}_2$ and $\underline{\lambda}_1$ and $\underline{\lambda}_2$ are as in (13) and (14). As with IBIS, we consider solutions with participation by the agents. It follows that the principal's choice problem can be formulated as

$$\begin{aligned} &\max_{\Delta w} \underline{\lambda} f(e^T(\Delta w))[\Delta x_S - 2\Delta w] + x_F - 2x_0 \\ &\text{subject to} \\ &w_0 = C(e^T(\Delta w)) - \underline{\lambda} f(e^T(\Delta w))\Delta w. \end{aligned} \tag{19}$$

The FOC for the preceding problem is

$$\underline{\lambda} f_A(e^T(\Delta w))\Delta x_S = C'^T(\Delta)). \tag{20}$$

As with IBIS, the derivation of (20) also applies the symmetries in the agents' optimal effort levels and function f.

3 Comparing the Incentive Schemes

The principal can align the agents' objectives with her own by offering a TBIS. However, this is made possible at a price. Namely, both agents are paid the higher wages whenever winning takes place. Thus, it is not obvious which scheme between IBIS and TBIS is more profitable for the principal. Indeed, as the following examples illustrate, the answer to the question depends on both the team-specific productivity and the probability distribution that governs nature's choice of position-specific productivity.

Example 1: Suppose $f(e) = (e_1 + e_2)/2$, $C(e_i) = e_i^2/2$, and Z has density function $z(\lambda) = 1$ when $\lambda \in [0,1]^2$ and $z(\lambda) = 0$ when $\lambda \notin [0,1]^2$. In addition, $0 < x_S - x_F \leq 12$ and wages are normalized so that $w_0 = 0$ and. We have $\bar{\lambda}_1 = 1/2$ and $\underline{\lambda}_1 = \underline{\lambda}_2 = 1/3$. With $\bar{\lambda}_1 = 1/2$, (8) implies $e_A^I(w) = e_B^I(w) = (w_1 - w_0)/8$ and with $\underline{\lambda}_1 = \underline{\lambda}_2 = 1/3$, (16) implies $e_A^T(w) = e_B^T(w) = (w_1 - w_0)/3$.

With these optimal effort levels and the normalization of $w_0 = 0$, (18) and (20) implies that the optimal wage structure is $w_1^I = (x_S - x_F)/2$ under IBIS and $w_1^T = (x_S - x_F)/4$ under TBIS. Thus, the principal's maximum profit with IBIS is

$$\frac{(x_S - x_F)^2}{64} + x_F$$

and with TBIS is

$$\frac{(x_S - x_F)^2}{36} + x_F.$$

It follows that TBIS is more profitable than IBIS.

Example 2: Consider the same setting as in Example 1 except that now $Z(\lambda)$ has density function $z(\lambda)$ with $z(\lambda) = 2$ when $\lambda \in [0,1]^2$ and $\lambda_1 \geq \lambda_2$ and $z(\lambda) = 0$ otherwise. In this case, $\bar{\lambda}_1 = 2/3$, $\underline{\lambda}_1 = 2/3$, and $\underline{\lambda}_2 = 0$. By (8) and (16), $e_A^I(w) = e_B^I(w) = (w_1 - w_0)/6$ and $e_A^T(w) = e_B^T(w) = (w_1 - w_0)/3$. By (18) and (20), with $w_0 = 0$, $w_1^I = (x_S - x_F)/2$ and $(x_S - x_F)/4$. Hence, the principal's maximum profit with IBIS is

$$\frac{(x_S - x_F)^2}{36} + x_F$$

and with TBIS is

$$\frac{(x_S - x_F)^2}{36} + x_F.$$

This shows that that IBIS and TBIS are equally profitable to the principal.

The difference between the preceding examples is in their cumulative distributions of $\lambda = (\lambda_1, \lambda_2)$. The distribution in Example 1 implies $\bar{\lambda}_1 < \underline{\lambda}_1 + \underline{\lambda}_2$ while the distribution in Example 2 implies $\bar{\lambda}_1 = \underline{\lambda}_1 + \underline{\lambda}_2$. As a result, TBIS is more profitable than IBIS in Example 1 while the two schemes are equally profitable for the principal in Example 2. The examples illustrate a possible trade-off between incentives for referrals and incentives for effort provision. In what follows we show that for a class of team-specific productivity functions including the one in the preceding examples, $\bar{\lambda}_1 < \underline{\lambda}_1 + \underline{\lambda}_2$ is both necessary and sufficient for the TBIS to be more preferable for the principal.

Theorem 1. *Suppose $f(e)$ is symmetric, differentiable, and homogeneous of degree 1 and $C(e_i) = e_i^2/2$ for $i = A, B$. Then, TBIS is more profitable than IBIS for the principal if and only if $\bar{\lambda}_1 < \underline{\lambda}_1 + \underline{\lambda}_2$.*

Proof. See the Appendix. □

Since $\bar{\lambda}_1 \leq \underline{\lambda}_1 + \underline{\lambda}_2$ is always satisfied, a direct application establishes the following corollary.

Corollary 2. *Suppose $f(e)$ is symmetric, differentiable, and homogeneous of degree 1 and $C(e_i) = e_i^2/2$ for $i = A, B$. Then, TBIS is at least as profitable as IBIS for the principal.*

Notice that the team-specific productivity functions in Theorem 1 include the CES form as a special case. Hence, the agents efforts can be complementary, in the sense that one agent's effort affects the other agent's "marginal winning probability" (i.e. $f_i(e_A, e_B)$). Notice also that one possible interpretation for the necessary and sufficient condition is that is that clients cannot identify the most capable agent for their cases, so that there is always a positive probability that the un-contacted agent is more capable (i.e. $\lambda_1 < \lambda_2$ holds with positive probability). With this interpretation, our Corollary states that in case clients can always identify the most capable agents for their case, IBIS and TBIS are equally profitable, despite the fact that the agents may be complementary in the sense as specified above. This is the essence of the referral problem.

4 Discussion

Our analysis points out that a principal should offer a TBIS to those agents with partial overlapping specialization. The same leading Boston lawyer cited before [4] also explained that:

> "the client with the tax case who comes to the partner who happens to be a real estate expert need not be sent out of the office; the attorney can either get the advice from his own partner who is a tax export or he can introduce his client to that partner. There will be just one fee and that must somehow be shared by the two partners."

However, this is possible only when the two layers have different specializations. In fact, when they are (identical) experts in the same fields, there is no gain in referring to another lawyer.

As shown by Shumsky and Pinkerhis (2003) this rasoning is valid not only for layers but in many other different activities. For instance, in healthcare organizations. Ferris et al. (2001) study a large, multi-specialty capitated group practice before and after the elimination of a gatekeeping system that required patients to receive authorization from a primary care physician before being allowed to visit a specialist.

There are many other example of professional services that can be cited. Shumsky and Pinker (2002) examine services in which customers encounter a gatekeeper who makes an initial diagnosis of the customer's problem and then may refer the customer to a specialist. The gatekeeper may also attempt to solve the problem, but the probability of treatment success decreases as the problem's complexity increases. They examine the relative benefits of compensation systems designed to

[4] Reginald Heber Smith, American Bar Association Journal, 1940.

overcome the effects of this information asymmetry and show that bonuses based solely on referral rates do not always ensure first-best system performance and that an appropriate bonus based on customer volume may be necessary as well.

Chain store shops also as libraries and used cars shops are other examples.

5 Conclusions

This paper studies individual and team based incentive scheme. We consider a principal-agent model with sequential moves by the agents. Agents' productivity has both a *team* and a *position-specific* component. We solve the game by *backward induction*, first finding the agents' optimal actions and effort levels and then determining the optimal contract for the principal given the agents' decisions. We compare the expected profits the two types of contracts generate for the principal. Our theoretical results show that IBIS can never be more profitable than TBIS for the principal. We establish a necessary and sufficient condition for the TBIS to be more profitable than IBIS for the principal.

Proof of Theorem 1

Notice first by the symmetry and homogeneity we have [5]

$$2f_A(e_A, e_B) = f(1,1) \tag{21}$$

whenever $e_A = e_B$. Since $C(e_i) = e_i^2/2$, by (18), (2), and (21),

$$e_i^I(\Delta w) = \frac{1}{2}\bar{\lambda}_1 f(1,1)\Delta x_S \tag{22}$$

and

$$e_i^T(\Delta w) = \frac{1}{2}\underline{\lambda} f(1,1)\Delta x_S. \tag{23}$$

On the other hand, from (8) and (16) it follows

$$e_i^I(\Delta w) = \frac{1}{4}\bar{\lambda}_1 f(1,1)\Delta w \tag{24}$$

and

$$e_i^T(\Delta w) = \frac{1}{2}\underline{\lambda} f(1,1)\Delta w. \tag{25}$$

Now, combining (22) with (24) and (23) with (25), we get

$$\Delta w^I = 2\Delta x_S, \quad \Delta w^T = \Delta x_S. \tag{26}$$

Plugging the optimal wage gaps in (26) into the optimal effort functions in (24) and (25), we have the symmetric optimal effort level at the solution as

$$e_i^I(\Delta w) = \frac{1}{2}\bar{\lambda} f(1,1)\Delta x_S$$

and

$$e_i^T(\Delta w) = \frac{1}{2}\underline{\lambda} f(1,1)\Delta x_S.$$

The optimal wage gap Δw^I in (26) and symmetric effort function $e_i^I(\Delta w^I)$ in (24) together with

[5] The Euler's theorem implies $e_A f_A(e_A, e_B) + e_B f_B(e_A, e_B) = f(e_A, e_B)$. Next, with symmetry, $f_A(e_A, e_B) = f_B(e_A, e_B)$ whenever $e_A = e_B$. Putting these properties together, the homogeneity in f implies $2f_A(e_A, e_B) = f(1,1)$ whenever $e_A = e_B$.

the participation constraint in (17) imply that the maximum expected profit with IBIS is [6]

$$\bar{\lambda}_1 f(e^I(\Delta^I))[\Delta x_S - \Delta w^I] + x_F - 2w_0^I = \left(\frac{\bar{\lambda}_1 f(1,1)\Delta x_S}{2}\right)^2 + x_F.$$

Similarly, the optimal wage gap Δw^T in (26) and symmetric effort function $e_i^T(\Delta w^T)$ in (25) together with the participation constraint in (19) imply that the maximum expected profit with TBIS is

$$\underline{\lambda} f(e^T(\Delta^T))[\Delta x_S - 2\Delta w^T] + x_F - 2w_0^T = \left(\frac{\underline{\lambda} f(1,1)\Delta x_S}{2}\right)^2 + x_F.$$

The rest of the proof follows directly from the preceding maximum profits with IBIS and TBIS.

[6]Notice that we applied the fact that $f(e_A^I(\Delta^I), e_B^I(\Delta W^I)) = e_A^I(\Delta w^I) f(1,1)$ in deriving the following expression for the maximum profit with IBIS.

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