THREE ESSAYS ON BEHAVIOURAL CONTRACT THEORY

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<u>Certified that the Thesis entitled</u>

Three Essays on Behavioural Contract Theory submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under the supervision of **Prof. (Dr.) Swapnendu Bandyopadhyay, Professor, Department of Economics, Jadavpur University** and neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere/elsewhere.

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CONTENTS

CHAPTER 1

OVERVIEW

1.1. Introduction

"The purely economic man is indeed close to being a social moron. Economic theory has been much preoccupied with this rational fool."

— Richard H. Thaler, *Misbehaving: The Making of Behavioural Economics*

After the emergence of experiments in economics the economic literature has grown rapidly and have moved away quite a lot from individual rationality defined by pure self-interestedness. Even though stalwarts like Samuelson, Friedman and Hayek had suggested that economics is unamenable to scientific experiments, experimental results have shown that our dinner is not always dependent on the self-interestedness of 'the butcher, the brewer, or the baker'. There is something more to it. The effects of psychological, emotional, cultural, cognitive and social factors which almost remained out of the purview of 'classical economic theory' should be integrated with individual or institutional decision making. The concept of *homo economicus* can be made more robust by incorporating human psychological behaviours. People show positive traits like compassion, love, care for others and also negative traits like envy, jealousy, spite etc. Evidence of this can also be found in the experimental literature. Experimental results show that spitefulness (Van Lange (1999), Fehr, Hoff and Kshetramade (2008)), altruism, fairness (in experiments on dictator game) play an important role in decision making. In the experimental version of the ultimatum game, (Guth et. al. (1982)) it has been observed that 17 out of 21 proposers offered equal to or more than twenty percent of their initial endowments. This number went up from 17 to 18 when the same experiment was repeated. The number of rejections of such offers were one initially but in the repeated experiment it went up to four. This generosity of the proposer which is a clear deviation from the theoretical predictions can only be attributed to fairness (Rabin (1993)) and altruism. The respondent is ready to suffer a utility loss by rejecting a small offer as it is more than compensated by observing the proposer losing a larger amount. In other variations of the ultimatum game, it has been observed that respondents were more concerned about equitable payoffs rather than absolute payoffs (Fehr, Hoff and Fischbacher (2003)). In later versions of the same experiment similar results were observed. In dictator game experiment (Forsythe et. al. (1994)) fifty five percent proposers offered amount equal to or more than twenty percent of the initial endowment as opposed to forty five percent offering nothing to the respondents. This clearly shows the role of altruism in cognitive decision making as even without the fear of rejection many proposers offered non-zero amounts. Psychological behavioural patterns also play a role in a country's overall economic development. Zak and Knack (2001) in their general equilibrium growth model have shown that in social, economic and institutional environments with low trust will have low investment which eventually will dampen long run growth. This increases the possibility for such societies to get into poverty traps. The importance of trust and reciprocity was observed in an investment setting by Berg, Dickhaut and McCabe (1995). Their observation suggests that reciprocal behaviour exists in human behaviour. The game was repeated another time and it was seen that on average there was more trust and trustworthiness. Here there is one sender and one receiver. The sender is ready to offer a non-zero amount to the receiver (through the experimenter, who multiplies this amount by some multiplication factor) in expectation of a higher amount. Common theory suggests that the sender being a self-interested individual should send zero and the receiver being another self-interested person should do the same. But in effect we see senders trusting the anonymously paired receiver whereas on the other hand the senders reciprocate the same trust.

The psychological behaviour of individuals can be modelled under a principal-agent framework to analyze the nature of contracts. Some studies have attempted the same.

1.2. Survey of Literature

Various experimental evidences have proved the existence of other-regarding preferences in behavioural decision making (Guth, Schmittberger & Schwarze (1982), Camerer (2003))[1]. In fact relaxing the self-regarding hypothesis is crucial for contract theory since the aim is to design appropriate incentives, and therefore people's attitude towards other's wellbeing as well as his own wellbeing is crucial for incentive design. However, far little work has been done to see how classical contract-theoretic predictions change in the presence of other-regarding preferences.

Few recent papers have addressed the issue of incorporating other regarding (or social) preferences into contract theory[2]. Two of the initial important papers that addressed other regarding preferences in hidden action framework are Itoh (2004) and Englmaier and Wambach (2010). Itoh (2004) is in fact one of the earliest to focus on other-regarding preferences in a moral hazard framework. He, in a discrete effort framework, looked into the interaction between a self-regarding principal and an other-regarding agent and showed that the principal is in general worse-off the more other-regarding the agent is. Although Itoh (2004) briefly mention other-regarding principal, he didn't analyze it in detail. Englmaier and Wambach (2010)[3] address optimal incentive contracts with inequity-averse agents and show that many of the standard contract theoretic predictions doesn't hold when agents are inequity averse. In their model both effort and project outcomes are continuous. But they do not focus on other-regarding principal. Dur and Glazer (2008) use a principal-agent model with contractible effort to study profit-maximizing contracts when a risk-averse worker envies his employer. They show that with an envious agent the principal can optimally offer a profit-

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[1] For a comprehensive survey of these experimental studies see Fehr and Schmidt (2003).
[2] For a survey on this topic see Englmaier (2005).
[3] They focus on continuum of outcomes whereas we focus on discrete outcomes in chapter 2 and continuous outcome is dealt with in the next chapter.

sharing contract even when the effort is contractible. This runs contrary to the standard notion in contract theory[4]. They also show that envy tightens the worker's participation constraint and calls for higher pay and/or a softer effort requirement. Englmaier and Leider (2008) incorporate reciprocal preferences in line with Rabin (1993), Dufwenberg and Kirchsteiger (2004) and/or Falk and Fischbacher (2006) into a moral hazard framework and derive properties of the optimal contract and implications for organizational structure but with a self-regarding principal.[5]

The issue of vertical comparison is also not uncommon in contract theory literature. In a labour market experiment by Charness and Kuhn (2004) it was found that agents are much more concerned about the employer than other agents in terms of fairness. Earlier papers, such as Akerlof (1982), Rabin (1993) and Dur and Glazer (2008) talk about fairness issues and ‘vertical’ comparison where agents compare themselves with their bosses. Thus, people are not only concerned about their own payoffs but also about how much they are better off compared to others, viz. higher-ups.

There are several papers that deals with multi-agent problems in principal agent model. In case of multi-agent situation, the question of team contract and relative performance contract arises. The impact of an increase of one agent’s project outcome on the wage of another agent employed in another project (cross wage effect) can be either positive (team contract) or negative (relative performance contract) or zero (independent contracts). Initially, economic theory on incentives mostly focussed on relative performance contracts which discourages possible cooperation and increases competition among co-workers (for an overview see Hart and Holmstrom (1987)). But this strand of work failed to explain the lack of relative

[4] In standard hidden action with contractible effort the principal optimally offers a fixed wage contract to an agent.
[5] Also, Hart and Moore (1998) incorporate social preferences into a contracting problem but that was done in an incomplete contracting framework. Other papers that address contracting with loss-averse agents are de Meza and Webb (2007) and Herweg, Muller, Weinschenk (2010).

performance contracts that we see in reality over the years.[6] Works by Holmstrom & Milgrom (1990) & Itoh (1993) show that a principal can be better off by offering a team contract that induces cooperation in a static setup. Several other papers such as Varian (1990), Ramakrishnan and Thakor (1991), Macho-Stadler and Perez-Castrillo (1993) and also Itoh (1992) discuss the importance of encouraging employees' cooperation, pointing towards the optimality of offering team contracts. Che and Yoo (2001) specifically address this issue and show the optimality of team or joint production over individual production in both static and dynamic framework.

There is a huge body of literature that examines the optimality of team production vis-à-vis non-team production (specifically relative performance evaluation) in the presence of social preferences. Papers by Itoh (2004), Englmaier and Wambach (2010), Bartling (2011), Bartling and Siemens (2010) show that it might be optimal for the principal to adopt team contracts over other forms of contracts.[7] These papers, in a multi-agent setting, explained the optimality of team production (team incentives) mainly through the existence of inequity aversion among agents. In these papers the agents have social preferences (inequity-averse), but the principal is assumed to be self-regarding. In the last core chapter of this dissertation, we make an attempt to explain the existence of team production in terms of the existence of social preferences both of the principal and the agent which is a crucial difference compared to the above cited papers.[8]

[6] For more see Jensen and Murphy (1990), Holmstrom and Milgrom (1991, 1994) and also Che and Yoo (2001) for more.

[7] Other papers that address the effect of social preferences and comparison in multi agent setting are Demougin and Fluet (2006), Goel and Thakor (2006), Neilson and Stowe (2010) and Rey Biel (2008). For more references see Banerjee (2020).

[8] In addition to this, social comparisons within the boundaries of the firm influence the design of the firm through selection of production technologies (see Nickerson and Zenger (2008) and Obloj and Zenger (2017).

1.3. Motivation and Outline of The Thesis:

The existing literature mostly deals with self-regarding principal and other-regarding agent(s). But since principal and agents are both social animals it is not very unusual for them to show more than just self-regardingness. Recent literature and experiments have also suggested the presence of social comparison in human decision making. This common human behaviour is well articulated by distinguished professor of behavioural economics and Nobel Memorial Prize winner of 2017, Richard H. Thaler in his celebrated work *Misbehaving: The Making of Behavioural Economics*. He criticizes the notion of assuming an 'economic man' as a 'social moron' and a 'rational fool'. In principal agent models this holds true as well. As is previously mentioned that experiments on dictator game, ultimatum games have also shown the existence of social comparisons in decision making. In existing literature, the agents are assumed to be other-regarding whereas the principal is assumed to be a 'rational fool' only concerned about his own monetary payoff. Till date the only paper that specifically addressed other-regarding principal is Banerjee and Sarkar (2017). They characterize in detail the optimal contracts when first an other-regarding principal interacts with a self-regarding agent. They show that the optimal contract differs considerably when the principal is 'inequity averse' vis-a-vis the self-regarding case. They also analyze in some detail the interaction of an other-regarding principal with an other-regarding agent. In their paper the principal can be both 'in-equity averse' and/or 'status-seeking' and they concentrate on discrete efforts only. There is still scope for further research with a more general structure with continuous effort and output levels. The structure can also be made more generalized. We try to study how the optimal contract changes with an other-regarding principal and agent(s). We also study a comparison between individual production (single agent hired) and team production (two agents hired) under the presence of social preferences.

In chapter 2, we formulate a simplified principal-agent model with discrete outcomes and continuous effort choices. The principal (employer) has hired an agent (employee) to work in a project. The agent puts in effort into the project. The outcome of the project is verifiable whereas the effort of the agent is not. This creates a moral hazard problem. Since the effort is non-verifiable therefore the agent is paid according to the outcome of the project. High output indicates higher effort was exerted. But high effort does not always guarantee high output even though the chance of realizing higher output increases. The optimal incentive contract is calculated for self-regarding principal and agent as a benchmark case. It is found that for lower outside option, principal optimally shares the gross payoff equally if the project succeeds when both are self-regarding. For higher outside option participation constraint binds and the success wage increases with increased outside option of the agent. Then principal is assumed as spiteful and agent is assumed to be self-regarding. Spitefulness is in the sense that the principal always likes to be ahead of the agent in terms of payoff. It gives her an additional utility by being ahead. Here, it is found that the wage offered and the optimal effort will be lower than the self-regarding benchmark setup. A self-regarding agent is weakly better off with a less spiteful principal. Then finally the principal and the agent both are considered to be other-regarding in nature. The principal is spiteful who likes being ahead and the agent suffers from a disutility by being behind in terms of payoff from the principal. Under this structure optimal wage is weakly decreasing with respect to principal's spitefulness. The optimal wage is positively related with the inequity averseness of the agent. These results are quite intuitive as a highly spiteful principal will offer lower wage since he likes being ahead of the agent. An inequity-averse agent on the other hand will prefer to reduce the payoff difference so with increased inequity-averseness success wage will increase. This success wage is compared with the previous two cases and it is found that this success wage lies between the benchmark case (both self-regarding) and only principal other-regarding case. When the principal and the agent have exactly opposite other-regardingness, we get the self-regarding benchmark results. A few other alternative specifications for the other-regarding function are done as extensions and the main results qualitatively remain same.

In chapter 3, the model of spiteful principal and inequity-averse agent discussed in chapter 2 is generalized with continuous output level. The principal is other-regarding in nature. Here other-regardingness can be of two types: inequity-averseness and status-seeking (spiteful). Both are considered for the analysis. This chapter is done following Englmaier and Wambach (2010). It is found that if the principal is non-linearly other-regarding then the optimal contract wage schedule is unlikely to be linear when effort is contractible. This result is different from the result found in Englmaier and Wambach (2010) where the wage contract is linear when effort is contractible. In Englmaier and Wambach (2010) the principal is assumed to be self-regarding. But here since the analysis is done with an other-regarding principal, it has been observed that the wage schedule will be linear if and only if the principal is linearly other-regarding. So, the Englmaier and Wambach (2010) result of linear wage contract holds with contractible effort only under this condition. It is also found that the wage offered by a status-seeking principal will be less than the wage offered by a self-regarding principal which will be lesser than the wage offered by a spiteful principal. When effort is non-contractible, optimal contract for risk-averse agent is strictly increasing even if when the principal is spiteful. It is also found that given the output level, the wage schedule is decreasing with respect to the spitefulness parameter of the principal and increasing with respect to the inequity averseness parameter of the agent. An agent with infinite concern regarding the inequity-averseness will be offered an equal share of the success output by the principal. Holmstrom (1979) stated that an agent’s wage should ideally depend on the output level of the project since it is an indicator for the effort exerted by the agent. If the output contains any component which is not an indicator of effort choice of the agent, then the optimal wage should not be dependent on that part. This sufficient statistics result of Holmstrom (1979) hold when both the principal and the agent have exactly opposite other-regarding preferences with same other-regarding functions. Otherwise, optimal wage schedule contains non-relevant information regarding the effort choice.

In chapter 4 which is a multi-agent extension or a generalization of chapter 3, here two agents are hired for working in two separate projects. Outcomes of the projects are verifiable by the principal but efforts of the two agents are not. The same Englmaier and Wambach (2010) model is followed for the analysis. The question of optimality of relative performance contract or team contract arises here. When two agents are hired for two separate projects then if the wage of one agent increases when the output of the other project rises then this type of contract is called team contract. But when a rise in one project's output leads to a fall in the wage of the other agent employed in the other project then it is called a relative performance contract. If output of one project has no impact on the wage of the other agent from the other project, then it is an unrelated contract. The relation between one project and the wage offered in the other project is referred to as cross wage effect. In this chapter both the principal and the agents are assumed to be other-regarding. The principal is other-regarding vis-à-vis the agents. The agent is inequity-averse vis-à-vis the principal and also vis-à-vis the other agent (peer comparison). Peer comparison also arises in this analysis because they are employed in two separate projects so they can be offered different wages. Different wages can cause a wage comparison and inequity-aversion. The analysis suggests that with not so high cross wage effect, a not so high status seeking principal or an inequity averse principal will offer a contract which is increasing with respect to its own output. Englmaier & Wambach (2010) showed the optimality of 'team contracts' when principal is self-regarding and agents were other-regarding and projects are technologically independent. The same result is generalized here with inequity averse principal under an additional condition of not so high own wage effect. On the other hand, under the same additional condition, with a sufficiently status-seeking principal a relative performance contract can be optimal if the agents' wages are far apart. It is also found that the wages offered to the agents rise when the agents are more concerned about their payoff difference vis-à-vis the principal. If the agents are not highly concerned about their payoff difference vis-à-vis the principal, then an increase in status-seekingness of the principal will lower the wages for both the agents. Agents are better off with a more inequity-averse principal. It has also been shown that the principal optimally removes the entire payoff difference between the agents by offering the agents equal wages if the agents are too much concerned about their own payoff differences. This is similar to the result found in Englmaier & Wambach (2010). With an increase in peer comparison, the wage gap of the two agents is optimally reduced by the principal.

In chapter 5, the principal compares between individual production and team production. The principal has a choice to hire one agent (individual production) or two agents (team production). This chapter is a generalization of Che and Yoo (2001). The same structure is followed for inequity-averse principal and agent(s). Che and Yoo (2001) has found that individual production is always optimum if synergy is not present in team. But here our result deviates when we introduce other-regardingness for principal and agent(s). Our findings suggest that an inequity-averse principal dealing with an inequity-averse agent will prefer team production over individual production even without synergy if and only if both of their inequity concerns are not very low. The principal having a high inequity-aversion and the agent having a very low inequity aversion will not suffice for the optimality of team production over individual production. For team production to be optimal without synergy both of their inequity-averseness should be non-trivially positive. It is also found that with a sufficiently high project outcome, the optimal wage increases with a rise in inequity-averseness parameter of the agent(s). The analysis is done for static and dynamic framework both. The dynamic framework is relevant as many times industrial contracts last for more than once. The repeated interaction throws some light on how the contract performs in the long run. It is observed that the principal is better off under repeated setting than under the static setting. The wage offered in the repeated setup is comparatively lower than the wage offered under static setup. It is also observed that under repeated interaction the principal is more likely to choose team production over individual production irrespective of the fact whether the team has synergy or not.

Finally, chapter 6 provides the summary of the results obtained in chapters 2 to 5 and sets out the agenda for future research. Bibliographical references are presented thereafter.

CHAPTER 2

OPTIMAL INCENTIVE CONTRACTS WITH A SPITEFUL PRINCIPAL: SINGLE AGENT (DISCRETE OUTCOMES)

2.1. Introduction:

Spiteful behaviour existed in human beings from times immemorial. It can stem from many things, one might be envy (Wobker (2015), Nickerson and Zenger (2008), Canen and Canen (2012)) or more generally from social comparison[9]. To be a bit more specific one might feel a loss in her wellbeing when she observes that others around her has achieved more compared to her[10] even if she has an increased payoff/achievement compared to an earlier reference point[11] and this can lead to the person becoming spiteful. Thus, spiteful behavior can originate from a sense of relative under-achievement although there can be various other factors like cultural[12], behavioral[13] and/or genetic[14].

There are various ways in which spite is conceived in the literature. One is the 'willingness of an individual to incur a cost to one-self in order to inflict harm on others even in the absence of any direct benefit' (Fehr and Fischbacher (2005), Smead and Forber (2013)). Another is 'desire to reduce another's material payoff for the mere purpose of increasing one's relative payoff'' (Fehr, Hoff and Kshetramade (2008)). In this chapter we define spite a la Fehr, Hoff and Kshetramade (2008), i.e. the '***desire to reduce another's material payoff for the mere purpose of increasing one's relative payoff***''.

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[9] For more on social comparison see Festinger (1954), Easterlin (1974), Clark and Oswald (1996), McBride (2001), Nickerson and Zenger (2008).
[10] Can be consumption, material payoffs or other forms of achievements, fame etc.
[11] For an earlier paper on envy see (Banerjee A.V. (1990)).
[12] See Cason, Saijo & Yamato (2002), Durham (1974), Gentis, Bowles, Boyd and Fehr (2003), Zeigler-Hill, Noser, Roof, Vonk and Markus (2015).
[13] See Wobker (2015), Brandts, Saijo and Schram (2004) and Loewenstein (2000).
[14] For more on Hamiltonian Spite see Hamilton (1964, 1970).

Social psychologists have found evidence of spiteful behavior in individuals (Van Lange 1999). Van Lange examined social preferences of more than 2000 individuals in Netherlands and found that approximately 12-13 percent of the subjects were willing to pay for increased in-equality. He found that these subjects preferred an allocation (480 for self, 80 for other) over (540 for self, 280 for other), in the process sacrificed own absolute payoff and total overall surplus for the sake of increased in-equality between 'self' and the 'other'.

In many cases spiteful preferences pose serious obstacle to trade, cooperation and in the overall process of development. Fehr, Hoff and Kshetramade (2008) in an experiment conducted in the state of Uttar Pradesh, India found evidence of spiteful behavior among upper caste people in the sense that the upper caste preferred increased in-equality vis-a-vis the lower caste and this led to persistence of underdevelopment in that particular region. This was contrary to the popular belief that in developing countries where institutions and contract enforcement is weak, social preferences should induce cooperation and reciprocal behavior, thus negating the contract enforcement problem. But negative social preferences such as spite can in fact aggravate the problem through reduced cooperation and the desire to reduce other party's payoff, leading to increased in-equality. More striking is the possibility that since caste is inherited from predecessors these preferences can cause underdevelopment to persist across generations.

The target of this chapter is to flesh out some of the contract theoretic implications of spite, and therefore will fall in the realm of 'behavioral contract theory'. We study the interaction of a spiteful principal first with a self-regarding agent and then with an in-equity averse agent. The principal is spiteful a la Fehr, Hoff and Kshetramade (2008). We assume that the principal is always ahead and derives additional pleasure from being ahead. An inequity-averse agent suffers utility loss from being behind. We show that the spiteful principal optimally offers (weakly) lower wage to the agent compared to the self-regarding benchmark and this wage falls with increased spitefulness. Whereas when the agent is inequity averse then the optimal wage will depend on the relative strength of the principal's spitefulness and the agent's inequity-aversion. For lower outside option of the agent, if the degree of spitefulness is exactly equal to the degree of inequity aversion optimal wage will be exactly equal to the self-regarding benchmark. Otherwise, the principal will optimally offer lower success wage vis-à-vis the benchmark. Thus, this chapter throws light on the fact that given similar other-regarding functions ('symmetric' in this sense) if the principal and the agent have exactly opposite other-regarding preferences, in some cases, we get back the self-regarding benchmark. For higher outside option such that the agent's participation constraint binds the principal will optimally offer (weakly) lower success wage vis-a-vis the benchmark. Throughout our analysis we assume effort to be continuous. This is an important distinction of this analysis with Banerjee and Sarkar (2017). We model other regarding preferences in line with the distributional approach a la Fehr and Schmidt (1999) and Nelson and Stowe (2003). As we proceed, we provide alternative specifications of other-regardingness and examine the possible changes in the optimal contractual structure. In addition to this we also provide an alternative modeling approach to spitefulness where spite is defined in our context as '**the desire to reduce agent's wage**'. We show that our main results go through with this changed specification as well.

The rest of the chapter is organized as follows: In section 2.2 we examine the benchmark self-interested principal-agent case. In section 2.3 we analyze the interaction between a spiteful principal and self-regarding agent. Section 2.4 analyzes the case where the principal is spiteful and the agent is in-equity averse. Section 2.5 provides an alternative modelling approach to spitefulness and derives qualitatively similar results. Section 2.6 talks briefly about the principal being behind interacting with a spiteful agent. Section 2.7 concludes the chapter.

2.2. The Self-interested Benchmark:

We start with the standard self-interested benchmark where a *self-interested* principal and a *self-interested* agent interact. Both the principal and agent are risk-neutral. The principal hires an agent for engaging in a project, where the agent can choose effort denoted by $e \in [0,1]$ which can also be taken as the probability of success. Effort is non-verifiable and hence non-contractible. Cost to the agent for implementing effort e is $\frac{e^2}{2}$. The project can either succeed or fail. The project returns b in case of success and 0 in case of failure and the project outcome is verifiable[15].

The timing of the game is as follows: the principal offers a wage contract $\{w_s, w_f\}$ where the agent is paid w_s in case of success and w_f if the project fails where $w_s \geq w_f$. We assume that $w_j \geq 0$, $j = s, f$, which implies that a limited liability (LL) constraint operates and therefore the agent cannot be paid a negative amount. The agent then can either accept or reject the contract. If rejected, the game ends and the agent receives her outside option u and the principal receives 0. If accepted the contract starts, the project outcome is then realized and wages are paid accordingly. The principal's optimization problem is therefore

$$\text{Max } U_P = e(b - w_s) - (1-e)w_f$$

subject to the following participation constraint

$$ew_s + (1-e)w_f - \frac{e^2}{2} \geq u$$

the incentive compatibility constraint given by

[15] Without loss of generality we focus on two outcomes. Our results hold if we consider continuum of outcomes.

$$e = \arg\max\left\{ e w_s + (1-e) w_f - \frac{e^2}{2} \right\}$$

and the limited liability constraints $w_s \geq 0$ and $w_f \geq 0$. At the optimum the limited liability constraint will bind and therefore we get $w_f = 0$ implying that the principal will optimally pin down the failure wage to zero. The above incentive compatibility constraint can be written as $e = (w_s - w_f) = \Delta w$ let. Therefore internalizing all the above constraints we can rewrite the above optimization problem as

$$\text{Max } U_P = w_s (b - w_s)$$

$$\text{s.t. } w_s \geq \sqrt{2u}$$

Before proceeding we clarify a technical point that at $u \geq \frac{b^2}{8}$ the participation constraint binds and at $u = \frac{b^2}{2}$ the expected payoff of the principal goes to zero which gives us the upper bound of u that we should consider. Given this, it is straightforward to calculate the optimal contract and is formalized in the following proposition:

Proposition 2.1:

(a) If $u \in [0, \frac{b^2}{8})$ *then the optimal contract is characterized as* $\left\{ w_s{}^* = \frac{b}{2}, w_f{}^* = 0 \right\}$.

(b) If $u \in \left[\frac{b^2}{8}, \frac{b^2}{2} \right]$ *the optimal contract is given as* $\left\{ w_s{}^* = \sqrt{2u}, w_f{}^* = 0 \right\}$.

(c) Optimal effort is given as $e^* = w_s{}^*$.

Thus for low outside option the principal optimally shares the gross payoff equally from a successful project. For high outside options such that the participation constraint binds the success wage increases with increased outside option of the agent. Given this we consider the case of a spiteful principal interacting with a self-regarding agent.

2.3. Spiteful Principal and Self-regarding Agent:

Suppose the principal is spiteful in the sense that she enjoys being ahead of the agent always. Similar in approach to Dur and Glazer (2008) we will only consider cases where the principal is always (weakly) ahead of the agent[16]. Thus we abstract from issues related to how agents (employees, workers) feel as they are relatively better off and therefore we abstract from agents' status concerns[17]. Therefore the utility function of the principal is not only a function of her own material payoff but also of the agent's material payoff[18]. We work with a modified version of a piecewise linear utility function due to Fehr and Schmidt (1999) with modifications by Neilson and Stowe (2003). The function captures a broader class of other-regarding preferences viz. 'inequity-aversion' and 'spitefulness' (or may be 'status-seeking')[19]. All the other basic assumptions are kept same as the benchmark case. Since we assume that the principal is weakly ahead always, following Fehr and Schmidt (1999) and Neilson and Stowe (2003) we can write the utility function of the principal if the project succeeds as

$$U_P = b_j - w_j - \pi\rho f(b_j - 2w_j) \quad \text{where } b_j - w_j \geq w_j{}^{20},\ j = s, f \tag{1}$$

where $f'(b_j - 2w_j) > 0$, $f(0) = 0$. In this chapter specifically we focus on a 'spiteful' principal who enjoys being ahead and therefore $\rho < 0$. $\pi > 0$ represents the 'spitefulness parameter' (other regarding parameter) of the principal. The greater is π the more spiteful the

[16] Since employees hardly earn more than the employers barring a few exceptions like professional sports we ignore that possibility. See Dur and Glazer (2008) for more on this approach.
[17] See Itoh (2004) and Banerjee and Sarkar (2017) for analysis on status seeking agents.
[18] For more on other regarding preferences and different approaches see Itoh (2004).
[19] See Itoh (2004), Banerjee and Sarkar (2017) for a similar approach.
[20] Itoh (2004) also works with the same function. Here we take the agents payoff to be her wage. One can alternatively specify agent's payoff net of her effort cost, i.e. $w - d$ and it is straightforward to extend our analysis in this direction.

principal. To make matters specific and tractable assume $\rho = -1$. This will not affect our results qualitatively. Therefore with this simple modification the principal's utility function will have the following form

$$U_P = b_j - w_j + \pi f(b_j - 2w_j) \quad \text{where } b_j - w_j \geq w_j \tag{1a}$$

Therefore as mentioned previously we model spite in the sense of the '***desire to reduce another's material payoff for the mere purpose of increasing one's relative payoff***'. One can proceed with the general functional form $f(b - 2w_j)$ as in Banerjee and Sarkar (2017), but for better tractability of our model and for the sake of closed form solutions we make the specific assumption that $f(b_j - 2w_j) = b_j - 2w_j$ which satisfies $f'(b - 2w_j) > 0$. Fehr and Schmidt (1999) use such a simplified specification in their paper[21]. In case of failure, since $b_f = 0$ and $w_f = 0$ (limited liability binds as we will see), the net utility of the principal will be zero. Internalizing the limited liability constraint we can now state the optimization problem that the principal faces

$$Max \ \ \mathrm{e}[b - w_s + \pi(b - 2w_s)]$$

Subject to the following incentive compatibility constraint and the participation constraint

$$e = w_s \tag{IC}$$

$$ew_s - \frac{e^2}{2} \geq u \tag{PC}$$

Again internalizing the incentive compatibility constraint the optimization problem becomes

$$Max \ \ w_s[b - w_s + \pi(b - 2w_s)]$$

[21] Fehr and Schmidt (1999) term this as 'linear inequity aversion' (linear spitefulness in our context).

Subject to $w_s \geq \sqrt{2u}$.

Solving the above maximization problem we can characterize the optimal contract as

Proposition 2.2:

(a)If $u \in [0, \frac{k^2b^2}{8})$ *then the optimal contract is* $\left\{\tilde{w}_s = \frac{kb}{2}, \tilde{w}_f = 0\right\}$ *where* $k = \frac{(1+\pi)}{(1+2\pi)} < 1$. *Optimum success wage falls with increased 'spitefulness' of the principal.*

(b) If $u \in \left[\frac{k^2b^2}{8}, \frac{k^2b^2}{2}\right]$ *the optimal contract is given as* $\left\{\tilde{w}_s = \sqrt{2u}, \tilde{w}_f = 0\right\}$.

(c) A self-regarding agent is weakly better-off with a less 'spiteful' principal.

(d) Optimal effort is given by $\tilde{e} = \tilde{w}_s$ *and is (weakly) lower compared to the benchmark case.*

Computing the above optimal contract is straightforward and is omitted for brevity. The existence part is relegated to the appendix. It is worth mentioning that the principal's expected payoff becomes zero when $u = \frac{k^2b^2}{2}$. Note that a spiteful principal will optimally lower the success wage compared to the self-interested benchmark when the agent's outside option is low. Since the agent's participation constraint doesn't bind for $u \in [0, \frac{k^2b^2}{8})$ and the principal gets additional pleasure from being ahead, the principal can optimally lower the agent's wage and also get the agent to accept the contract. Also the more 'spiteful' the principal lower will be the wage that she will offer. The optimal success wage $\tilde{w}_s = \frac{kb}{2}$ increases in b with slope $\frac{k}{2} < \frac{1}{2}$ since $k < 1$. Thus the optimal contract is a linear sharing rule similar to Englemair and

Wambach (2010) but with the slope less than $\frac{1}{2}$. For high outside option such that the participation constraint binds the principal has no other option but to offer $\tilde{w}_s = \sqrt{2u}$ and which is again (weakly) less than self-regarding benchmark since the outside option depends on the principal's spitefulness. Since the success wage is (weakly) lower compared to the benchmark case the optimal effort put in by the agent is also (weakly) lower. Therefore with spiteful principal the inefficiency is greater vis-a-vis the self-regarding benchmark.

2.3.1. Alternative Specification:

In an alternative specification of the above model, we assume that the principal compares him payoff $(b - w_s)$ with agent's net payoff i.e. $(w_s - \frac{e^2}{2})$ making him a benign principal since the net payoff is lesser than the agent's actual payoff. **We can justify this case by pointing out that the principal might observe e but cannot verify it to a third party or a court. Therefore, the principal will be able to compute $(w_s - \frac{e^2}{2})$ and compare it with $(b - w_s)$ but still cannot write a contract contingent on e.** Given this clarification we proceed to analyze the optimal contract in this situation. The agent is assumed to be self-regarding as before. The utility function of the principal under the current specification is given as

$$U_P = b_j - w_j + \pi(b_j - 2w_j + \frac{e^2}{2}), j = s, f, \; i = 0,1.$$

Under this specification the principal will derive some benefit from spite even when the project fails since the agent puts in effort and the principal takes into account the agent's effort cost. That is the principal will get utility $\frac{\pi e^2}{2}$. Give this the expected utility of the principal can be written as

$$EU_P = e\left[b - w_s + \pi\left(b_s - 2w_s + \frac{e^2}{2}\right)\right] + (1-e)\frac{\pi e^2}{2}$$

$$= e[b - w_s + \pi(b_s - 2w_s)] + \frac{\pi e^2}{2} \qquad (1b)$$

The PC and IC will be same as they are in the previous subsection. By internalizing the IC the principal's problem boils down to:

$$\max_{w_s}\{b(1+\pi)w_s - \left(1 + \frac{3\pi}{2}\right)w_s^2\}$$

$$\text{Subject to } w_s \geq \sqrt{2u}$$

Solving above we can state the following proposition which is similar in spirit to proposition 2:

Proposition 2.2.1:

(a) If $u \in \left[0, \frac{k_1^2b^2}{8}\right)$ *the optimal contract will be* $\left\{\tilde{\tilde{w}}_s = \frac{k_1 b}{2},\ \tilde{\tilde{w}}_f = 0\right\}$ *where* $k_1 = \frac{(2+2\pi)}{(2+3\pi)} < 1.$

Optimum success wage falls with increased 'spitefulness' of the principal.

(b) If $u \in [\frac{k_1^2b^2}{8}, \frac{k_1^2b^2}{2}]$ *the optimal contract is given as* $\left\{\tilde{\tilde{w}}_s = \sqrt{2u},\ \tilde{\tilde{w}}_f = 0\right\}$.

(c) Optimal effort is given by $\tilde{\tilde{e}} = \tilde{\tilde{w}}_s$ *which is higher than when the agent deals with a not so benign principal.*

(d) The agent is better off dealing with a more benign principal.

Note that $k_1 - k = \frac{\pi(1+\pi)}{(3\pi+2)(2\pi+1)} > 0$ and therefore the principal pays more success wage compared to the previous case. As a consequence the optimum effort put by the agent at the optimum will also be higher. This is not surprising since in this situation the principal is 'benign' and therefore the agent is better off dealing with a more benign principal. The rest are similar to the previous section.

Given above now we proceed and consider the case of a spiteful principal interacting with an inequity-averse agent.

2.4. Spiteful Principal and Inequity-Averse Agent:

We extend our model of the previous section and assume the agent to be in-equity averse. Since the agent is behind she can only be in-equity averse. Similar to section 2.3 we model agent's in-equity aversion similar to Fehr and Schmidt (1999) and is given below

$$U_A = w_j - \alpha v(b_j - 2w_j)\,,\; j = s, f \tag{2}$$

where $\alpha > 0$ captures the degree of agent's inequity aversion. The agent suffers disutility from being behind when the project succeeds since $b_s - 2w_s > 0$ and the greater is $(b_s - 2w_s)$ the more will be the utility loss from inequity aversion. When the project fails $b_f = 0$ and $w_f = 0$ (the limited liability will indeed bind) and therefore the agent doesn't suffer any utility loss. Thus we should have $v'(b_j - 2w_j) > 0$, $v(0) = 0$. Similar to our approach in the previous section (linear inequity-aversion a la Fehr and Schmidt) for better tractability we assume $v(b_j - 2w_j) = b_j - 2w_j$ which satisfy the assumptions on $v(.)$. Since the limited liability constraint will bind at the optimum we internalize that as we proceed. But before that we need to make the following assumption:

Restriction 2.1: *The principal's degree of spitefulness is not less than the agent's degree of inequity aversion, i.e.* $\pi \geq \alpha$.

The above parametric restriction ensures that at the optimum the principal is ahead (at least weakly) which is one of our primitive assumptions. If this doesn't hold then at the optimum, under certain situations, the principal will be behind and the utility functions defined in (1) and

(2) will not be valid. Thus we might encounter a mathematical inconsistency. To address that and to fix ideas we impose the above restriction.

Given the above specification of the agent's utility principal's maximization problem becomes

$$\text{Max } e\left[b - w_s + \pi(b - 2w_s)\right]$$

subject to the incentive compatibility constraint given by

$$e = \arg\max\left\{e\left(w_s - \alpha(b - 2w_s)\right) - \frac{e^2}{2}\right\}$$

which can be re-written as

$$e = w_s - \alpha(b - 2w_s) \tag{IC1}$$

And the participation constraint given by

$$w_s \geq \frac{\sqrt{2u} + \alpha b}{(1 + 2\alpha)} \tag{PC1}$$

Taking into account all the constraints we get the optimization problem as

$$\text{Max } U^P = \left[w_s - \alpha(b - 2w_s)\right]\left[b - w_s + \pi(b - 2w_s)\right]$$

Subject to

$$w_s \geq \frac{\sqrt{2u} + \alpha b}{(1 + 2\alpha)}.$$

Before proceeding we need to remember that since the principal is always ahead we need $\frac{b}{2} \geq \frac{\sqrt{2u} + \alpha b}{(1 + 2\alpha)}$ which implies $u < \frac{b^2}{8}$. Given this we can solve the optimal incentive contract which is given in the following proposition:

Proposition 2.3:

(a) $\left\{\hat{w}_s = \frac{b\Delta}{2}, \hat{w}_f = 0\right\}$ *is the optimal contract if* $0 < u < \frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2$ *where* $\Delta = \frac{1+3\alpha+\pi+4\alpha\pi}{1+2\alpha+2\pi+4\alpha\pi} \leq 1$.

(b) In the above case the principal will optimally offer the self-regarding benchmark wage if $\pi = \alpha$*, i.e. the degree of spitefulness is exactly equal to the degree of in-equity aversion of the agent. Otherwise, the wage will be lower than the self-regarding benchmark.*

(c) Ceteris paribus increase in spitefulness of the principal leads to lower optimum success wage. The optimum success wage increases with a ceteris paribus increase in inequity aversion of the agent.

(d)If $\frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2 \leq u \leq \frac{b^2}{8}$ *the optimal contract is characterized as* $\left\{\hat{w}_s = \frac{\sqrt{2u}+\alpha b}{(1+2\alpha)}, \hat{w}_f = 0\right\}$. $\hat{w}_s$ *weakly increases with* α *for* $\frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2 \leq u \leq \frac{b^2}{8}$.

(e) The principal is always better-off dealing with a relatively less inequity-averse agent.

(f)Optimal effort is given by $\hat{e} = \hat{w}_s - \alpha(b - 2\hat{w}_s)$ *. Optimal effort will be exactly equal to the self-regarding benchmark iff agent's inequity aversion is equal to the degree of spitefulness of the principal.*

Proof:

Deriving the optimal contracts is straightforward. Regarding part (c) one can show that $\frac{\partial\Delta}{\partial\pi} = \frac{-(1+4\alpha+4\alpha^2)}{(1+2\alpha+2\pi+4\alpha\pi)^2} < 0$ implying that optimal success wage decreases with increased spitefulness of the principal. Again $\frac{\partial \Delta}{\partial \alpha} = \frac{\left(1+4\pi+4\pi^2\right)}{\left(1+2\alpha+2\pi+4\alpha\pi\right)^2} > 0$ implying that the more inequity averse the agent the higher will be the optimum success wage.

For part (d) first note that $[\Delta - 2\alpha(1-\Delta)] \le 1$ if $\Delta \le 1$. Now $\frac{\partial \hat{w}_s}{\partial \alpha} = \frac{b - 2\sqrt{2u}}{(1+2\alpha)^2} \ge 0$ if $u \le \frac{b^2}{8}$ and hence the result. If $\pi = \alpha$ implying $\Delta = 1$ then the range collapses to one point $u = \frac{b^2}{8}$ and $\frac{\partial \hat{w}_s}{\partial \alpha} = 0$. Part (e) follows from (c). In addition to this regarding (e) one can also show that $\Delta - k = \frac{\alpha(1+2\pi)^2}{\left(1+2\alpha+2\pi+4\alpha\pi\right)(1+2\pi)} > 0$ implying that the principal has to offer higher wage to an inequity averse agent compared to a self-regarding agent and therefore she would prefer a less inequity averse agent. Regarding (f) when $0 < u < \frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2$ optimal effort $\hat{e} = \frac{b\Delta}{2} - \alpha b(1-\Delta)$. When $\alpha = \pi$ then $\Delta = 1$ implying $\hat{e} = e^*$ otherwise $\hat{e} < e^*$. Again when the participation constraint of the agent binds implying $\frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2 \le u \le \overline{\overline{u}}$, optimal effort is given as $\hat{e} = \sqrt{2u}$. **QED**

The intuition of the part (b) of the above proposition is as follows: ceteris paribus a more spiteful principal will optimally reduce the success wage. But that would increase the inequity between the principal and the agent since the agent is assumed to be behind always. If the agent is inequity averse this will lead to a reduction in her utility and also her optimal effort. This leads to a fall in the principals expected payoff (expected utility). When $\alpha = \pi$ i.e. the degree of inequity aversion of the agent is exactly equal to the degree of spitefulness of the principal these two effects cancel out and the principal will optimally offer the self-regarding benchmark success wage. Otherwise, the principal will optimally reduce the success wage.

This implies that even if the principal and the agent are other regarding and if they are other-regarding with the same magnitude in the opposite direction we get back the benchmark result. Put differently 'symmetric' principal and agent (in terms of their utility functions) having opposite other-regardingness induces the self-regarding result.

Part (c) of the above proposition is straightforward. A more spiteful principal derives greater utility from being ahead and therefore will optimally increase the wage gap by reducing the success wage. On the contrary a more inequity-averse agent gets hurt from being behind and therefore increased inequity will lead to lower optimum effort being put in by the agent. This hurts the principal and therefore the principal optimally offers higher success wage with a ceteris paribus increase in the inequity aversion of the agent.

Intuition for part (d) is similar to the earlier proposition. If the agent's participation constraint binds the principal has no other option but to offer $\hat{w}_s = \frac{\sqrt{2u} + \alpha b}{(1+2\alpha)}$. Ceteris paribus increase in agent's inequity-aversion leads to increased success wage being offered by the principal and the intuition is similar to that of part (c). Finally, part (e) is a consequence of the fact that the principal has to offer a relatively higher success wage to a more inequity-averse agent and this hurts the principal. Therefore, the principal is better-off dealing with a less inequity-averse agent.

2.4.1. Alternative Specifications:

2.4.1.1. Specification 1:

Once again, we consider the case where the principal takes into account the effort cost of the agent while comparing her payoff $b - w_s$ with the 'net payoff' $(w_s - \frac{e^2}{2})$ of the agent whereas the agent doesn't take into account own effort cost while comparing payoff differences. The clarification given in section 3.1 applies here as well, **i.e. although the principal might**

observe e but cannot verify it to a third party or a court, the principal can factor-in e while comparing relative payofs. Thus, under the current specification the principal's expected payoff function will be similar to equation (1b) and after internalizing the incentive compatibility constraint $e = \{w_s - \alpha(b - 2w_s)\}$ the maximization problem faced by the principal will be

$$\max_{w_s} \left\{[w_s - \alpha(b - 2w_s)][b - w_s + \pi\left(b - 2w_s + \frac{w_s - \alpha(b-2w_s)}{2}\right)]\right\}$$

$$\text{Subject to } w_s \geq \frac{\sqrt{2u} + \alpha b}{(1+2\alpha)}$$

Similar to the previous section we need to assume the following in order to ensure that the principal is ahead at the optimum.

Restriction 2.2: $\alpha < \frac{\pi}{2(1+\pi)}$.[22]

The above restriction implies that $\alpha < 1, \forall\, \pi > 0$. Solving the above optimization problem we get the following proposition

Proposition 2.3a:

(a) The optimal contract for $u \in [0, \frac{b^2(1+\pi+\alpha)^2}{2(2+3\pi-2\alpha\pi)^2})$ *is* $\{\hat{\hat{w}}_s = \frac{b\Delta_1}{2},\ \hat{\hat{w}}_f = 0\}$ *where* $\Delta_1 = \frac{6\alpha+6\pi\alpha-4\alpha^2\pi+2\pi+2}{(1+2\alpha)(2+3\pi-2\alpha\pi)}$. *The optimal success wage decreases with increased spite of the principal and increases with increased in-equity aversion of the agent.*

(b) For sufficiently high outside option such that $u \in [\frac{b^2(1+\pi+\alpha)^2}{2(2+3\pi-2\alpha\pi)^2}, \frac{2b^2(1+\pi+\alpha)^2}{(2+3\pi-2\alpha\pi)^2}]$ *the optimal contract is* $\{\hat{\hat{w}}_s = \frac{\sqrt{2u}+\alpha b}{(1+2\alpha)},\ \hat{\hat{w}}_f = 0\}$. $\hat{\hat{w}}_s$ *increases weakly with the inequity-aversion of the agent.*

[22] In addition to this we need the technical assumption that $\alpha \neq \frac{\pi}{2(1+\pi)}$. Otherwise, a defined optimal success wage will not exist.

(c) *The optimal effort is given by* $\hat{e} = \hat{\hat{w}}_s - \alpha(b - 2\hat{\hat{w}}_s)$.

(d) *Ceteris paribus the principal is better off dealing with a less inequity averse agent whereas the agent is better off under a less spiteful principal.*

Proof:

Part (b), (c) and (d) of the above proposition are straightforward. For part (a) we get $\frac{\partial \Delta_1}{\partial \pi} = \frac{2(\alpha-1)}{(2+3\pi-2\alpha\pi)^2}$ which is certainly negative given restriction 2. The last proposition comes from the expression $\frac{\partial \Delta_1}{\partial \alpha} = \frac{2[4\alpha\pi^2(\alpha-1)+4\alpha^2\pi+5\pi^2+7\pi+2]}{(1+2\alpha)^2(2+3\pi-2\alpha\pi)^2}$. From restriction 2 we know that $\alpha < 1$. Thus the sign of the numerator seems ambiguous. Even if $\alpha \approx 0$ we get $\frac{\partial \Delta_1}{\partial \alpha} \approx \frac{2(5\pi^2+7\pi+2)}{(2+3\pi)^2} > 0$ which is positive, therefore one can conclude that $\frac{\partial \Delta_1}{\partial \alpha} > 0 \; \forall \; \alpha \in (0, \frac{\pi}{2(1+\pi)}]$. Hence the result.

QED

We can also assume the reverse that the agent takes into account her effort cost while comparing payoff differences whereas the principal doesn't. We explore that below.

2.4.1.2. Specification 2:

Let us now make the alternative assumption that the agent who is inequity averse compares her payoff net of effort cost with the payoff of the principal who doesn't take the effort cost of the agent into account. Restriction 1 still holds for mathematical consistency and the rest of the specification is the same as above. Given this changed specification the agent's utility function can be written as

$$U_A = w_j - \alpha\left(b_j - 2w_j + \frac{e^2}{2}\right), j = s, f.$$

So the principal will maximize her expected utility function given below:

$$e[b - w_s + \pi(b - 2w_s)]$$

subject to the incentive compatibility constraint

$$e = \arg\max\left\{e\left[w_s - \alpha\left(b - 2w_s + \frac{e^2}{2}\right)\right] - (1-e)\frac{\alpha e^2}{2} - \frac{e^2}{2}\right\}$$

$$=> e = \frac{w_s - \alpha(b - 2w_s)}{(1+\alpha)}$$

and the participation constraint (after internalizing the above incentive compatibility constraint) is given by

$$w_s \geq \frac{\sqrt{2u(1+\alpha)} + \alpha b}{(1+2\alpha)}$$

The optimal contract in the above case will be $\{\hat{\hat{w}}_s = \frac{b\Delta}{2},\ \hat{\hat{w}}_f = 0\}$ for all $u \in [0, \frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)})$ where Δ is defined as in Proposition 3 and $\{\hat{\hat{w}}_s = \frac{\sqrt{2u(1+\alpha)}+\alpha b}{(1+2\alpha)},\ \hat{\hat{w}}_f = 0\}$ for $u \in [\frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)}, \frac{b^2}{8(1+\alpha)}]$. The optimal effort is given by $\hat{\hat{e}} = \frac{\hat{\hat{w}}_s - \alpha(b-2\hat{\hat{w}}_s)}{(1+\alpha)}$. This effort is less than the effort when the spiteful principal was dealing with an agent who only compares their payoff not the net payoff. Note that for lower outside option the optimal success wage is same as that of the spiteful principal dealing with a less severe inequity averse agent (i.e. $\hat{\hat{w}}_s = \hat{w}_s$). This is slightly surprising since one would expect the optimal wage to increase given above specification. But note that the agent puts in lower effort which reduces principals expected payoff. To negate that the principal increases the success wage and at the margin the optimal success wage is exactly equal proposition 3 when outside option is low. But for sufficiently high outside option the optimal success wage is lower than that of proposition 3. The rest remains similar to proposition 3.

2.5. Alternative Modelling of Spitefulness:

In this extension we deal with an alternative specification of spite where spite is defined in this particular context as '**the desire to reduce agent's wage**'. Given this interpretation we model the utility function of the principal as $U_P = b_j - w_j - \rho\, w_j$, $j = s, f$ where ρ now measures the degree of principal's spitefulness. Everything else remains the same as the earlier model. When such a principal interacts with a self-regarding agent then the optimal contract can be characterized as $\left\{ \overline{w}_s = \frac{b}{2(1+\rho)},\ \overline{w}_f = 0 \right\}$ $\forall u \in \left[0, \frac{b^2}{8(1+\rho)^2} \right]$ and $\left\{ \overline{w}_s = \sqrt{2u}, \overline{w}_f = 0 \right\}$ $\forall u > \frac{b^2}{8(1+\rho)^2}$. For low outside option success wage falls with increased spitefulness of the principal. Also the principal will optimally offer lower wage compared to the self-regarding benchmark.

When such a spiteful principal interacts with an inequity-averse agent where agent's inequity aversion is defined in the sense of equation (2), the optimal contract can be found as

$$\left\{ w'_s = \frac{b[1 + 2\alpha + \alpha(1+\rho)]}{2(1+\rho)(1+2\alpha)}, w'_f = 0 \right\} \forall u \in \left[0, \frac{b^2[1+\alpha(1-\rho)]^2}{8(1+\rho)^2} \right]$$

and $$\left\{ w'_s = \frac{\sqrt{2u_0} + \alpha b}{(1+2\alpha)}, w'_f = 0 \right\} \; if\ u > \frac{b^2[1+\alpha(1-\rho)]^2}{8(1+\rho)^2}.$$

Note that $w' > \overline{w}$ implying that the principal optimally offers higher success wage to an inequity-averse agent than a self-regarding agent. The argument is similar to the previous case where the inequity aversion of the agent makes the participation constraint of the agent stringent and thus the principal has to offer relatively higher wage to make the agent accept the contract. Also w' increases with agent's degree of inequity aversion and falls with principal's degree of spitefulness. Note that we need to put the restriction that the principal is sufficiently spiteful in the sense $\rho \geq \frac{\alpha}{1+\alpha}$ in order to ensure that the principal is ahead always (at least weakly). Otherwise, we will once again encounter a mathematical inconsistency. Thus, even with this changed specification of spite one can generate similar results which are quite intuitive and therefore out results of section 2.3 and 2.4 are pretty robust.

2.6. Principal Behind and a Spiteful Agent: An Extension

So far, we have assumed that the principal is ahead. But now let's look into the situation where the principal is behind and the agent is ahead. We assume that the agent is aggressive and takes into account the difference between her net payoff ($w_s - \frac{e^2}{2}$) and the principal's payoff ($b - w_s$). Thus, we consider a case of an 'aggressive Spiteful' agent. As usual the agent is 'spiteful' in the sense that she enjoys being ahead. Therefore, the agent's utility function can be expressed as $U_A = w_j + \alpha\left(b_j - 2w_j + \frac{e^2}{2}\right)$, $j = s, f$. The principal instead of being spiteful is now inequity averse since he is behind and he takes into account the difference between w_s and $(b - w_s)$ to measure the payoff gap. Therefore, the principal's utility function can be expressed as $U_P = b - w_j - \pi(2w_j - b)$, $j = s, f$. The parameters π and α are now the inequity-aversion and spite parameters respectively. Since the principal is behind, for consistency we need $\alpha \geq \pi$ to hold. Therefore, in this case the principal will maximize her expected payoff $EU_P = e[b - w_s - \pi(2w_s - b)]$, subject to the standard incentive compatibility, participation and the limited liability constraints. Additionally, we have another constraint $w_s \geq \frac{b}{2}$ since we assume that the principal is never ahead in this situation. The optimal contract for the lower outside option will be $\{w_s''' = \frac{b\Delta}{2},\ w_f''' = 0\}$ for all $u \in [0, \frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)})$ where $\Delta = \frac{1+3\alpha+\pi+4\alpha\pi}{1+2\alpha+2\pi+4\alpha\pi} \geq 1$ given $\alpha \geq \pi$. Note that for $\alpha > \pi$, the principal will optimally pay more to the agent such that she herself remains behind. This is due to the fact that since the agent is spiteful, the agent enjoys being ahead and therefore will put more effort if paid more wage. This helps the principal on the effort aspect. But on the other hand, the principal is worse-off on two accounts. Since she is paying more her payoff goes down directly as well as through her in-equity aversion component since she is now further behind. Thus, the positive effort aspect and the negative reduction in payoff through increased wage work at opposite directions. If the spitefulness of the agent is sufficiently high than the in-equity aversion of the agent, the principal will optimally pay more to the agent even if she herself is behind. Again if $\alpha = \pi$ then both effects exactly cancel each other and we get back the benchmark for lower outside option. For higher outside option $u \in [\frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)}, \frac{b^2(1+\pi+\alpha)^2}{2(1+2\pi)^2(1+\alpha)}]$ the optimal contract is characterized as $\left\{ w_s''' = \frac{\sqrt{2u(1+\alpha)}+\alpha b}{(1+2\alpha)},\ w_f''' = 0 \right\}$ where $\frac{\sqrt{2u(1+\alpha)}+\alpha b}{(1+2\alpha)} \geq \frac{b}{2}$ implying $u \geq \frac{b^2}{8(1+\alpha)}$ which is automatically satisfied in this case. Given that the expected payoff of the principal is zero at wage rate $w_s = \frac{2(1+\pi)}{(1+2\pi)}\frac{b}{2}$ and this is always greater than $\frac{b}{2}$ (making the agent always ahead), here the limits differ from section 4.2.1. That is now the limit is $u \in [\frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)}, \frac{b^2(1+\pi+\alpha)^2}{2(1+2\pi)^2(1+\alpha)}]$ instead of $u \in [\frac{b^2(1+\pi+\alpha)^2}{8(1+2\pi)^2(1+\alpha)}, \frac{b^2}{8(1+\alpha)}]$. The optimal effort is higher since the agent is being paid more and he is ahead. The agent would prefer a lesser inequity-averse principal.

2.7. Concluding Observations:

First in a continuous effort hidden action framework with two outcomes we characterized the optimal contracts when a spiteful principal interacts with a single agent. The principal is always ahead in our model. We show that the principal optimally offers lower wage to the agent compared to the self-regarding case and this wage falls with increased spitefulness. If the agent is inequity averse then the optimal wage depends on the relative strength of the principal's spitefulness and the agent's inequity-aversion. For lower outside option of the agent if the degree of spitefulness is exactly equal to the degree of inequity aversion, optimal wage will be exactly equal to the self-regarding case. Same holds for higher outside option such that the agent's participation constraint binds where the principal offers weakly lower wage compared to the self-regarding benchmark[23].

The definition of spitefulness that we employ is that the principal derives an additional utility from increasing her payoff difference with the agent. There is an alternative definition of spitefulness viz. 'the willingness of an individual to incur a cost to one-self in order to inflict harm on others even in the absence of any direct benefit' we didn't employ. This can be one point of objection. But we conjecture that our main conclusions will go through with that definition as well.

To generalize the results found in this closed model a robust general form of other-regarding functions is introduced in the next chapter for both the principal and the agent. The output is also considered as continuous.

[23] For a discussion on empirical studies, stylized facts that support some of our findings see Englmaier and Wambach (2010). We avoid reproducing it here.

Appendix:

Existence of optimal contracts in Proposition 2.2:

Solution of the above proposition is straightforward. We only show the existence of the optimal contracts. $\forall\, u \in [0, \frac{k^2 b^2}{8})$ the principal's equilibrium payoff is $\pi^p = \frac{kb}{2}\left[\frac{(2b-kb)}{2} + \pi\,(b-kb)\right] > 0$ and agent's is $\pi^A = \frac{k^2 b^2}{8} > u$. Again $\forall\, u \in \left[\frac{k^2 b^2}{8}, \frac{k^2 b^2}{2}\right]$, $\pi^A = u$ and $\pi^p \geq 0$ given the definition of $u = \frac{k^2 b^2}{2}$. Thus, the above contracts are optimal. **QED**.

Existence of optimal contracts in Proposition 2.3:

$\forall\, u \in [0, \frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2)$ the principal's equilibrium payoff is $\pi^p = \hat{e}\left[\left(b - \frac{b\Delta}{2}\right) + \pi\,(b - b\Delta)\right] \geq 0$ since $\hat{e} \geq 0$, $\Delta \leq 1$ and agent's is $\pi^A = \frac{k^2 b^2}{8} > u$. Again $\forall\, u \in \left[\frac{b^2}{8}[\Delta - 2\alpha(1-\Delta)]^2, \frac{b^2}{8}\right]$, $\pi^A = u$ and $\pi^p \geq 0$. **QED**.

CHAPTER 3

OPTIMAL INCENTIVE CONTRACTS WITH A SPITEFUL PRINCIPAL: SINGLE AGENT (CONTINUOUS EFFORT AND OUTCOMES)

3.1. Introduction:

In this chapter we propose a model with general other-regarding functions and continuous output and efforts and show that optimal wage indeed falls with increased spite of the principal. This is a generalization of the structure introduced in chapter 2. In contrast with the previous chapter here the output level and other-regarding functions are in general form. We provide a reasonably detailed characterization of optimal contracts with spiteful principal and inequity averse agent in this general structure. The structure of Englmaier and Wambach (2010) is followed in the present chapter. Under the realistic case of non-contractible effort, the principal needs to compensate the agent more to reduce the utility loss as the agent is inequity averse. Following Englmaier and Wambach (2010), a spiteful principal can also elicit costly effort by reducing inequity. It is found that even though the exact nature of the contract is difficult to find out as there are many forces at play but it can be said that if agent's inequity averseness nature is dominant enough then the optimal wage is rising with respect to output. If risk-aversion of the agent is sufficiently lower, the spiteful principal will extract higher fixed amount. Similar to the result found in the previous chapter, here also under the general setup of single agent it is found that if the agent's concern for inequity rises then the principal offers higher wages to reduce the loss in utility of the agent. A principal with higher spitefulness will offer lower wages given the participation and incentive compatibility constraint. Holmstrom (1979)'s sufficient statistics results (which says that the optimal wage contract should ideally depend on that part of principal's profit which is dependent on the effort choice of the agent and not on some component which is not an indicator for the effort level chosen) are tested under the present setup. Interestingly we show that this result holds when the principal and the agent has exactly opposite other-regarding preferences, otherwise not. This, in essence, supports our conjecture that we go back to the benchmark when the principal and the agent has exactly opposite other-regarding preferences, a result we get in our closed form model discussed in the previous chapter. Thus, we show that in essence, almost all important results of our closed form model hold qualitatively in a reasonably general structure. We carry out the analysis in a single principal-agent framework; multiple agent case is done in chapter 4. In summary, this chapter is a robustness study of our closed form solutions where we provide a general structure with continuous outcomes and general functional forms.

The rest of the chapter is structured as follows: in the first part of section 3.2 the results are discussed when the effort level is assumed to be observable, the case without any moral hazard. The second part of section 3.2 is more realistic with non-contractible effort. Concluding remarks are discussed in section 3.3.

3.2. General Model of Spiteful Principal and Inequity-Averse Agent:

In this generalization we assume a standard principal-agent setup very similar to Englmaier and Wambach (2010) where a principal hires an agent to work in her project. The output of the project x is verifiable and it is continuously distributed in the interval $[\underline{x}, \overline{x}]$. The output follows the density function $f(x|e)$ which depends on the effort level exerted by the agent (e). The agent receives a wage $w(x)$ for working in the project. The more is the wage the more is the utility that she gets. The effort gives disutility to the agent the cost being $c(e)$ and $c'(e) > 0$. Following Fehr and Schmidt (1990) we assume the agent to be inequity-averse vis-à-vis the principal. The agent compares the principal's payoff $(x - w(x))$ with her payoff $w(x)$ and the more is the difference between the two i.e. $(x - 2w(x))$ the more is the disutility for the agent.

This disutility due to inequity function is given by $G(x - 2w(x))$. The function is assumed to be convex and therefore $G'(.)$ and $G''(.) > 0$ holds with the restriction that $G'(0) = 0$ and $G''(0) = 0$. In line with Dur and Glazer (2008), we focus on the case with principal always at least weakly ahead of the agent. This restriction helps us in simplifying our analysis a bit without losing much in terms of economic intuition and essence.

The utility function of agent is additively separable in utility from wealth $(u(w))$, inequity function $G(.)$ and effort cost $c(e)$. Mathematically,

$$U_A = u(w(x)) - \alpha G\big([x - w(x)] - w(x)\big) - c(e)$$

Here $\alpha(> 0)$ is the inequity-aversion parameter of the agent. The expected utility of the agent is

$$EU_A = \int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e)$$

The outside option for the agent is u. Therefore, the principal must offer a wage that makes the agent at least as well off as her outside option in terms of utility so the participation constraint is

$$EU_A \geq u$$

The principal is assumed to be risk neutral, interested in maximizing expected profit. The utility function of the principal is given as

$$U_P = x - w(x) + \pi S(x - 2w(x))$$

$\pi > 0$ is the spite parameter of the principal. The more is the value of $\pi > 0$, the more spiteful is the principal. $S(.)$ is the spite function with assumptions $S'(.) > 0$ and $S''(.) > 0$, with the restrictions that $S'(0) = 0$ and $S''(0) = 0$ holds.

The expected utility function of the principal is therefore

$$EU_p = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$

We further assume the monotone likelihood ratio property which says the more is the output realized the more is the possibility that high effort was exerted.

$$\frac{\partial\left(\frac{f_e(x|e)}{f(x|e)}\right)}{\partial x} = \left(\frac{f_e(x|e)}{f(x|e)}\right)' > 0$$

Following Innes (1990) we assume the slope of the optimal contract lies between 0 and 1 so that $0 \leq w'(x) \leq 1$ which is a reasonable assumption as an increase in output by one unit can not increase the wage more than one unit.

3.2.1. Contractible Effort:

First, we consider the case with no moral hazard i.e. the effort level e is contractible. Here, the principal maximizes her expected profit subject to the participation constraint only. The principal's problem can be stated as

$$\max_{w(x)} EU_p = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$

s.t. $\int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) \geq u$ (PC)

First, to fix ideas, we consider the case of a risk neutral agent. The agent is risk-neutral with respect to her wage, i.e. $u(w(x)) = w(x)$. The results that we get by solving the principal's optimization problem are summarized in the following proposition:

Proposition 3.1

(a). If effort is contractible then for a risk-neutral agent the optimal wage schedule $w(x)$ *will solve the equation* $\alpha\lambda G'(x-2w(x))=k''+\pi S'(x-2w(x))$ *where* k'' *is a constant.*

(b). For contractible effort a risk neutral agent is offered a linear unique optimal contract with slope $\frac{1}{2}$ *if and only if the principal is linearly other regarding.*

(c). Given an output realization, optimal wage offered by a linearly spiteful principal will be less than what is offered by a self-regarding principal. That is given x *the following holds:*

$$w(x)^{Spiteful-Prin} < w(x)^{SelfRegard-Prin}$$

Proof: See the appendix.

To explain the result we go step by step. When a self-regarding principal interacts with a risk-neutral agent who is inequity averse, the source of only welfare loss is the concern for the agent's inequity. Thus under contractibility the welfare loss is minimized by offering a linear contract with slope exactly equal to $\frac{1}{2}$ although the principal extracts some amount through a fixed extraction[24]. But here there is an additional effect. The principal is also spiteful. If the principal is non-linearly other-regarding then this affects the optimal wage contract in a complicated way. The optimal wage schedule is unlikely to be linear and should solve the equation given in proposition 1 (a). Note that the principal is always ahead and since the principal is spiteful then the principal and the agent's other-regardingness move in the opposite direction leading to a relatively inequitable wage contract compared to a self-regarding principal. But if $S(.)$ is non-linear, $w(x)$ will be non-linear and the exact nature will depend on the nature of $S(.)$ and the extent of principal's spite (π). This is an important difference with Englmaier and Wambach (2010) where the optimal wage schedule is linear when the principal

[24] This is similar to the Englmaier and Wambach (2010) first proposition.

and the agent are both risk-neutral, the agent is inequity-averse and effort is contractible. But an interesting feature of $S(.)$ gives us the Englmaier and Wambach (2010) result. Part (b) of the proposition talks about that.

If the principal is linearly spiteful, i.e. $S(.)$ is linear, then in effect the agent's inequity-aversion only matters. Put differently, since the agent's inequity aversion is convex, that welfare loss dominates and we get a linear optimal contract with slope $\frac{1}{2}$. This minimizes the welfare loss. But interestingly, the lump-sum extraction is likely to be higher if the principal is spiteful compared to when the principal is self-regarding. Thus the ability of the principal to extract this lump-sum payment is restricted by the agent's inequity concern. Thus there will be in-equity at the optimum and it will be more for a spiteful principal. But the optimal contract will be linear with slope exactly equal to $\frac{1}{2}$. Thus the Englmaier and Wambach (2010) first proposition can be generalized for a linearly spiteful principal but not for non-linearly spiteful principal.

The third part of the proposition is straightforward and can be explained as follows: a spiteful principal who loves to be ahead will offer lower wage compared to a self-regarding principal. This explains the result.

But what happens when the agent is risk averse? In the absence of moral hazard and any kind of other-regardingness, the only concern for the principal is to insure the risk-averse agent to income fluctuations and therefore the principal pays the agent a fixed wage. This is the standard first best solution. When the agent is inequity averse, this adds an additional dimension and the agent's concern for inequity changes the nature of the optimal contract. In other words, agent's risk-aversion and inequity aversion both have to be addressed and this makes the optimal wage contract increasing with a slope between 0 and $\frac{1}{2}$, the exact shape might not be linear. Note that when the slope of wage schedule is exactly equal to 0 then risk-aversion is the only concern and if the slope is exactly equal to $\frac{1}{2}$ then inequity-aversion of the agent is the only concern. When both needs to be addressed the optimal wage schedule has a slope in between 0 and $\frac{1}{2}$. This is there in Englmaier and Wambach (2010), proposition-2. Here the principal is also spiteful which is the additional feature of this model. If the principal is spiteful she would like to be ahead and would optimally pay as low as possible subject to the participation constraint of the agent. Put differently, a spiteful principal world tilt the contract towards slope 0 and would optimally prefer to expropriate all the increase in output. **This effect reinforces the risk-aversion effect** and pushes the slope of the wage schedule below $\frac{1}{2}$. So under full contractibility the optimal wage schedule is increasing with slope between 0 and $\frac{1}{2}$. So qualitatively, this doesn't change the nature of the optimal wage schedule but with spiteful principal the slope will be relatively closer to zero compared to the self-regarding principal case. Thus, the following proposition is the generalized extension of Englmaier and Wambach (2010) with other-regarding principal but the result in essence remains the same.

Proposition 3.2

If effort is contractible then the optimal contract for a risk averse agent is strictly increasing with a slope between 0 and $\frac{1}{2}$ and this holds for a spiteful principal as well. ***For spiteful principal the slope will be relatively closer to 0 compared to the self-regarding principal.***

Proof: See the appendix.

Thus even in the absence of any need for incentive provision, the presence of agent's inequity aversion and the principal's spitefulness lead to some sort of profit sharing at the optimal and the fixed wage result of standard moral hazard is altered, although the spiteful principal will expropriate a larger portion of the profit compared to the self-regarding principal.

From the contractible effort case we now move over to the more realistic scenario of non-contractible effort.

3.2.2. Non-Contractible Effort:

In this section we do away with the assumption of observable effort and we focus on the more realistic assumption of non-contractible effort leading to the problem of moral hazard. Here, along with the participation constraint the principal also has to take into account the incentive compatibility constraint (IC) of the agent which is given by the following:

$$e = arg \max_{e} EU_A$$

$$\Rightarrow \frac{\partial EU_A}{\partial e} = \int_{\underline{x}}^{\overline{x}} f_e(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c'(e) = 0 \qquad \text{(IC)}$$

The IC ensures that the agent in her own interest chooses the effort that maximizes her expected utility and is therefore self-enforcing. Now the principal maximizes her expected payoff subject to the participation constraint (PC) and the incentive compatibility constraint (IC). Similar to our approach of the contractible effort case we start with risk-neutral agents.

In standard moral hazard when a risk-neutral principal interacts with a risk-neutral agent, without limited liability there is no welfare loss and the moral hazard problem doesn't bite. That is there exits contracts such that first best is implementable. One such contact is where the principal makes the agent the residual claimant. The agent being risk-neutral doesn't mind income fluctuations and puts in first best effort. These kinds of contracts are known as 'selling the project' or 'selling the firm' contracts which are very similar to a franchise contract where the franchisee pays a fixed amount to the franchiser and keeps the residual. In essence in this kind of contracts the slope of the wage schedules is 1, i.e. $w'(x) = 1$ and the incentive provision is extreme. When the agent is inequity averse, providing high-powered incentives and making the agent residual claimant might lead to unequal distribution of payoffs and therefore goes against the inequity concern of the agent. Thus, in order to strike a balance between the two opposing effects the optimal contact that is offered is increasing with a slope between $\frac{1}{2}$ and 1, which points to somewhere in between the inequity concern contract and the extreme incentive provision. When the principal is spiteful, then optimally she would like to extract a larger fixed amount. Given that making the agent residual claimant implements the first best effort, a larger fixed amount extraction (given that the participation constraint binds) will tilt the slope more towards 1 from very lower levels of x. In other words, increased spitefulness of the principal increases the slope of the wage schedule for all x. In this situation **spitefulness reinforces the risk-neutrality effect and goes against the inequity-aversion effect of the agent**. But given that agent's inequity-aversion is a concern, at the optimum, the slope of the wage schedule will be lower than 1. Overall, for every x, the slope of $w(x)$ will be higher for a spiteful principal compared to a self-regarding principal. The optimal contract is characterized in the following result.

Proposition 3.3

If effort is non-contractible then a risk neutral agent will be offered a wage contract strictly increasing with a slope between $\frac{1}{2}$ *and 1 and this holds for a spiteful principal as well. For every* x*,* $w'(x)$ *will be higher for a spiteful principal compared to a self-regarding principal.*

Proof: See the appendix.

Since the principal is always ahead, she will extract a lump-sum payment that will keep her ahead all the time. Moreover, as the agent becomes more inequity concerned she suffers utility loss and therefore the principal needs to compensate the agent for her loss in utility. Thus reduction of inequity-aversion can also be viewed as an additional incentive instrument by which the principal can elicit costly effort and this is present for a spiteful principal as well. This is similar to Englmaier and Wambach (2010).

Next we consider the full-fledged general case of a risk-averse and inequity-averse agent.

Proposition 3.4

Optimal contract for risk-averse agent is strictly increasing and this holds even if the principal is spiteful. $w'(x)$ *is higher for a spiteful principal vis-à-vis a self-regarding principal if the agent is not so risk-averse.*

Proof: See the appendix.

The wage schedule is determined by the interplay of four forces and is not straightforward. First, a risk-averse agent prefers a fixed wage to insure him against the income uncertainty. Secondly, x being an imperfect proxy measure for effort exerted by the agent, for incentive reasons, a higher x call for a higher wage to be paid. Third, the agent being inequity-averse needs to be paid increased wage as output rises such that payoff difference is minimized. Here the second and the third force work in the same direction whereas the first force works in the opposite direction. These forces are there in Englmaier and Wambach (2010). But here, additionally, we have a fourth force, i.e. the spitefulness of the principal. A spiteful principal will optimally pay a lower wage. But overall the agent's concern for fairness and incentive forces are sufficiently strong and dominates all other countervailing forces and we get an increasing contract, although the exact nature of the contract is difficult to find out. As principal's spite increases, the changes in the slope of the wage schedule will depend on the extent of risk-aversion of the agent and also the extent of inequity-aversion of the agent. If risk-aversion is sufficiently lower, the insurance concern is not there and therefore the spiteful principal will extract higher fixed amount and will try to make the agent residual claimant. This will push up the slope of $w(x)$ for every x. So, increased spite will reinforce the incentive effect. But if the agent is sufficiently risk-averse and also is highly inequity averse then $w'(x)$ might fall with increased π for every x.

But one can find out how the optimum wage schedule behaves with changes in π and α. The following proposition throws some light on that and the result we get is similar to our closed form result.

Proposition 3.5

Given x, $w(x)$ is decreasing in π and increasing α.

Proof: See appendix.

As the principal, ceteris paribus, becomes more spiteful, she will try to maximize payoff differences and will offer the agent lower wages, given that the agent accepts the contract and puts in the incentive compatible effort. On the other hand, if ceteris paribus, the agent's concern for inequity rises (i.e. increase in α) then the principal needs offer higher wages to reduce the payoff differences and compensate for the loss in utility of the agent. Thus similar to our closed form result, increased spitefulness of principal leads to reduced optimal wage, whereas increased inequity aversion of agents leads to increased optimal wage. One can show that as the agent's inequity aversion increases towards infinity then the optimal contract will be an equal split of output

On the sufficient Statistics result:

It can be deduced from Holmstrom (1979)'s seminal work that if any part of the principal's profit doesn't depend on the agent's effort and is truly idiosyncratic then the optimal contract should be independent of that part of the principal's profit. This is in essence the sufficient statistic result. For exposition suppose the profit of the firm is separated into two parts x and y. The first part x is dependent on effort exerted by the agent (e) whereas the second part y is purely randomly distributed according to a certain distribution function. The sufficient statistic result says that the optimal contract should not depend on y. Englmaier and Wambach (2010) showed that this result might not hold where agents exhibit inequity-aversion and at the optimal contract might depend on y. Since the agent is also concerned about inequity and the inequity depends on that idiosyncratic part of the profit, that part should feature in the optimal contract that the principal offers. We find an interesting generalization of the result with other-regarding principal. We show that when the principal and the agents have exactly opposite other-regarding preferences and the other regarding functions such that $G''(.) = S''(.)$ holds for any x, then the sufficient statistics result holds. Otherwise doesn't. This is due to the fact that if the agent is behind she suffers a welfare loss. But the principal gains an exact amount from being ahead and in essence there is no overall welfare loss and only the incentive value of the signal remains. This is stated in the following proposition:

Proposition 3.6

The sufficient statistics result holds when both the principal and the agent have exactly opposite other-regarding preferences $(\pi = \alpha)$ *with same other-regarding functions implying* $G''(.) = S''(.)$ *for any* x*. Otherwise, optimal contracts contain non-relevant information with respect to effort choice***.**

Proof: See appendix.

This result is again similar to our result that opposite other-regarding preferences induce the benchmark result. The benchmark sufficient statistic result holds with opposite other-regarding preferences. This, in essence, supports our conjecture that we go back to the benchmark when the principal and the agent has exactly opposite other-regarding preferences, a result we get in our closed form model. Obviously the sufficient statistic result will hold in the special case where all the self-regarding, i.e. $\pi = \alpha = 0$ which is the benchmark case.

Corollary 3.1:

For both self-regarding principal and agents ($\pi = \alpha = 0$) the sufficient statistics result holds which is nothing but the benchmark case.

Thus, we attempt to provide a sufficiently thorough characterization of optimal contracts with continuous output and efforts and with general functional forms. We show that in essence important results of our closed form model hold qualitatively in this general structure as well.

3.3. Concluding Observations:

In the previous chapter with two outcomes, we characterized the optimal contracts when a spiteful principal interacts with a single agent. As a robustness check we extended our study to continuous output and efforts and with general functional forms. We show that in essence almost all important results of our closed form model hold qualitatively in this general structure. The optimal wage schedule is derived with the interplay of three forces – the risk averseness and inequity averseness of the agent and the spitefulness of the principal. These forces work in different directions which makes the model more interesting. A risk averse agent prefers fixed wage but since he is also inequity averse so he needs to get compensated more to reduce the payoff difference when output rises. On the other hand, a spiteful principal prefers paying as much low wage as possible. The first two forces were also there in Englmaier and Wambach (2010) but in addition to that here we have a third force – the spitefulness of the principal. This makes Englmaier and Wambach (2010), a special case of this present chapter when the other-regarding parameter of the principal is zero. In addition to that, the sufficient statistics results of Holmstorm are generalized for other-regarding principal and agent.

A natural extension of this chapter is to analyze a situation where a spiteful principal interacts with more than one agent. This is analyzed in detail in the next chapter.

Appendix

Proof of Proposition 3.1

(a). The principal's problem is given by

$$\max_{w(x)} EU_p = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$

$$\text{s. t. } \int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) \geq u \qquad \text{(PC)}$$

and the Lagrangian takes the form

$$\mathcal{L} = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$
$$+ \lambda \left[\int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) - u \right]$$

The FOC is given by

$$f(x|e)\{-1 - 2\pi S'(x - 2w(x))\} + \lambda[f(x|e)\{u'(w(x)) + 2\alpha G'(x - 2w(x))\}] = 0$$

The second order sufficient condition which is as follows:

$$4\pi S''(x - 2w(x)) - \lambda\{4\alpha G''(x - 2w(x)) - u''(w(x))\} < 0$$

Therefore, for maximization we need to have

$$\lambda\{4\alpha G''(.) - u''(w)\} > 4\pi S''(.). \qquad \text{(A1)}$$

Dividing both sides by $f(x|e)$ we get

$$\{1 + 2\pi S'(x - 2w(x))\} = \lambda\{u'(w(x)) + 2\alpha G'(x - 2w(x))\} \qquad \text{(FOC1)}$$

$$\Rightarrow \frac{\{1 + 2\pi S'(x - 2w(x))\} - \lambda u'(w(x))}{2\alpha\lambda} = G'(x - 2w(x))$$

For risk neutral agent $u'(w(x))$ is constant and therefore let $u'(w(x)) = k$. Rearranging the above equation, we get

$$G'(x - 2w(x)) = k' + \frac{\pi S'(x-2w(x))}{\alpha\lambda} \quad \text{where } k' = \frac{1-\lambda k}{2\alpha\lambda}$$

$$\Rightarrow \alpha\lambda G'(x - 2w(x)) = k'' + \pi S'(x - 2w(x)) \qquad \text{(A2)}$$

The optimum wage schedule will solve the above equation.

(b). For linear other-regarding principal function $S'(x - 2w(x))$ is constant and therefore

$$G'(x - 2w(x)) = k_2 \text{ (a constant).}$$

Since $G(.)$ is monotonic with $G''(.) > 0$, we get $x - 2w(x) = k_3$ (constant) implying $w(x) = \frac{x}{2} - \frac{k_3}{2}$ where k_3 is some constant. Note that when $\pi > 0$ then $k'' + \pi S'(x - 2w(x))$ is a larger constant than when $\pi = 0$. Thus a spiteful principal will extract a larger lump-sum payment compared to a self-regarding principal.

(c). If $S'(x - 2w(x)) = k_5$ (constant) then we can write (A1) as $G'(x - 2w(x)) = k_4 + \pi k_5$. Since $G'(.) > 0$ and $G''(.) > 0$, if $\pi > 0$ then $x - 2w(x)$ is higher compared to when $\pi = 0$. Hence the relation:

$$w(x)^{Spiteful-Prin} < w(x)^{SelfRegard-Prin}, \text{ given } x.$$

In similar fashion it can be proved that the result remains same if the inequity averseness function $G(.)$ is linear instead of the spite function $S(.)$. **QED**

Proof of Proposition 3.2

By differentiating FOC1 by x we get

$$2\pi S''(.)\big(1-2w'(x)\big)=\lambda\big\{u''(w(x))w'(x)+2\alpha G''(.)\big(1-2w'(x)\big)\big\}$$

$$\Rightarrow w'(x)[4\alpha\lambda G''(.)-\lambda u''(w(x))-4\pi S''(.)]=2\alpha\lambda G''(.)-2\pi S''(.)$$

$$\Rightarrow w'(x)=\frac{2\alpha\lambda G''(.)-2\pi S''(.)}{[4\alpha\lambda G''(.)-\lambda u''(w(x))-4\pi S''(.)]}$$

$$=\frac{\frac{1}{2}[4\alpha\lambda G''(.)-\lambda u''(w(x))-4\pi S''(.)]+\frac{1}{2}\lambda u''(w(x))}{[4\alpha\lambda G''(.)-\lambda u''(w(x))-4\pi S''(.)]}$$

$$=\frac{1}{2}+\frac{\lambda u''(w(x))}{2[4\alpha\lambda G''(.)-\lambda u''(w(x))-4\pi S''(.)]}$$

Since $u''(w(x))<0$, the numerator is negative and the denominator is positive from the second order condition (A1). Therefore $\frac{\lambda u''(w(x))}{2[4\alpha\lambda G''(.)-\lambda u''(w)-4\pi S''(.)]}<0$. Thus $0<w'(x)<\frac{1}{2}$ will hold and this doesn't depend on π and the nature of $S(.)$.

Also as π increases the denominator of $\frac{\lambda u''(w(x))}{2[4\alpha\lambda G''(.)-\lambda u''(w)-4\pi S''(.)]}$ falls and therefore the magnitude of the term increases, implying that $\frac{\lambda u''(w(x))}{2[4\alpha\lambda G''(.)-\lambda u''(w)-4\pi S''(.)]}$ becomes more negative. Thus with an increase in spitefulness $w'(x)$ falls and moves away from $\frac{1}{2}$ towards zero, thus reinforcing agent's inequity-aversion effect. **QED**

Proof of Proposition 3.3

(a). Since the effort is not contractible the principal has to take into account the incentive compatibility constraint which is given by

$$e=arg\max_{e} EU_A$$

$$\Longrightarrow \frac{\partial EU_A}{\partial e} = \int_{\underline{x}}^{\overline{x}} f_e(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c'(e) = 0$$

Thus the principal's problem is given by

$$\max_{w(x)} EU_p = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$

s.t.

$$\int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) \geq u \qquad \text{(PC)}$$

$$\int_{\underline{x}}^{\overline{x}} f_e(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c'(e) = 0 \qquad \text{(IC)}$$

The Lagrangian can be formed as

$$\mathcal{L} = \int_{\underline{x}}^{\overline{x}} f(x|e)\{x - w(x) + \pi S(x - 2w(x))\}dx$$

$$+ \lambda\left[\int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) - u\right]$$

$$+ \mu\left[\int_{\underline{x}}^{\overline{x}} f_e(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c'(e)\right]$$

The First Order Conditions (FOC) are given by

$$f(x|e)\{-1 - 2\pi S'(.)\} + \lambda[f(x|e)\{u'(w(x)) + 2\alpha G'(.)\}] + \mu[f_e(x|e)\{u'(w(x)) + 2\alpha G'(.)\}] = 0 \qquad \text{(A3)}$$

$$\int_{\underline{x}}^{\overline{x}} f(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c(e) - u = 0$$

$$\int_{\underline{x}}^{\overline{x}} f_e(x|e)\{u(w(x)) - \alpha G(x - 2w(x))\}dx - c'(e) = 0$$

The last two first order conditions give us that both the participant constraint and the incentive compatibility constraints will bind at the optimum.

Dividing the first FOC (A3) both sides by $f(x|e)$ we get

$$\{1 + 2\pi S'(.)\} = \left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{u'(w(x)) + 2\alpha G'(.)\} \qquad \text{(A4)}$$

From the first FOC we derive the second order sufficient condition which is as follows:

$$4\pi S''(.) - \left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} < 0$$

Therefore for maximization we need to have

$$\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} > 4\pi S''(.). \qquad \text{(A5)}$$

Differentiating (A4) with respect to x we get

$$2\pi S''(.)\big(1 - 2w'(x)\big)$$
$$= \left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{u''(w(x))w'(x) + 2\alpha G''(.)\big(1 - 2w'(x)\big)\}$$
$$+ \left\{\mu\Big(\frac{f_e(x|e)}{f(x|e)}\Big)'\right\}\{u'(w(x)) + 2\alpha G'(.)\}$$

$$\Rightarrow w'(x)\left[\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w)\} - 4\pi S''(.)\right]$$
$$= 2\alpha G''(.)\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\} + \left\{\mu\Big(\frac{f_e(x|e)}{f(x|e)}\Big)'\right\}\{u'(w) + 2\alpha G'(.)\} - 2\pi S''(.)$$

$$\Rightarrow w'(x) = \frac{2\alpha G''(.)\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\} + \left\{\mu (\frac{f_e(x|e)}{f(x|e)})'\right\}\{u'(w(x)) + 2\alpha G'(.)\} - 2\pi S''(.)}{\left[\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} - 4\pi S''(.)\right]}$$

(A6)

For risk-neutral agent $u''(w) = 0$ and therefore we have

$$\Rightarrow w'(x) = \frac{\left[2\alpha G''(.)\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\} - 2\pi S''(.)\right] + \left\{\mu \left(\frac{f_e(x|e)}{f(x|e)}\right)'\right\}\{u'(w) + 2\alpha G'(.)\}}{\left[4\alpha G''(.)\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\} - 4\pi S''(.)\right]}$$

$$\Rightarrow w'(x) = \frac{1}{2} + \frac{\left\{\mu \left(\frac{f_e(x|e)}{f(x|e)}\right)'\right\}\{u'(w) + 2\alpha G'(.)\}}{\left[4\alpha G''(.)\left\{\lambda + \mu \frac{f_e(x|e)}{f(x|e)}\right\} - 4\pi S''(.)\right]}$$

The term $\frac{\left\{\mu \left(\frac{f_e(x|e)}{f(x|e)}\right)'\right\}\{u'(w)+2\alpha G'(.)\}}{\left[4\alpha G''(.)\left\{\lambda+\mu \frac{f_e(x|e)}{f(x|e)}\right\}-4\pi S''(.)\right]} > 0$ since the denominator is positive from the second order condition (A5) and $\left(\frac{f_e(x|e)}{f(x|e)}\right)' > 0$ because of the monotone likelihood ratio property.

Thus, under non-contractibility, for risk-neutral agents, $\frac{1}{2} < w'(x) < 1$ holds. This is true for $\pi > 0$ and the nature of $S(.)$.

An increase in π leads to an increase in $\frac{\left\{\mu \left(\frac{f_e(x|e)}{f(x|e)}\right)'\right\}\{u'(w)+2\alpha G'(.)\}}{\left[4\alpha G''(.)\left\{\lambda+\mu \frac{f_e(x|e)}{f(x|e)}\right\}-4\pi S''(.)\right]}$ and $w'(x)$ increases for every x. **QED**

Proof of Proposition 3.4

From (A6) above we get

$$w'(x) = \frac{2\alpha G''(.)\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\} + \left\{\mu\left(\frac{f_e(x|e)}{f(x|e)}\right)'\right\}\{u'(w(x)) + 2\alpha G'(.)\} - 2\pi S''(.)}{\left[\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} - 4\pi S''(.)\right]}$$

The second order condition ensures that the denominator is positive, given $u''(w(x)) < 0$. The numerator is also positive since $2\alpha G''(.)\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}$>$2\pi S''(.)$ and this is also ensured by the second order condition. The changes in $w'(x)$ as π changes depends on the nature of $u(x)$ and also on α and the nature of $G(.)$. If $u''(w(x))$ is sufficiently low then $w'(x)$ will increase with π for every x. (This is similar to proposition 6 where $u''(.) = 0$). If $u''(w(x))$ sufficiently high then also $\alpha G'(.)$ is sufficiently low then $w'(x)$ might fall with increased π. **QED**

Proof of Proposition 3.5

Differentiating (A4) with respect to π we get

$$2\left\{\pi S''(.)\left(-2\frac{\partial w(x)}{\partial \pi}\right) + S'(.)\right\}$$

$$= \left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\left\{u''(w(x))\frac{\partial w(x)}{\partial \pi} + 2\alpha G''(.)\left(-2\frac{\partial w(x)}{\partial \pi}\right)\right\} = 0$$

$$\Rightarrow \frac{\partial w(x)}{\partial \pi}\left[\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w)\} - 4\pi S''(.)\right] = -2S'(.)$$

$$\Rightarrow \frac{\partial w(x)}{\partial \pi} = \frac{-2S'(.)}{\left[\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} - 4\pi S''(.)\right]} < 0$$

Since the denominator is positive from the second order condition and $S'(.) > 0$.

Differentiating (A4) with respect to α we get

$$2\left\{\pi S''(.)\left(-2\frac{\partial w(x)}{\partial \alpha}\right)\right\}$$

$$= \left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\left\{u''(w(x))\frac{\partial w(x)}{\partial \alpha} + 2\alpha G''(.)\left(-2\frac{\partial w(x)}{\partial \alpha}\right) + 2G'(.)\right\}$$

$$\Rightarrow \frac{\partial w(x)}{\partial \alpha}\left[\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.) - u''(w(x))\} - 4\pi S''(.)\right] = 2G'(.)\left\{\lambda + \mu\frac{f_e(x|e)}{f(x|e)}\right\}$$

$$\Rightarrow \frac{\partial w(x)}{\partial \alpha} = \frac{2G'(.)\left\{\lambda+\mu\frac{f_e(x|e)}{f(x|e)}\right\}}{\left[\left\{\lambda+\mu\frac{f_e(x|e)}{f(x|e)}\right\}\{4\alpha G''(.)-u''(w(x))\}-4\pi S''(.)\right]} > 0. \quad \textbf{QED}$$

Proof of Proposition 3.6

The profit of the firm is separated into two parts x and y. x is assumed to be distributed following the function $f(x|e)$ which depends on the exerted effort level e and y is randomly distributed with density function $g(y)$. Here we will show that the sufficient statistics results don't apply when agent is inequity averse. Now the principal's optimization problem is

$$\max_w EU_p = \int_{\underline{x}}^{\overline{x}} f(x|e)x dx + \int_{\underline{y}}^{\overline{y}} g(y)y dy$$

$$- \int_{\underline{x}}^{\overline{x}}\int_{\underline{y}}^{\overline{y}}\{w(x,y) - \pi S(x + y - 2w(x,y))\}f(x|e)\, g(y)dxdy$$

s.t. $EU_A = \int_{\underline{x}}^{\overline{x}}\int_{\underline{y}}^{\overline{y}}\{u(w(x,y)) - \alpha G(x + y - 2w(x,y))\}f(x|e)\, g(y)dxdy - c(e) \geq u$ (PC)

$$e = arg\max_e \int_{\underline{x}}^{\overline{x}}\int_{\underline{y}}^{\overline{y}}\{u(w(x,y)) - \alpha G(x + y - 2w(x,y))\}f(x|e)\, g(y)dxdy - c(e) \geq u$$

$\Rightarrow \int_{\underline{x}}^{\overline{x}}\int_{\underline{y}}^{\overline{y}}\{u(w(x,y)) - \alpha G(x + y - 2w(x,y))\}f_e(x|e)\, g(y)dxdy - c'(e) = 0$ (IC)

The Lagrangian is given by

$$\mathcal{L} = \int_{\underline{x}}^{\overline{x}} f(x|e)xdx + \int_{\underline{y}}^{\overline{y}} g(y)ydy$$

$$- \int_{\underline{x}}^{\overline{x}} \int_{\underline{y}}^{\overline{y}} \{w(x,y) - \pi S(x + y - 2w(x,y))\} f(x|e)\, g(y)dxdy$$

$$+ \lambda \left[\int_{\underline{x}}^{\overline{x}} \int_{\underline{y}}^{\overline{y}} \{u(w(x,y)) - \alpha G(x + y - 2w(x,y))\} f(x|e)\, g(y)dxdy - c(e) \right.$$

$$\left. - u \right]$$

$$+ \mu \left[\int_{\underline{x}}^{\overline{x}} \int_{\underline{y}}^{\overline{y}} \{u(w(x,y)) - \alpha G(x + y - 2w(x,y))\} f_e(x|e)\, g(y)dxdy \right.$$

$$\left. - c'(e) \right]$$

The FOC is given by

$$\Rightarrow -\{1 + 2\pi S'(x + y - 2w(x,y))\}$$

$$+ \left\{ \lambda + \mu \frac{f_e(x|e)}{f(x|e)} \right\} \{u'(w(x,y)) + 2\alpha G'(x + y - 2w(x,y))\} = 0$$

Differentiating this with respect to y we get,

$$\Rightarrow -2\pi S''(.) \left(1 - 2\frac{\partial w}{\partial y}\right) + \left\{ \lambda + \mu \frac{f_e(x|e)}{f(x|e)} \right\} \left\{ u''(w(x,y)) \frac{\partial w}{\partial y} + 2\alpha G''(.) \left(1 - 2\frac{\partial w}{\partial y}\right) \right\} = 0$$

$$\Rightarrow \frac{\partial w}{\partial y} \left[\left\{ \lambda + \mu \frac{f_e(x|e)}{f(x|e)} \right\} \{u''(w(x,y)) - 4\alpha G''(.)\} + 4\pi S''(.) \right] = 2\pi S''(.) - 2\alpha G''(.)$$

$$\Rightarrow \frac{\partial w}{\partial y} = \frac{2\alpha G''(.) - 2\pi S''(.)}{\left[\left\{ \lambda + \mu \frac{f_e(x|e)}{f(x|e)} \right\} \{4\alpha G''(.) - u''(w(x,y))\} - 4\pi S''(.) \right]} \neq 0$$

Here we see that optimal wage depends on y, which doesn't contain any information of agent's effort. When $\alpha = \pi = 0$ or when $\alpha = \pi$ and $G''(.) = S''(.)$ holds, we get $\frac{\partial w}{\partial y} = 0$.

QED

CHAPTER 4

OTHER-REGARDING PRINCIPAL AND MORAL HAZARD: MULTIPLE AGENTS

4.1. Introduction:

This chapter is the multi agent extension of the model discussed in the previous chapter. Similar to the previous chapter here also general other-regarding functions and continuous output and efforts are assumed. The principal and the agents are other-regarding. Here the principal can be both status-seeking or inequity averse in nature. This structure is more generalized than the structures in the previous chapters. In this structure the agents not only compare their payoff with the payoff of the principal but they also compare their payoffs with their peer. This is a very common feature observed in workplace. There are several papers that deal with this issue as is discussed in the introduction chapter. The same structure of Englmaier & Wambach (2010) is followed here. Similar to their structure here the agents are working in separate projects getting different wages. So, the issue of wage difference or peer comparison might arise if one agent gets higher wage than the other one. This is a new feature included in this chapter as this was not present there in previous chapters. This gives a new dimension to the entire structure as the project outcomes can be correlated which in turn affects the wages. The ceteris paribus impact of one unit increase in output of one project on the wage offered to the agent working in the other project is called the 'cross wage effect'. The cross wage effects can indicate whether the contract is a team contract, relative performance contract or an independent contract. The agents also compare their payoffs with the payoff of the principal similar to previous chapters.

The results suggest that with not so high cross wage effect, a not so high status seeking principal or an inequity averse principal will offer a contract which is increasing with respect to its own output. This type of contract will not only reduce the wage gap between the principal and the agent but it will also bridge the gap between the wages of the two agents therefore causing them less disutility. A higher wage with higher output will also elicit costly effort from the agent. Englmaier & Wambach (2010) showed the optimality of 'team contracts' when principal is self-regarding and agents are other-regarding and projects are technologically independent. The same result is generalized here with inequity averse principal under an additional condition of not so high own wage effect. It was also found that with not so high own wage effect, a sufficiently status seeking principal will prefer relative performance contract when agents' wages are far apart from each other. The optimal wage offered to both the agents will fall with an increase in spitefulness parameter of the principal given that the agents are not much inequity averse vis-a-vis the principal. It was also found that the wages offered to the agents rise when the agents are more concerned about their payoff difference vis-à-vis the principal. These results are quite intuitive in nature. If the agents are highly concerned about the payoff difference between the principal and themselves then the principal will need to offer more wages to the agents to reduce the disutility caused by this difference. If the agents are too much concerned about the payoff of their peers, then the principal optimally reduces the wage gap between the two agents without violating the incentive compatibility constraint. If the inequity averse agents are infinitely concerned about their own payoff differences, then the principal removes the entire wage gap between them by offering them equal wages.

In this chapter in the section 4.2 the multi-agent structure is introduced for a other-regarding principal and two other-regarding agents. Section 4.3 concludes the chapter.

4.2. General Model with Multi-agents:

In this extension we make use of the structure similar to that of Englmaier & Wambach (2010) with similar notations. We have a standard principal multi-agent setup where a principal hires two agents to work for her in two separate projects. The output of the project i is x_i , $i = \{1, 2\}$ and the outputs of the projects are technologically independent, verifiable and are continuously distributed in the interval $[\underline{x}_i, \overline{x}_i]$. The output follows density function $f_i(x_i|e_i)$ which depends on the effort level denoted by e_i exerted by the agent i working on that specific project. The effort level is non-verifiable and hence non-contractible. Each agent receives wage $w_i(x_1, x_2)$ for working in project i. The agents are risk-averse with respect to own wage, i.e. i.e. $u_i''\big(w_i(x_1, x_2)\big) \leq 0$ (This also incorporates the possibility of risk-neutrality). The effort gives disutility to the agent and the cost being $c_i(e_i)$ with the restriction that $c_i'(e_i) > 0$ and $c_i''(e_i) > 0$. Following the distributional approach a la Fehr and Schmidt (2003) we assume the agents to be inequity-averse vis-à-vis the principal. The principal's gross payoff is $(x_1 + x_2)$. Subtracting the wage payments for the two agents combined $(w_1(x_1, x_2) + w_2(x_1, x_2))$ from $(x_1 + x_2)$ gives her net-payoff. Agent i compares the principal's net payoff $(x_1 + x_2 - w_1(x_1, x_2) - w_2(x_1, x_2))$ with her own payoff $w_i(x_1, x_2)$ and the more is the difference between the two i.e. $(x_1 + x_2 - 2w_i(x_1, x_2) - w_j(x_1, x_2))$ the more is the disutility for agent i. This disutility due to inequity aversion for agent i is given by $G_i\Big(x_1 + x_2 - 2w_i(x_1, x_2) - w_j(x_1, x_2)\Big)$.[25] The function $G(.)$ is assumed to be convex with the properties $G_i'(.) > 0, G_i''(.) > 0, G_i'(0) = 0,\ G_i''(0) = 0$. Following Dur and Glazer (2008), we focus on the case where the principal is always weakly ahead of the agent and this is a difference with Englmaier & Wambach (2010). This is to fix ideas without losing much of economic intuition. Agent i

[25] Thus, in this continuous structure, the principal does not treat the agents' projects separately.

also compares her payoff with her peer's payoff (Holmstrom (1982), Itoh (2004)). If agent j is ahead of agent i then a rise in payoff difference $\left(w_j(x_1,x_2)-w_i(x_1,x_2)\right)$ leads to utility loss for agent i. This disutility function is given by $H_i\left(w_j(x_1,x_2)-w_i(x_1,x_2)\right)$ with the following assumptions:

If $w_j(x_1,x_2)>w_i(x_1,x_2)$ then $H_i'(.)>0$

If $w_i(x_1,x_2)>w_j(x_1,x_2)$ then $H_i'(.)<0$

$H_i''(.)>0$, $H_i'(0)=0$ and $H_i''(0)=0$.

Thus we assume agents to be only inequity-averse among themselves which is different to our discrete model (in previous sections) where they were status-seeking as well. The utility function of agent i is additively separable in utility from wealth $(u_i(w_i(x_1,x_2)))$, inequity functions $G_i(.)$, $H_i(.)$ and effort cost $c_i(e_i)$. That is mathematically,

$$U_A^i=u_i\left(w_i(x_1,x_2)\right)-\alpha_{Pi}G_i\left(x_1+x_2-2w_i(x_1,x_2)-w_j(x_1,x_2)\right)$$
$$-\alpha_{Ai}H_i\left(w_j(x_1,x_2)-w_i(x_1,x_2)\right)-c_i(e_i)$$

Here $\alpha_{Pi}(>0)$ is the inequity aversion parameter of agent i vis-à-vis the principal and $\alpha_{Ai}(>0)$ is the inequity aversion parameter of agent i vis-a-vis the other agent. Note, here we assume that the agents can only be inequity-averse for analytical convenience. Here we do not allow an agent who is ahead to be status-seeking. This is in contract to our discrete model where an agent can be status-seeking when she is ahead. **For notational convenience we denote $\boldsymbol{w_i=w_i(x_1,x_2)}$ and $\boldsymbol{w_j=w_j(x_1,x_2)}$ where $\boldsymbol{i,j=\{1,2\}, i\neq j}$.**

Expected utility of agent i:

$$EU_A^i = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_i(w_i) - \alpha_{Pi} G_i(x_1 + x_2 - 2w_i - w_j)$$

$$- \alpha_{Ai} H_i(w_j - w_i)\} dx_1 dx_2 - c_i(e_i)$$

The outside option for agent i is u_i. Therefore, the principal must offer a wage that makes the agent atleast as well off as her outside option in terms of utility so the participation constraint is

$$EU_A^i \geq u_i$$

The principal is assumed to be risk neutral with respect to the project return, interested in maximizing expected payoff. The principal's payoff function is given as:

$$U_p = x_1 + x_2 - w_1 - w_2 + \pi S_1(x_1 + x_2 - 2w_1 - w_2) + \pi S_2(x_1 + x_2 - w_1 - 2w_2)$$

where π is the other-regardingness parameter for the principal. If $\pi > 0$, the principal is 'status-seeking' in the sense that she likes being ahead of the agents. The more is the value of $(x_1 + x_2 - 2w_i - w_j)$ the more is the principal ahead of agent i and the more is the utility for the principal. On the other hand, if $\pi < 0$ then that captures the case of inequity-averse principal who likes to reduce the difference between their payoffs otherwise an increased payoff difference would lead to a loss of utility for the principal in that case.[26] $S_i(x_1 + x_2 - 2w_i - w_j)$ is the other-regarding function with the restrictions that $S_i'(.) > 0$, $S_i''(.) > 0$, $S_i'(0) = 0$, $S_i''(0) = 0$. As the principal is 'never behind' the agents, she gains

[26] Note that implicitly we have assumed that the principal has the same π vis-à-vis both the agents. One can assume different π_1 and π_2 without changing much of the analysis, qualitatively.

utility (or loses in case she is inequity-averse) equal to $\pi S_1(x_1 + x_2 - 2w_1 - w_2)$ from agent 1 and $\pi S_2(x_1 + x_2 - w_1 - 2w_2)$ from agent 2 respectively if she is status-seeking.[27]

The objective function of the other-regarding principal can be expressed as:

$$EU_p = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{x_1 + x_2 - w_1 - w_2 + \pi S_1(x_1 + x_2 - 2w_1 - w_2)$$

$$+ \pi S_2(x_1 + x_2 - w_1 - 2w_2)\}dx_1 dx_2$$

We further assume that the monotone likelihood property holds which says that the more is the output realized the more is the possibility that high effort was exerted.

$$\frac{\partial\left(\frac{f_{ie_i}(x_i|e_i)}{f_i(x_i|e_i)}\right)}{\partial x} = \left(\frac{f_{ie_i}(x_i|e_i)}{f_i(x_i|e_i)}\right)' > 0, \forall\, i = 1,2$$

Incentive compatibility constraint for agent i is given by

$$e_i = arg \max_{e_i} EU_A^i$$

$$\Rightarrow \frac{\partial EU_A^i}{\partial e_i} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_{ie_i}(x_i|e_i)\, f_j(x_j|e_j)\{u_i(w_i) - \alpha_{Pi} G_i(x_1 + x_2 - 2w_i - w_j)$$

$$- \alpha_{Ai} H_i(w_j - w_i)\}dx_1 dx_2 - c_i'(e_i) = 0$$

Thus we have a sufficiently general structure with two agents. A priori we do not assume symmetric agents anywhere. All special cases can be deduced for this general model by applying appropriate restrictions.

[27] Here implicitly we assumed that the principal is similarly other-regarding to both the agents which is for simplicity. The results will not change if the assume differential other-regardingness. Only the algebra will become more complicated.

Given the above structure, under non-contractibility, the principal's problem will be

$$\text{Max} \qquad EU_p = \int_{\underline{x}_1}^{\overline{x}_1}\int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{x_1 + x_2 - w_1 - w_2 + \pi S_1(x_1 + x_2 - 2w_1 - w_2) + \pi S_2(x_1 + x_2 - w_1 - 2w_2)\}dx_1 dx_2$$

Subject to the incentive compatibility constraints for both the agents

$$\int_{\underline{x}_1}^{\overline{x}_1}\int_{\underline{x}_2}^{\overline{x}_2} f_{i_{e_i}}(x_i|e_i)\, f_j(x_j|e_j)\{u_i(w_i) - \alpha_{Pi}G_i(x_1 + x_2 - 2w_i - w_j) - \alpha_{Ai}H_i(w_j - w_i)\}dx_1 dx_2 - c_i'(e_i) = 0; \quad i = 1,2$$

And the Participation constraints for both the agents

$$u_i(w_i(x_1, x_2)) - \alpha_{Pi}G_i\left(x_1 + x_2 - 2w_i(x_1, x_2) - w_j(x_1, x_2)\right) - \alpha_{Ai}H_i\left(w_j(x_1, x_2) - w_i(x_1, x_2)\right) - c_i(e_i) \geq u_i \;\; ; \quad i = 1, 2.$$

The optimal wage schedules, $w_1(x_1, x_2)$ and $w_2(x_1, x_2)$, are found using the first order approach. Define $w = \{w_1(x_1, x_2), w_2(x_1, x_2)\}$. But before going into the optimal contracts, we define 'team', 'relative performance' and 'independent' contracts in the continuous framework:

Definition 4.1:

A contract w is a 'team contract' if $\frac{\partial w_i}{\partial x_j} > 0\ \forall i \neq j$. *If* $\frac{\partial w_i}{\partial x_j} < 0\ \forall i \neq j$ *then w is a 'relative performance contract'. If* $\frac{\partial w_i}{\partial x_j} = 0\ \forall i \neq j$ *then w is referred to as an 'independent contract'.*

Given the above definition we proceed to characterize the optimal contracts in this multi agent framework.

We state our next result:

Proposition 4.1:

If $\frac{\partial w_j}{\partial x_i} < \frac{1}{2}$, t*he optimal contracts for both agents are increasing in own output if the principal is inequity-averse and/or not highly status-seeking.*

Proof: See appendix.

One primary objective while offering contracts under non-contractibility is to provide incentives to elicit costly effort from the agents. Thus, given that the monotone likelihood ratio property holds, the wages offered should increase in own output which is an imperfect signal of one's own effort. So overall there are three effects. First, the incentive effect calls for an increased wage as own output increases. Second, if the cross-wage effects are positive, then that increases the wage of both the agents and that reduces the inequity of payoff of the principal vis-à-vis the agents. This takes care of the inequity concern of an inequity-averse principal. Third in case of positive cross wage effects, the inequity among the agents also gets reduced. All three forces reinforce each other if the principal is inequity-averse (not highly status-seeking) and also the agents are inequity-averse vis-à-vis the principal and among themselves. Also $\frac{\partial w_j}{\partial x_i} < \frac{1}{2}$ ensures that the cross wage effect is not too high so that the principal can profitably employ the incentive effect (own wage effect) without getting behind. Thus given $\frac{\partial w_j}{\partial x_i} < \frac{1}{2}$, own wage should certainly increase with an increase in own output for the sake of eliciting the desired effort. Note that $\frac{\partial w_j}{\partial x_i} < \frac{1}{2}$ is sufficient but not necessary for own wage to increase with own output. If the principal is sufficiently status seeking then the principal might find it optimal to reduce wage since being ahead increases the principal's payoff.

Holmstrom (1982) showed that when the agents' project outcomes are correlated (affected by a common shock) then relative performance contracts are optimal and it helps in filtering out the common shock and hence exposes agents to less risk. When projects are technologically independent then perceived knowledge says that an agents' pay should not depend on other agents' output. But this doesn't hold if the agents and also the principal are other-regarding. To fix ideas suppose the agents are inequity-averse among themselves. Since the agents compare their payoffs and have interest in each other's payoffs then conditioning one agents payoff on other agents output might help in reducing inequity among agents. This interrelatedness leads to a different outcome vis-à-vis our perceived knowledge. Specifically, if the principal and the agents are inequity-averse, their fairness motives provide rationale for the widespread use to team contracts. But if the principal is status-seeking there can be possibility of relative performance contract becoming optimal. Let us analyze the situation when the principal is status-seeking. An increase in x_i leads to an increase in w_i, through the incentive effect. But this leads to a fall in the utility of a status-seeking principal who is now less ahead, we refer to this as the 'status-seeking effect'. This would induce the principal to optimally reduce the wage of the other agent, i.e. w_j. But this reduction of w_j has its negative effects through reduced incentive and effort for agent j. If the principal is sufficiently status-seeking then the 'status-seeking effect' is sufficiently strong and can outweigh other negative effects. Moreover, if the agents are far apart and suffer from high-inequity, then it might be optimal for the principal to induce a tournament among the agents through a 'relative performance contract' in which both agents would not like to fall too far behind of the other and get a reduced wage from other's relatively better performance. Thus a status-seeking principal and far-apart agents might tilt the optimal contract towards a 'relative performance contract'. All the above intuitions will certainly hold if the own wage incentive is not that high, i.e. $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$. If the own wage incentive is sufficiently high then the cross wage effects described above might weaken. Thus, $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$ is a sufficient condition for the above intuitions to hold. The following proposition shows that in the presence of fairness concerns among agents and principal's 'other-regardingness' leads to the possibility of 'team' and 'relative performance' contracts being offered at the optimum, certainly if the own wage incentive is not so high :

Proposition 4.2:

(a). If projects are technologically independent then an 'inequity-averse' and a 'self-regarding' principal will optimally offer 'team contracts' to inequity-averse agents if $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$.

(b). Given $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$, *if the principal is sufficiently status-seeking and the agents' wages are far apart then relative-performance contract is a possibility.*

Proof: See appendix.

This proposition also supports the empirically observed phenomenon of the pervasiveness of team contracts in reality. The first part of the proposition is also similar to what Englmaier & Wambach (2010) found out in the context of a 'self-regarding' principal and inequity-averse agents only with an additional condition. But for a sufficiently status-seeking principal relative performance contracts can be optimal and this is a notable change even without any correlation in project outcomes. Our next results try to further characterize the nature of the optimal contracts even further.

Proposition 4.3:

(a). Both $w_1(.)$ *and* $w_2(.)$ *fall with a ceteris paribus increase in* π *if* α_{Pi} *is not that large.*

(b). $w_i(.)$ *increases with a ceteris paribus increase in* α_{Pi}.

(c). Agents are better-off under a more inequity-averse Principal (less status-seeking Principal).

These are sufficient conditions.

Proof: See appendix.

Ceteris paribus, as the principal becomes more status-seeking (or relatively less inequity-averse), the principal will optimally offer lower wage. But if lower wage is offered then the agents being inequity-averse with respect to the principal, suffers from inequity. This will have a negative effect on their effort. So if α_{Pi} is not too high then this negative effect will be outweighed by the principal's 'status-seeking effect' and therefore the wages will certainly fall with increased π. The proposition gives sufficient condition for wages to fall with increased π.

Similarly, if α_{Pi} increases then agent i becomes more inequity-averse vis-à-vis the principal. This leads to a loss in agent i's utility since the agents are always behind. This creates a perverse impact on agent i's effort and to compensate for that the principal needs to provide higher wage to agent i.

Since wages fall with a ceteris paribus increase in π, the agents lose on two accounts. First is the direct effect of getting reduced wage and also the inequity between the agents and the principal rises. The effect of intra-agent inequity depends on the relative position of the agents' wages. But the first two negative effects are certain to outweigh any third effect (even if positive) and therefore the agents will prefer a relatively more inequity-averse principal (a less status seeking principal) who prefers to reduce payoff differences among her and the agents.

As the agents become more inequity-averse among themselves then the principal optimally reduces the agents' wage-gap and reduces the adverse effect of agents' inequity. The next proposition talks about that.

Proposition 4.4:

An increase in α_{Ai} *reduces the gap between* $w_1(.)$ *and* $w_2(.)$.

Proof: See appendix.

If the agents become more inequity-averse among them then both suffer from inequity aversion and experience a loss in utility. This becomes costly for the principal to induce the agents to participate as well as to incentivize them to provide higher effort. Therefore as α_{Ai} increases the principal will find it optimal to reduce the wage gap such that the loss due to increased inequity suffered by the agents are minimized.

This is also implies that as the inequity-concern among agents increases indefinitely then in the limit the wages will be equal.

Corollary 4.1:

As $\alpha_{Ai} \rightarrow \infty$ *we get* $w_1(x_1, x_2) = w_2(x_1, x_2)$.

4.3. Concluding Observations:

In this chapter we provide a comprehensive analysis of an interaction of an other-regarding principal with two other-regarding agents. We analyze both independent production technology and correlated project outcomes. We find that with 'status-seeking' and 'not so high inequity-averse' agents, a moderately inequity-averse or a status-seeking principal will offer an 'extreme relative performance contract', whereas she will offer an 'extreme team contract' if the agents are 'sufficiently inequity-averse' and this is similar to what we get in Itoh (2004) with self-regarding principal. Contrary to this a 'sufficiently inequity-averse' principal will offer an 'extreme' independent contract that minimizes her ex-ante expected payoff loss from being ahead keeping the work incentives intact. This is contrary to what we get in Itoh (2004) and other papers in multi agent framework with other-regarding agents and self-regarding principal. Similar results hold in essence when the projects of the agents are correlated as well. In addition to this we consider the case of a 'fair' principal who experiences a reduction in utility when the agents get different wages. We show that relative performance contracts are never optimal when a fair principal interacts with a self-regarding agent. Also team contract is more likely under a 'fair' principal compared to the standard case where the principal is other-regarding vis-a-vis the agents.

Then to complete our analysis we venture into the continuous effort and outcome case using a structure similar to Englmaier & Wambach (2010) and we generalize it with an other-regarding principal. We show that with continuous efforts and outcomes 'team contracts' are optimal when the principal is inequity-averse and not too status-seeking. But if the principal is sufficiently status-seeking optimality of 'relative performance contracts' is a possibility. While characterizing the nature of the optimal contracts, we provide sufficient conditions for the 'relative performance contracts' to be optimal in terms of the direct wage incentive effect. But independent contracts are never optimal. Thus, a comprehensive analysis is done where the interaction of an other-regarding principal and two other-regarding agents are modeled using various structures and alternative specifications and we get that with other-regarding principal and agents both team contracts and relative-performance contracts are a possibility across structures.

In the next chapter we focus on the problem faced by a principal while deciding whether to opt for individual production (single agent) or team production (multi agent) with or without synergy. Since the principal is the first mover in this sequential move principal agent problems therefore such a decision solely depends on the principal. The principal and the agents are assumed to be other-regarding and under such framework the principal compares her payoffs in team and individual production to find what is best for her.

Appendix

Proof of Proposition 4.1:

We can set the Lagrangian as

$$\mathcal{L} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{x_1 + x_2 - w_1 - w_2 + \pi S_1(x_1 + x_2 - 2w_1 - w_2)$$

$$+ \pi S_2(x_1 + x_2 - w_1 - 2w_2)\} dx_1 dx_2$$

$$+ \lambda_1 \left[\int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_1(w_1) - \alpha_{P1} G_1(x_1 + x_2 - 2w_1 - w_2) \right.$$

$$\left. - \alpha_{A1} H_1(w_2 - w_1)\} dx_1 dx_2 - c_1(e_1) - u_1 \right]$$

$$+ \lambda_2 \left[\int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_2(w_2) - \alpha_{P2} G_2(x_1 + x_2 - w_1 - 2w_2) \right.$$

$$\left. - \alpha_{A2} H_2(w_1 - w_2)\} dx_1 dx_2 - c_2(e_2) - u_2 \right]$$

$$+ \mu_1 \left[\int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_{1_{e_1}}(x_1|e_1)\, f_2(x_2|e_2)\{u_1(w_1) - \alpha_{P1} G_1(x_1 + x_2 - 2w_1 - w_2) \right.$$

$$\left. - \alpha_{A1} H_1(w_2 - w_1)\} dx_1 dx_2 - c_1'(e_1) \right]$$

$$+ \mu_2 \left[\int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1) f_{2_{e_2}}(x_2|e_2)\, \{u_2(w_2) - \alpha_{P2} G_2(x_1 + x_2 - w_1 - 2w_2) \right.$$

$$\left. - \alpha_{A2} H_2(w_1 - w_2)\} dx_1 dx_2 - c_2'(e_2) \right]$$

Maximizing with respect to w_1 we get the first First Order Conditions (FOC1) as

$$\frac{\partial \mathcal{L}}{\partial w_1} = -f_1(x_1|e_1)f_2(x_2|e_2)\{1 + 2\pi S_1'(.) + \pi S_2'(.)\}$$

$$+ \lambda_1[f_1(x_1|e_1)f_2(x_2|e_2)\{u_1'(w_1) + 2\alpha_{P1}G_1'(.) + \alpha_{A1}H_1'(.)\}]$$

$$+ \lambda_2[f_1(x_1|e_1)f_2(x_2|e_2)\{\alpha_{P2}G_2'(.) - \alpha_{A2}H_2'(.)\}]$$

$$+ \mu_1\left[f_{1_{e_1}}(x_1|e_1)f_2(x_2|e_2)\{u_1'(w_1) + 2\alpha_{P1}G_1'(.) + \alpha_{A1}H_1'(.)\}\right]$$

$$+ \mu_2\left[f_1(x_1|e_1)f_{2_{e_2}}(x_2|e_2)\{\alpha_{P2}G_2'(.) - \alpha_{A2}H_2'(.)\}\right] = 0$$

(FOC1)

Dividing both sides by $f_1(x_1|e_1)f_2(x_2|e_2)$ we get (FOC1)

$$\{1 + 2\pi S_1'(.) + \pi S_2'(.)\}$$

$$= \left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{u_1'(w_1) + 2\alpha_{P1}G_1'(.) + \alpha_{A1}H_1'(.)\}$$

$$+ \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2'(.) - \alpha_{A2}H_2'(.)\}$$

Similarly, from $\frac{\partial \mathcal{L}}{\partial w_2} = 0$ and manipulating we get the second first order condition (FOC2) as

$$\{1 + \pi S_1'(.) + 2\pi S_2'(.)\}$$

$$= \left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{\alpha_{P1}G_1'(.) - \alpha_{A1}H_1'(.)\}$$

$$+ \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{u_2'(w_2) + 2\alpha_{P2}G_2'(.) + \alpha_{A2}H_2'(.)\}$$

(FOC2)

The following conditions imply that the participation constraints will be satisfied and incentive compatibility constraints will bind at the optimum.

$$\frac{\partial \mathcal{L}}{\partial \lambda_1} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_1(w_1) - \alpha_{P1} G_1(x_1 + x_2 - 2w_1 - w_2)$$

$$- \alpha_{A1} H_1(w_2 - w_1)\} dx_1 dx_2 - c_1(e_1) - u_1 \geq 0$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_2(w_2) - \alpha_{P2} G_2(x_1 + x_2 - w_1 - 2w_2)$$

$$- \alpha_{A2} H_2(w_1 - w_2)\} dx_1 dx_2 - c_2(e_2) - u_2 \geq 0$$

$$\frac{\partial \mathcal{L}}{\partial \mu_1} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_{1_{e_1}}(x_1|e_1)\, f_2(x_2|e_2)\{u_1(w_1) - \alpha_{P1} G_1(x_1 + x_2 - 2w_1 - w_2)$$

$$- \alpha_{A1} H_1(w_2 - w_1)\} dx_1 dx_2 - c_1'(e_1) = 0$$

$$\frac{\partial \mathcal{L}}{\partial \mu_2} = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1) f_{2_{e_2}}(x_2|e_2)\, \{u_2(w_2) - \alpha_{P2} G_2(x_1 + x_2 - w_1 - 2w_2)$$

$$- \alpha_{A2} H_2(w_1 - w_2)\} dx_1 dx_2 - c_2'(e_2) = 0$$

All the above will hold at the optimum.

For a well-defined maximum, we assume that the following second order conditions are satisfied:

$$\mathcal{L}_{11} = \frac{\partial^2 \mathcal{L}}{\partial w_1^2} = \left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{u_1''(w_1) + 2\alpha_{P1} G_1''(.)(-2) + \alpha_{A1} H_1''(.)(-1)\}$$

$$+ \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2} G_2''(.)(-1) - \alpha_{A2} H_2''(.)(+1)\} - 2\pi S_1''(.)(-2)$$

$$- \pi S_2''(.)(-1)$$

$$= -\left[\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{4\alpha_{P1} G_1''(.) + \alpha_{A1} H_1''(.) - u_1''(w_1)\}\right.$$

$$\left. + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2} G_2''(.) + \alpha_{A2} H_2''(.)\} - 4\pi S_1''(.) - \pi S_2''(.)\right]$$

$$= -A < 0$$

Where $A = \left[\left\{ \lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)} \right\} \{4\alpha_{P1} G_1''(.) + \alpha_{A1} H_1''(.) - u_1''(w_1)\} + \left\{ \lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)} \right\} \{\alpha_{P2} G_2''(.) + \alpha_{A2} H_2''(.)\} - 4\pi S_1''(.) - \pi S_2''(.) \right] > 0$

So, for the second order condition to go through we need $A > 0$.

Again,

$$\mathcal{L}_{22} = \frac{\partial^2 \mathcal{L}}{\partial w_2^2} = -\left[\left\{ \lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)} \right\} \{\alpha_{P1} G_1''(.) + \alpha_{A1} H_1''(.)\} + \left\{ \lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)} \right\} \{4\alpha_{P2} G_2''(.) + \alpha_{A2} H_2''(.) - u_2''(w_2)\} - \pi S_1''(.) - 4\pi S_2''(.) \right] = -C < 0$$

Where

$C = \left[\left\{ \lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)} \right\} \{\alpha_{P1} G_1''(.) + \alpha_{A1} H_1''(.)\} + \left\{ \lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)} \right\} \{4\alpha_{P2} G_2''(.) + \alpha_{A2} H_2''(.) - u_2''(w_2)\} - \pi S_1''(.) - 4\pi S_2''(.) \right] > 0$

Once again for the second order condition to go through we need $C > 0$.

Also

$$\mathcal{L}_{12} = \frac{\partial^2 \mathcal{L}}{\partial w_2 \partial w_1}$$

$$= \left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)(-1) + \alpha_{A1}H_1''(.)(+1)\}$$

$$+ \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2''(.)(-2) - \alpha_{A2}H_2''(.)(-1)\} - 2\pi S_1''(.)(-1)$$

$$- 2\pi S_2''(.)(-1)$$

$$= -\left[\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.) - \alpha_{A1}H_1''(.)\}\right.$$

$$\left. + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.) - \alpha_{A2}H_2''(.)\} - 2\pi S_1''(.) - 2\pi S_2''(.)\right]$$

$$= -B$$

Where, $B = \left[\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.) - \alpha_{A1}H_1''(.)\} + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.) - \alpha_{A2}H_2''(.)\} - 2\pi S_1''(.) - 2\pi S_2''(.)\right]$

We need not know the sign of B but what we need is that $\mathcal{L}_{11}\mathcal{L}_{22} - \mathcal{L}_{12}^2 = AC - B^2 > 0$ should hold along with $\mathcal{L}_{11} < 0$ and $\mathcal{L}_{22} < 0$.

Now, Differentiating FOC1 with respect to x_1 we get

$$2\pi S_1''(.)\left(1-2\frac{\partial w_1}{\partial x_1}-\frac{\partial w_2}{\partial x_1}\right)+\pi S_2''(.)\left(1-\frac{\partial w_1}{\partial x_1}-2\frac{\partial w_2}{\partial x_1}\right)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{u_1''(w_1)\frac{\partial w_1}{\partial x_1}+2\alpha_{P1}G_1''(.)\left(1-2\frac{\partial w_1}{\partial x_1}-\frac{\partial w_2}{\partial x_1}\right)\right.$$

$$\left.+\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial x_1}-\frac{\partial w_1}{\partial x_1}\right)\right\}$$

$$+\left\{\mu_1\left(\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right)'\right\}\{u_1'(w_1)+2\alpha_{P1}G_1'(.)+\alpha_{A1}H_1'(.)\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(1-\frac{\partial w_1}{\partial x_1}-2\frac{\partial w_2}{\partial x_1}\right)\right.$$

$$\left.-\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial x_1}-\frac{\partial w_2}{\partial x_1}\right)\right\}$$

$$\Rightarrow\frac{\partial w_1}{\partial x_1}=\frac{\begin{array}{c}\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{2\alpha_{P1}G_1''(.)\left(1-\frac{\partial w_2}{\partial x_1}\right)+\alpha_{A1}H_1''(.)\frac{\partial w_2}{\partial x_1}\right\}\\+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(1-2\frac{\partial w_2}{\partial x_1}\right)+\alpha_{A2}H_2''(.)\frac{\partial w_2}{\partial x_1}\right\}\\+\left\{\mu_1\left(\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right)'\right\}\{u_1'(w_1)+2\alpha_{P1}G_1'(.)+\alpha_{A1}H_1'(.)\}-2\pi S_1''(.)\left(1-\frac{\partial w_2}{\partial x_1}\right)\\-\pi S_2''(.)\left(1-2\frac{\partial w_2}{\partial x_1}\right)\end{array}}{A}$$

The denominator $A>0$ from second order condition. If $\frac{\partial w_2}{\partial x_1}<\frac{1}{2}$, then $\frac{\partial w_1}{\partial x_1}>0$ certainly if $\pi<0$. So for inequity-averse principal all terms are positive. If $\frac{\partial w_2}{\partial x_1}<\frac{1}{2}$, then even if $\pi>0$, with a not too high $S_i''(.)$ we can still have $\frac{\partial w_1}{\partial x_1}>0$.

Similar analysis holds for $\frac{\partial w_2}{\partial x_2}>0$. Note that these are sufficient conditions, not necessary.

Hence the result. **QED**

Proof of Proposition 4.2:

Differentiating FOC1 with respect to x_2 we get

$$2\pi S_1''(.)\left(1-2\frac{\partial w_1}{\partial x_2}-\frac{\partial w_2}{\partial x_2}\right)+\pi S_2''(.)\left(1-\frac{\partial w_1}{\partial x_2}-2\frac{\partial w_2}{\partial x_2}\right)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{u_1''(w_1)\frac{\partial w_1}{\partial x_2}+2\alpha_{P1}G_1''(.)\left(1-2\frac{\partial w_1}{\partial x_2}-\frac{\partial w_2}{\partial x_2}\right)\right.$$

$$\left.+\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial x_2}-\frac{\partial w_1}{\partial x_2}\right)\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(1-\frac{\partial w_1}{\partial x_2}-2\frac{\partial w_2}{\partial x_2}\right)\right.$$

$$\left.-\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial x_2}-\frac{\partial w_2}{\partial x_2}\right)\right\}+\left\{\mu_2\left(\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right)'\right\}\{\alpha_{P2}G_2'(.)-\alpha_{A2}H_2'(.)\}$$

$$\Rightarrow\frac{\partial w_1}{\partial x_2}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{4\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)-u_1''(w_1)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)\}-4\pi S_1''(.)-\pi S_2''(.)\right]$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{2\alpha_{P1}G_1''(.)\left(1-\frac{\partial w_2}{\partial x_2}\right)+\alpha_{A1}H_1''(.)\frac{\partial w_2}{\partial x_2}\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(1-2\frac{\partial w_2}{\partial x_2}\right)+\alpha_{A2}H_2''(.)\frac{\partial w_2}{\partial x_2}\right\}$$

$$-2\pi S_1''(.)\left(1-\frac{\partial w_2}{\partial x_2}\right)-\pi S_2''(.)\left(1-2\frac{\partial w_2}{\partial x_2}\right)$$

$$+\left\{\mu_2\left(\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right)'\right\}\{\alpha_{P2}G_2'(.)-\alpha_{A2}H_2'(.)\}$$

$$\Rightarrow \frac{\partial w_1}{\partial x_2} = \frac{\begin{array}{c}\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{2\alpha_{P1}G_1''(.)\left(1-\frac{\partial w_2}{\partial x_2}\right) + \alpha_{A1}H_1''(.)\frac{\partial w_2}{\partial x_2}\right\} \\ + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(1-2\frac{\partial w_2}{\partial x_2}\right) + \alpha_{A2}H_2''(.)\frac{\partial w_2}{\partial x_2}\right\} \\ + \left\{\mu_2 \left(\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right)'\right\}\{\alpha_{P2}G_2'(.) - \alpha_{A2}H_2'(.)\} - 2\pi S_1''(.)\left(1-\frac{\partial w_2}{\partial x_2}\right) \\ -\pi S_2''(.)\left(1-2\frac{\partial w_2}{\partial x_2}\right)\end{array}}{A}$$

The denominator is positive from the second order condition for maximization. If the principal is inequity-averse ($\pi < 0$) and $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$ holds then all terms except $-\alpha_{A2}H_2'(.)$ in the numerator is positive. Thus, for an inequity-averse principal, if $\frac{\partial w_i}{\partial x_i} < \frac{1}{2}$ holds then almost certainly $\frac{\partial w_1}{\partial x_2} > 0$ and therefore the optimal contract will be a team contract. Similar result holds if $\pi = 0$, i.e. the principal is self-regarding. But if $\pi > 0$ then there are three negative terms $-2\pi S_1''(.)\left(1-\frac{\partial w_2}{\partial x_2}\right)$, $-\pi S_2''(.)\left(1-2\frac{\partial w_2}{\partial x_2}\right)$ and $-\alpha_{A2}H_2'(.)$ and if π and α_{A2} is suficiently high then it is possible that $\frac{\partial w_1}{\partial x_2} < 0$ implying the optimality of a relative performance contract. In addition to this, if $H_2'(.)$ is sufficiently high implying a large gap between the agents' wages, then it might be optimal for the principal to offer a relative performance contract.

Similarly, by differentiating FOC2 by x_1 we get

$$\Rightarrow \frac{\partial w_2}{\partial x_1} = \frac{\begin{array}{c}\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{\alpha_{P1}G_1''(.)\left(1-2\frac{\partial w_1}{\partial x_1}\right) + \alpha_{A1}H_1''(.)\frac{\partial w_1}{\partial x_1}\right\} \\ + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{2\alpha_{P2}G_2''(.)\left(1-\frac{\partial w_1}{\partial x_1}\right) + \alpha_{A2}H_2''(.)\frac{\partial w_1}{\partial x_1}\right\} \\ + \left\{\mu_1 \left(\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right)'\right\}\{\alpha_{P1}G_1'(.) - \alpha_{A1}H_1'(.)\} - \pi S_1''(.)\left(1-2\frac{\partial w_1}{\partial x_1}\right) - 2\pi S_2''(.)\left(1-\frac{\partial w_1}{\partial x_1}\right)\end{array}}{C}$$

Once again from the second order condition $C > 0$. Same rationale as above holds in this case also.

Hence, the result. **QED**

Proof of Proposition 4.3:

(a). By differentiating FOC1 by π we get

$$2\pi S_1''(.)\left(-2\frac{\partial w_1}{\partial \pi}-\frac{\partial w_2}{\partial \pi}\right)+2S_1'(.)+\pi S_2''(.)\left(-\frac{\partial w_1}{\partial \pi}-2\frac{\partial w_2}{\partial \pi}\right)+S_2'(.)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{u_1''(w_1)\frac{\partial w_1}{\partial \pi}+2\alpha_{P1}G_1''(.)\left(-2\frac{\partial w_1}{\partial \pi}-\frac{\partial w_2}{\partial \pi}\right)\right.$$

$$\left.+\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial \pi}-\frac{\partial w_1}{\partial \pi}\right)\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(-\frac{\partial w_1}{\partial \pi}-2\frac{\partial w_2}{\partial \pi}\right)\right.$$

$$\left.-\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial \pi}-\frac{\partial w_2}{\partial \pi}\right)\right\}$$

$$\Rightarrow \frac{\partial w_1}{\partial \pi}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{4\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)-u_1''(w_1)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)\}-4\pi S_1''(.)-\pi S_2''(.)\right]$$

$$+\frac{\partial w_2}{\partial \pi}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)-\alpha_{A1}H_1''(.)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.)-\alpha_{A2}H_2''(.)\}-2\pi S_1''(.)-2\pi S_2''(.)\right]$$

$$=-2S_1'(.)-S_2'(.)$$

$$\Rightarrow A\frac{\partial w_1}{\partial \pi}+B\frac{\partial w_2}{\partial \pi}=-2S_1'(.)-S_2'(.) \qquad \text{(A1)}$$

Similarly, from FOC2 we get

$$\frac{\partial w_1}{\partial \pi}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)-\alpha_{A1}H_1''(.)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.)-\alpha_{A2}H_2''(.)\}-2\pi S_1''(.)-2\pi S_2''(.)\right]$$

$$+\frac{\partial w_2}{\partial \pi}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)\}\right.$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{4\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)-u_2''(w_2)\}-\pi S_1''(.)$$

$$\left.-4\pi S_2''(.)\right]=-S_1'(.)-2S_2'(.)$$

$$\Rightarrow B\frac{\partial w_1}{\partial \pi}+C\frac{\partial w_2}{\partial \pi}=-S_1'(.)-2S_2'(.) \qquad \text{(A2)}$$

Solving (A1) and (A2) we get,

$$\frac{\partial w_1}{\partial \pi}=\frac{\begin{vmatrix}-2S_1'(.)-S_2'(.) & B\\ -S_1'(.)-2S_2'(.) & C\end{vmatrix}}{\begin{vmatrix}A & B\\ B & C\end{vmatrix}}=\frac{S_1'(.)(2C-B)+S_2'(.)(C-2B)}{B^2-AC}$$

$$=\frac{\begin{array}{c}S_1'(.)[3\alpha_{A1}H_1''(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\\ +\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{6\alpha_{P2}G_2''(.)+3\alpha_{A2}H_2''(.)-2u_2''(w_2)\}\\ -6\pi S_2''(.)]+S_2'(.)[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{3\alpha_{A1}H_1''(.)-3\alpha_{P1}G_1''(.)\}\\ +\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{3\alpha_{A2}H_2''(.)-u_2''(w_2)\}+3\pi S_1''(.)]\end{array}}{B^2-AC}$$

The denominator is negative from the second order Hessian matrix condition. For numerator, note that terms $-6\pi S_2''(.)$ and $3\pi S_1''(.)$ Move in the opposite direction and cancels each other quite a bit. The only other negative term $-3\alpha_{P1}G_1''(.)$ is unlikely to outweigh all other positive terms and certainly if $3\alpha_{P1}$ is not that large. This along with the second order conditions and risk averse agents we will certainly get $\frac{\partial w_1}{\partial \pi} < 0$.

Similarly, it can be shown that $\frac{\partial w_2}{\partial \pi} < 0$.

(b). Now by differentiating FOC1 by α_{P1} we get

$$2\pi S_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{P1}} - \frac{\partial w_2}{\partial \alpha_{P1}}\right) + \pi S_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{P1}} - 2\frac{\partial w_2}{\partial \alpha_{P1}}\right)$$

$$= \left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{u_1''(w_1)\frac{\partial w_1}{\partial \alpha_{P1}} + 2\alpha_{P1}G_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{P1}} - \frac{\partial w_2}{\partial \alpha_{P1}}\right)\right.$$

$$\left. + 2G_1'(.) + \alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial \alpha_{P1}} - \frac{\partial w_1}{\partial \alpha_{P1}}\right)\right\}$$

$$+ \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{P1}} - 2\frac{\partial w_2}{\partial \alpha_{P1}}\right)\right.$$

$$\left. - \alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial \alpha_{P1}} - \frac{\partial w_2}{\partial \alpha_{P1}}\right)\right\}$$

$$\Rightarrow \frac{\partial w_1}{\partial \alpha_{P1}}\left[\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{4\alpha_{P1}G_1''(.) + \alpha_{A1}H_1''(.) - u_1''(w_1)\}\right.$$

$$\left. + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2''(.) + \alpha_{A2}H_2''(.)\} - 4\pi S_1''(.) - \pi S_2''(.)\right]$$

$$+ \frac{\partial w_2}{\partial \alpha_{P1}}\left[\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.) - \alpha_{A1}H_1''(.)\}\right.$$

$$\left. + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.) - \alpha_{A2}H_2''(.)\} - 2\pi S_1''(.) - 2\pi S_2''(.)\right]$$

$$= 2G_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

$$\Rightarrow A\frac{\partial w_1}{\partial \alpha_{P1}} + B\frac{\partial w_2}{\partial \alpha_{P1}} = 2G_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

Similarly, from FOC2 we get

$$\pi S_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{P1}}-\frac{\partial w_2}{\partial \alpha_{P1}}\right)+2\pi S_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{P1}}-2\frac{\partial w_2}{\partial \alpha_{P1}}\right)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{\alpha_{P1}G_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{P1}}-\frac{\partial w_2}{\partial \alpha_{P1}}\right)+G_1'(.)\right.$$

$$\left.-\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial \alpha_{P1}}-\frac{\partial w_1}{\partial \alpha_{P1}}\right)\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{u_2''(w_2)\frac{\partial w_2}{\partial \alpha_{P1}}+2\alpha_{P2}G_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{P1}}-2\frac{\partial w_2}{\partial \alpha_{P1}}\right)\right.$$

$$\left.+\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial \alpha_{P1}}-\frac{\partial w_2}{\partial \alpha_{P1}}\right)\right\}$$

$$\Rightarrow \frac{\partial w_1}{\partial \alpha_{P1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)-\alpha_{A1}H_1''(.)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.)-\alpha_{A2}H_2''(.)\}-2\pi S_1''(.)-2\pi S_2''(.)\right]$$

$$+\frac{\partial w_2}{\partial \alpha_{P1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)\}\right.$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{4\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)-u_2''(w_2)\}-\pi S_1''(.)$$

$$\left.-4\pi S_2''(.)\right]=G_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

$$\Rightarrow B\frac{\partial w_1}{\partial \alpha_{P1}}+C\frac{\partial w_2}{\partial \alpha_{P1}}=G_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

From here by solving these we get,

$$\frac{\partial w_1}{\partial \alpha_{P1}} = \frac{\begin{vmatrix} 2G_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} & B \\ G_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} & C \end{vmatrix}}{\begin{vmatrix} A & B \\ B & C \end{vmatrix}} = \frac{(2C-B)G_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}}{AC - B^2}$$

The denominator is positive from the second order condition.

Now,

$$(2C - B) = \left[3\alpha_{A1}H_1''(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\right.$$
$$\left. + \left\{\lambda_2 + \mu_2 \frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{6\alpha_{P2}G_2''(.) + 3\alpha_{A2}H_2''(.) - 2u_2''(w_2)\} - 6\pi S_2''(.)\right]$$

$(2C - B) > 0$ since the negative term $-6\pi S_2''(.)$ will be outweighed but other positive terms and we get that from the second order conditions. (If π is negative then certainly $\frac{\partial w_1}{\partial \alpha_{P1}} > 0$). Also $G_1'(.) > 0$ as principal is always at least weakly ahead of the agents. Note that there is no negative terms in the numerator for inequity-averse principal. Therefore, we have $\frac{\partial w_1}{\partial \alpha_{P1}} > 0$. Similarly we can show that $\frac{\partial w_2}{\partial \alpha_{P2}} > 0$. **QED**

Proof of Proposition 4.4:

Differentiating FOC1 by α_{A1} we get

$$2\pi S_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)+\pi S_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{A1}}-2\frac{\partial w_2}{\partial \alpha_{A1}}\right)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{u_1''(w_1)\frac{\partial w_1}{\partial \alpha_{A1}}+2\alpha_{P1}G_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right.$$

$$\left.+\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial \alpha_{A1}}-\frac{\partial w_1}{\partial \alpha_{A1}}\right)+H_1'(.)\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{\alpha_{P2}G_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{A1}}-2\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right.$$

$$\left.-\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right\}$$

$$\Rightarrow \frac{\partial w_1}{\partial \alpha_{A1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{4\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)-u_1''(w_1)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)\}-4\pi S_1''(.)-\pi S_2''(.)\right]$$

$$+\frac{\partial w_2}{\partial \alpha_{A1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)-\alpha_{A1}H_1''(.)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.)-\alpha_{A2}H_2''(.)\}-2\pi S_1''(.)-2\pi S_2''(.)\right]$$

$$=H_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

$$\Rightarrow A\frac{\partial w_1}{\partial \alpha_{A1}}+B\frac{\partial w_2}{\partial \alpha_{A1}}=H_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

Similarly, from FOC2 we get

$$\pi S_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)+2\pi S_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{A1}}-2\frac{\partial w_2}{\partial \alpha_{A1}}\right)$$

$$=\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\left\{\alpha_{P1}G_1''(.)\left(-2\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right.$$

$$\left.-\alpha_{A1}H_1''(.)\left(\frac{\partial w_2}{\partial \alpha_{A1}}-\frac{\partial w_1}{\partial \alpha_{A1}}\right)-H_1'(.)\right\}$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\left\{u_2''(w_2)\frac{\partial w_2}{\partial \alpha_{A1}}+2\alpha_{P2}G_2''(.)\left(-\frac{\partial w_1}{\partial \alpha_{A1}}-2\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right.$$

$$\left.+\alpha_{A2}H_2''(.)\left(\frac{\partial w_1}{\partial \alpha_{A1}}-\frac{\partial w_2}{\partial \alpha_{A1}}\right)\right\}$$

$$\Rightarrow \frac{\partial w_1}{\partial \alpha_{A1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{2\alpha_{P1}G_1''(.)-\alpha_{A1}H_1''(.)\}\right.$$

$$\left.+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{2\alpha_{P2}G_2''(.)-\alpha_{A2}H_2''(.)\}-2\pi S_1''(.)-2\pi S_2''(.)\right]$$

$$+\frac{\partial w_2}{\partial \alpha_{A1}}\left[\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}\{\alpha_{P1}G_1''(.)+\alpha_{A1}H_1''(.)\}\right.$$

$$+\left\{\lambda_2+\mu_2\frac{f_{2_{e_2}}(x_2|e_2)}{f_2(x_2|e_2)}\right\}\{4\alpha_{P2}G_2''(.)+\alpha_{A2}H_2''(.)-u_2''(w_2)\}-\pi S_1''(.)$$

$$\left.-4\pi S_2''(.)\right]=-H_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

$$\Rightarrow B\frac{\partial w_1}{\partial \alpha_{A1}}+C\frac{\partial w_2}{\partial \alpha_{A1}}=-H_1'(.)\left\{\lambda_1+\mu_1\frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}$$

From here by solving these we get,

$$\frac{\partial w_1}{\partial \alpha_{A1}} = \frac{\begin{vmatrix} H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} & B \\ -H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} & C \end{vmatrix}}{\begin{vmatrix} A & B \\ B & C \end{vmatrix}} = \frac{(B+C)H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}}{AC - B^2}$$

$$\frac{\partial w_2}{\partial \alpha_{A1}} = \frac{\begin{vmatrix} A & H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} \\ B & -H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\} \end{vmatrix}}{\begin{vmatrix} A & B \\ B & C \end{vmatrix}} = \frac{-(A+B)H_1'(.)\left\{\lambda_1 + \mu_1 \frac{f_{1_{e_1}}(x_1|e_1)}{f_1(x_1|e_1)}\right\}}{AC - B^2}$$

In case if $w_2 > w_1$ then $H_1'(.) > 0$ therefore $\frac{\partial w_1}{\partial \alpha_{A1}} > 0$ and $\frac{\partial w_2}{\partial \alpha_{A1}} < 0$. The result holds for both status-seeking and inequity-averse principals.

This implies that as α_{A1} increases the gap between $w_2(.)$ and $w_1(.)$ falls.

Similar result can be shown in case of α_{A2} as well.

Proof of Corollary 4.1:

Participation constraint for agent i:

$$EU_A^i = \int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{u_i(w_i) - \alpha_{Pi} G_i(x_1 + x_2 - 2w_i - w_j)$$

$$- \alpha_{Ai} H_i(w_j - w_i)\} dx_1 dx_2 - c_i(e_i) \geq u_i$$

Now we divide both side of PC by α_{Ai} to get,

$$\int_{\underline{x}_1}^{\overline{x}_1} \int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\left\{\frac{u_i(w_i)}{\alpha_{Ai}} - \frac{\alpha_{Pi} G_i(x_1 + x_2 - 2w_i - w_j)}{\alpha_{Ai}} - H_i(w_j - w_i)\right\} dx_1 dx_2$$

$$- \frac{c_i(e_i)}{\alpha_{Ai}} \geq \frac{u_i}{\alpha_{Ai}}$$

Now consider the case when α_{Ai} is so large so that $\alpha_{Ai} \to \infty$

$$\lim_{\alpha_{Ai}\to\infty}\left[\int_{\underline{x}_1}^{\overline{x}_1}\int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\left\{\frac{u_i(w_i)}{\alpha_{Ai}} - \frac{\alpha_{Pi}G_i\big(x_1 + x_2 - 2w_i - w_j\big)}{\alpha_{Ai}} - H_i\big(w_j - w_i\big)\right\} dx_1 dx_2 - \frac{c_i(e_i)}{\alpha_{Ai}}\right] \geq \lim_{\alpha\to\infty}\frac{u_i}{\alpha_{Ai}}$$

$$\Rightarrow \int_{\underline{x}_1}^{\overline{x}_1}\int_{\underline{x}_2}^{\overline{x}_2} f_1(x_1|e_1)\, f_2(x_2|e_2)\{-H_i\big(w_j - w_i\big)\} dx_1 dx_2 \geq 0$$

This can only hold if $H_i\big(w_j - w_i\big) = 0$. Therefore $w_1(x_1, x_2) = w_2(x_1, x_2)$ as $\alpha_{Ai} \to \infty$.

CHAPTER 5

INDIVIDUAL VERSUS TEAM PRODUCTION WITH SOCIAL PREFERENCES

5.1. Introduction:

Joint production or team work is quite common in workplace all over the world**.** Recent paper by Sanyal & Hisam (2018) studies the impact of team work on faculty members of Dhofar University in Oman. They find strong positive correlation between team work and the climate of trust and increased performance among the faculty. Team work plays a big role in healthcare system as well as improving quality of patient care and in reducing work issues (Lerner et. al. 2009). High-risk jobs like military, fire-fighting, disaster management all require cooperation of teammates to reduce risks. Working in teams can create new ideas through open communication, can solve problems, build up complementary strengths and trust among different co-workers. Ichniowski et. al. (1997) finds that team work achieves substantially higher levels of productivity as compared to traditional strict work rules with hourly wage and close supervision using data from thirty-six homogenous steel production lines of seventeen companies. Boning et. al. (1998) also shows that team work increases productivity using a panel dataset on U.S. mini-mills production lines. They found that problem solving in teams is most common in complex production lines.[28] In short, the above papers highlight the pervasiveness and several advantages of team production over individual production. From a theoretical point of view Itoh (1992) argues that if the agent's cost of effort is convex then it is optimal to assign multiple agents to perform a single task since that can lower the total cost of performance. Hemmer (1995) shows that if there exists direct synergy from performing two

[28] More examples of the prevalence of team production can be found in Che and Yoo (2001).

tasks, then it might be optimal to assign these tasks jointly instead of separately to exploit the synergy better.

In this chapter we investigate the choice of individual versus team production where both the principal and the agents have social preferences. Specifically, we focus on an inequity-averse principal's choice of individual vis-à-vis team production where the agent(s) are 'inequity-averse' with respect to the principal. The principal compares her net payoff to that of the agent(s)' and so does the agent(s). Thus, in this model there is 'vertical' social comparison.[29] The structure we use is that of Che and Yoo (2001) with single project (see section-III of their paper) where we incorporate these social preferences. The principal is assumed to be never behind.[30] The principal can hire 'one' agent or a 'team of two agents' for a project. So, we are in a single project framework. When one agent is hired, we refer to it as 'individual production'. When two agents are hired then we refer to it as 'team production'.[31] We show that in a static framework, even without synergy, a sufficiently inequity-averse principal interacting with inequity-averse agent(s) can opt for team production. In case of team production the principal's total wage payment is higher compared to individual production which makes team production unattractive vis-à-vis individual production; but this also makes the principal less ahead of the team compared to individual production and therefore suffers less from inequity which makes team attractive compared to individual production. Thus, these two effects work in the opposite direction and the second effect might dominate the first for a moderately inequity-averse principal interacting with sufficiently inequity-averse agents and therefore the principal might prefer team production over individual production even without synergy. Thus, the nature of social preferences crucially affects the choice of individual vis-à-vis team production which was not addressed in Che and Yoo (2001) and earlier papers.

[29] The relevance of vertical comparison is discussed in section 5.1.2.
[30] This is in line with Dur and Glazer (2008).
[31] This is similar to Che and Yoo (2001).

Interestingly, if the principal is sufficiently inequity-averse she chooses to eliminate inequity altogether and therefore the inequity effects of the agent(s) are also minimized. Under this situation the principal will choose team production if and only if the team has synergy and this is a necessary and sufficient condition. Thus, a sufficiently inequity-averse principal will never choose team production without synergy. Under the special cases, when an inequity-averse principal interacts with self-regarding agent(s) and also when a self-regarding principal interacts with inequity-averse agent(s), the principal will always choose individual production over team production without synergy.

We extend our model to a dynamic framework and find that social preferences crucially affect the choice between individual and team production in the dynamic set up as well. But, ceteris paribus, a moderately inequity-averse principal will prefer team production more over individual production compared to the static framework. This, in essence, is similar to the finding of Che and Yoo (2001) which show that dynamic interaction tilts the choice in favour of team production as compared to static interaction. Also, under the repeated setup, 'team wage' is lower than the 'team wage' of the static setup. Thus, the principal is better off under repeated setting than under the static setting. But for a sufficiently inequity-averse principal, the incentive for team production remains the same across short-term and long-term relationships and this is again due to the fact that the principal finds it optimal to remove inequity vis-à-vis the agent(s) completely. Thus, social preferences of both the principal and the agent(s) do have a nontrivial impact on the choice of team vis-à-vis individual production even under the dynamic setting.

5.1.1. Some Literature on Dynamic Contracting:

This chapter is also related to the dynamic contracting literature. Many employment contracts last for a longer period and the agents face the same decision problem repeated over and over again throughout the span of the contract. Therefore, cooperation might become common in the repeated setup than under static setup. Macleod & Malcomson (1989), Baker et. al. (1994, 1999, 2001), Meyer and Vickers (1997), Schmidt and Schnitzer (1995), Bernheim and Whinston (1998) along with few others deal with dynamic contracting problems with a single agent, whereas we also consider a multi agent environment. Arya et.al. (1997) talks about group incentives in a two-period dynamic model. Che and Yoo (2001) specifically deal with individual production versus team production in a dynamic framework. We follow the Che and Yoo (2001) approach closely and examine their finding with social preferences.

This chapter is organized as follows. In section 5.2 we analyze the static model of individual production and team production. Section 5.3 considers repeated interaction. Section 5.4 provides some concluding remarks.

5.2. The Static Framework:

We attempt to extend the work of Che and Yoo (2001) to a more generalized setup with an inequity-averse principal and inequity-averse agent or agents. The principal can hire a single agent to perform a task (referred henceforth as individual production) or can hire a team of two symmetric agents (referred henceforth as team production). The task returns a gross payoff of $R > 0$ if the project succeeds and 0 if fails. Both the principal and agents are assumed to be risk neutral. The effort(s) put in by the agent(s) are not verifiable and hence non-contractible; however the outcome of the project is verifiable and hence contractible. Agent(s) are paid according to the outcome of the project. Effort is assumed to be discrete. We assume that the agents cannot be paid a negative amount and therefore a limited liability constraint operates.[32]

In case of individual production the chosen agent makes an effort choice of $e = 0, 1, 2$ at the cost ec, where $c > 0$.[33] The task succeeds with probability q_e when the agent puts in effort e, where $1 > q_2 > q_1 > q_0 \geq 0$. Similar to Che and Yoo (2001) we assume that $q_2 +$

[32] This limited liability might arise from the freedom of the workers to quit the job at any given time, or it can arise from institutional constraints such as laws that prohibit extraction from workers.
[33] Since the agents are similar, the choice of agents is not an issue.

$q_0 \geq 2q_1$ holds which in essence implies that $q_2 - q_1 \geq q_1 - q_0$.[34] This ensures that the agent will choose either $e = 0$ or $e = 2$. We refer to $e = 2$ as 'work' and $e = 0$ as 'shirk'.[35]

Contrary to this, in case of team production there are two symmetric agents with similar utility and effort cost functions.[36] They work on the same project. In case of team production the agents can either put $e = 1$ (work) or $e = 0$ (shirk).[37] The cost function is similar as before. Similar to the individual production case the outcome of the project is contractible but efforts put in by the agents are not. This implies that only a team signal is available, which is nothing but the outcome of the project. Therefore, both agents will receive the same wage depending on the outcome of the project and the principal cannot offer different wages to the agents. Following Che and Yoo (2001), the probability of success is denoted by p_{kl}, where $k \in \{0, 1\}$ and $l \in \{0, 1\}$ represent agent 1 and 2's effort decisions respectively satisfying $1 > p_{11} > p_{10} = p_{01} \geq p_{00} \geq 0$. We assume that $p_{10} > q_0$ holds, which implies that the project is more likely to succeed with at least one 'working' agent in a team compared to when it is run by a single 'shirking' agent. In line with Che and Yoo (2001) we impose the following supermodularity condition:

p_{kl} is supermodular (weakly) in (k, l) if $p_{11} + p_{00} \geq 2p_{01}$ holds. (SUP)

The above supermodularity condition implies that an agent's work increases her partner's productivity gain from selecting 'work'.[38] Throughout we assume R to be sufficiently large

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[34] Thus success probability q is (weakly) supermodular in individual effort. This implies that success probability (weakly) increases at an increasing rate with increased effort. This is in essence similar to the convexity of q with respect to effort, here with discrete effort.

[35] We start with 0, 1 and 2 units of effort in case of individual production to maintain parity and comparability with team production where agents putting 0 or 1 unit of effort is possible (as we will see soon). Thus, in our model all three units of efforts are possible ex-ante, 0 and 2 in case of individual production and 0 or 1 in case of team production. (Similar to Che and Yoo (2001)). More as we proceed. Also see footnote 15.

[36] The agents are assumed to be symmetric for simplicity.

[37] This ensures that the total effort is same when an agent works in case of individual production and both agents work in case of team production (Similar to Che and Yoo (2001)). Thus the total effort cost is same in both cases which rules out the cost dimension mentioned in Itoh (1992) and therefore we can focus on the effect of social preferences in the choice of individual vis-à-vis team production.

[38] As we will see this makes both the agent's mutual sanction through repeated shirking self-enforcing, in case of repeated interaction.

such that the principal finds it optimal to elicit 'work' in case of individual production and 'work' from both the agents in case of team production. This implies that the principal wants to implement the same aggregate effort across both the regimes. We also assume that the outside option of the agent(s) to be equal to zero.[39]

Before proceeding, following Che and Yoo (2001), we spell out certain terminologies that characterize the technology in case of team production. If $p_{11} > q_2$ holds then the team is said to have 'synergy' meaning that a team production is more productive than individual production when in both cases agents are working and also the aggregate effort is same in both cases.[40] If $p_{00} < q_0$ holds then "each agent's shirking has a negative externality on her partner's shirking productivity". This is referred to as "sabotage". Given an agent's effort level as k, $\Delta_k = (p_{k1} - p_{k0})$ gives how much her productivity depends on the effort decision of her peer. Thus (Δ_0, Δ_1) measures the technological interdependence between the agents under team production and a higher value of (Δ_0, Δ_1) implies more technological interdependence. Next, we spell out our major point of departure from Che and Yoo (2001) and we assume that the principal and agent(s) have social preferences (i.e. other-regarding), specifically the principal and the agent(s) to be inequity-averse.

5.2.1. Preferences:

To model social preferences, we follow the distributional approach in line with Fehr and Schmidt (1999)'s specifications. In line with Fehr and Schmidt (1999)'s original specification of linear other-regardingness, the principal's utility function in case of individual production can be written as

[39] This implies that the participation constraint will be satisfied and will not bind at the optimum.

[40] Synergy can happen from the inherent complemenarity of the agents' efforts and one's effort has a positive externality/influence on the other's effort (can also be interpreted in terms of task complementarity given a particular project). It can also stem from work chemistry among the two agents leading to increased probability of success compared to when one is working alone in a project. This latter interpretation points to a behavioural dimension of synergy.

$$U_P = R_j - w_j - \pi(R_j - 2w_j) \quad \text{where } R_j - w_j \geq w_j \,;\, j = s, f \,. \tag{1a}$$

s and f denotes success and failure respectively.[41]

In case of team production, the principal's utility function can be written as

$$U_P = R_j - 2w_j - \pi(R_j - 4w_j) \quad \text{where } R_j - 2w_j \geq 2w_j \,;\, j = s, f. \tag{1b}$$

Once again, s and f denotes success and failure respectively.

π is the inequity aversion parameter where $0 < \pi < 1$. Note that according to the primitives of our model $R_s = R$ and $R_f = 0$.

In case of individual production the principal compares her net payoff $R_j - w_j$ to her total pay-out w_j to the chosen agent whereas in case of team production the principal compares her net payoff $R_j - 2w_j$ to her total pay-out to the team amounting $2w_j$. In case of team production since there is only one project outcome and the agents are symmetric, w_j will be the same for both the agents. Following Dur and Glazer (2008) it is assumed that the principal is always (at least weakly) ahead of the agent(s) in both forms of production. Therefore, in case of team production, the principal being inequity-averse experiences a loss in utility of $\pi(R_j - 4w_j)$ from being ahead of the team. Thus, for the principal, the comparison unit is the particular chosen agent in case of individual production, whereas in case of team production the comparison unit is the team. Thus, in this chapter we extend the concept of social preferences vis-à-vis a team as well. Moreover, the principal (weakly) suffers from advantageous inequity in both forms of production.

The agents are assumed to be inequity-averse and are always behind (at least weakly) vis-à-vis the principal. Similar to the principal we model each agent's inequity aversion in terms of Fehr and Schmidt (1999)'s linear other-regardingness and is given below:

[41] For a different approach to modeling inequity aversion see Bolton and Ockenfels (2000).

In case of individual production it is

$$U_A = w_j - \alpha(R_j - 2w_j)\,,\ j = s, f \tag{2a}$$

Whereas in case of team production for a particular agent it is

$$U_A = w_j - \alpha(R_j - 3w_j)\,,\ j = s, f \tag{2b}$$

where $0 < \alpha < 1$ captures the degree of agent's inequity aversion. Each agent compares principal's $R_j - w_j$ to her own w_j in case of individual production whereas principal's $R_j - 2w_j$ to her own w_j in case of team production.[42]

Since we focus on contracts where limited liability binds, we will have $w_f = 0$. Also, for notational convenience we denote $w_s = w$. Thus, the agent gets w in case of success and zero wage in case of failure. The above set of assumptions makes our analysis and findings tractable and therefore should not a viewed as a drawback of our analysis.

A point worth noting is that since we are in a single project framework and there is only one project signal, the agents get same wage depending on the project signal. Thus, the question of agents having social preferences among each other does not really arise. Therefore, in this chapter, we only have vertical social comparison, horizontal social comparison among agents is not possible.

Given the above, we now go over to the analysis of individual vis-à-vis team production. The inequity-averse principal has two effects. First is the 'direct positive' effect

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[42] One can introduce the above preferences as "all individuals in the society have identical Fehr and Schmidt (1999) preference with $\alpha > \pi$ where α is the coefficient for non-favorable inequity aversion and π is the coefficient for favorable inequity aversion".
That is all individuals have preferences like

$$u_1(x_1,\ x_2\ ) = \ x_1 - \alpha \max\{x_2 - x_1, 0\} - \pi \max\{x_1 - x_2, 0\}$$
$$u_2(x_1,\ x_2\ ) = \ x_2 - \alpha \max\{x_1 - x_2, 0\} - \pi \max\{x_2 - x_1, 0\}$$

where u_1 is the utility of player 1 and u_2 is the utility of player 2. x_1 and x_2 denotes the net payoffs of player-1 and player-2 respectively. Defining player-1 as the principal and player-2 as the agent and given that the principal is never behind we get $x_1 - x_2 \geq 0$ and therefore $x_2 - x_1 \leq 0$. Thus the preferences effectively become

$$u_P(x_1,\ x_2\ ) = \ x_1 - \pi\ (x_1 - x_2)$$
$$u_A(x_1,\ x_2\ ) = \ x_1 - \alpha\ (x_1 - x_2)$$

where P and A denote principal and agent(s) respectively. This structure is exactly what we have above. Here we do not need the assumption $\alpha > \pi$ since it does not affect any of our results.

where the principal's utility increases with reduced wage payment. But there is a 'negative indirect' effect which comes from her inequity aversion. Since the principal is never behind, reduced wage payment will make her more ahead and that will lead to a fall in utility. If π is sufficiently large then the 'negative indirect' effect will dominate and at the optimum the principal will offer higher wage(s) to the agent(s). Therefore, in this situation, the incentive compatibility of the agent(s) will not bind. But when π is not that large, the 'negative indirect' effect will be outweighed by the 'direct positive' effect and the principal will find it optimal to pay as less as possible. Thus, when π is not that large, the incentive compatibility constraints of the agent(s) which are $q_2\{w - \alpha(R - 2w)\} - 2c \geq q_0\{w - \alpha(R - 2w)\}$ in case of individual production and $p_{11}[w - \alpha(R - 3w)] - c \geq p_{01}[w - \alpha(R - 3w)]$ in case of team production, will bind at the optimum. Therefore, as we proceed, we need to consider the above two possibilities. First, where the principal is moderately inequity-averse in the sense $\pi < \frac{1}{2}$ and the other is when the principal is sufficiently inequity-averse and therefore $\pi \geq \frac{1}{2}$ holds.[43] We first consider the case where $\pi < \frac{1}{2}$ holds.

5.2.2. Case 1: $\pi < \frac{1}{2}$ holds.

When $\pi < \frac{1}{2}$ holds the principal's payoff increases with reduced wage in both forms of production and therefore the optimum wage will be determined from the binding incentive compatibility constraint(s) of the agent(s). We examine individual production and team production under such a scenario.

[43] These thresholds values came be found from the preference functions of the principal (see equations 1(a) and 1(b)).

5.2.2.1. Individual Production:

In case of individual production the principal engages a single agent for her project. The expected payoff functions of the principal and the agent in individual production will look like the following:

$$U_P^{IP} = q_2[R - w - \pi(R - 2w)] \tag{3a}$$

$$U_A^{IP} = q_2[w - \alpha(R - 2w)] - 2c \tag{3b}$$

The superscript IP stands for individual production. Given the above, it will be incentive compatible for the agent to put in $e = 2$ over $e = 0$ iff $q_2\{w - \alpha(R - 2w)\} - 2c \geq q_0\{w - \alpha(R - 2w)\}$ holds, which boils down to $w \geq \frac{2c+\alpha R(q_2-q_0)}{(1+2\alpha)(q_2-q_0)}$. Therefore the principal will optimally offer $w^* = \frac{2c+\alpha R(q_2-q_0)}{(1+2\alpha)(q_2-q_0)}$ in case of success and zero in case of failure. Therefore the principal's net expected payoff in case of individual production will be

$$U_P^{IP} = \frac{q_2}{(1+2\alpha)}\left[R(1 + \alpha - \pi) - \frac{2c(1-2\pi)}{(q_2-q_0)}\right] \tag{4}$$

5.2.2.2. Team Production:

In case of team production the expected payoff functions of the principal and each agent will look like the following:

$$U_P^{TP} = p_{11}[R - 2w - \pi(R - 4w)] \tag{5a}$$

$$U_A^{TP} = p_{11}[w - \alpha(R - 3w)] - c \tag{5b}$$

We conduct similar exercise in case of team production as well. Conditional on the other agent putting $e = 1$, it is incentive compatible for an agent to put $e = 1$ over $e = 0$ iff $p_{11}[w - \alpha(R - 3w)] - c \geq p_{01}[w - \alpha(R - 3w)]$, i.e. if $w \geq \frac{c+\alpha R(p_{11}-p_{01})}{(1+3\alpha)(p_{11}-p_{01})}$ holds. Thus, in case of team production the principal will optimally offer $W^* = \frac{c+\alpha R(p_{11}-p_{01})}{(1+3\alpha)(p_{11}-p_{01})}$ to each agent in case of success and zero in case of failure. Plugging it into the principal's net expected payoff function we get the optimal expected payoff of the principal in case of team production as

$$U_P^{TP} = \frac{p_{11}}{(1+3\alpha)}\left[R(1+\alpha-\pi+\alpha\pi) - \frac{2c(1-2\pi)}{(p_{11}-p_{01})}\right] \quad (6)$$

Before going into our first result we state the following lemma:

Lemma 4.1:

Given R sufficiently large, both w^* *and* W^* *are increasing in* α.

The above lemma can be explained as follows: As α increases the agent(s)' inequity aversion increases and this leads to a fall in the agent(s)' payoffs. Thus, the principal needs to pay an increased wage to address the inequity concern of the agent and also ensure that at the optimum the incentive compatibility constraint binds, ensuring that the desired effort being elicited. Thus both w^* and W^* increases with a ceteris paribus increase in α.

Comparing (4) and (6) we can state our first proposition:

Proposition 4.1:

An inequity-averse principal interacting with inequity-averse agent(s) can prefer team production over individual production even without synergy $(p_{11} \leq q_2)$ *only if the principal's and the agent(s)' inequity aversions are not that low. This is a necessary condition. Otherwise the inequity-averse principal will prefer individual production over team production without synergy.*

Proof:

Without synergy $(p_{11} \leq q_2)$ we get $(p_{11} - p_{01}) < (q_2 - q_0)$ since $p_{01} > q_0$. Also $\frac{p_{11}}{(1+3\alpha)} < \frac{q_2}{(1+2\alpha)}$ and $\frac{2c(1-2\pi)}{(p_{11}-p_{01})} > \frac{2c(1-2\pi)}{(q_2-q_0)}$ holds. Comparing (4) and (6) we get that the only way $U_P^{TP} > U_P^{IP}$ can hold is if $R\alpha\pi$ is sufficiently high given $\pi > 0$ and $\alpha > 0$. This can only happen if both π and α are not that low. Otherwise an inequity-averse principal will certainly prefer individual production over team production. **QED**

The intuition of the above proposition can be provided as follows: First, if $p_{11} \leq q_2$, the team doesn't have synergy and in both the team production and individual production total effort elicited is 2. But to elicit this total effort the principal needs to pay higher total incentive in case of team production over individual production. Thus without bringing in social preferences, without synergy, the principal will choose individual production over team production and this is in essence one of Che and Yoo (2001)'s main result. But if we bring in social preferences things can change. Note that as π increases the principal loses more from inequity aversion in case of individual production than team production since the principal is paying more to the team and is less ahead of the team. This tilts the choice in favour of team production for an inequity-averse principal and therefore with increased π the principal might prefer team production over individual production. If inequity aversion (α) of the agent(s) increases then both w^* and W^* increases and that raises the cost of the principal in both team and individual production. But this incremental wage increase is more for team production (since wage is paid to both agents) than individual production and therefore an increase in α hurts the principal more directly in case of team production at the margin. There is a positive effect also since this leads to reduced inequity for the principal at the margin and here the inequity is reduced more in case of team production than in case of individual production. For not so high α the first effect dominates and the principal is hurt more in case of team production from direct wage increase. Thus for lower α the principal is likely to prefer individual production over team production. On the other hand, for sufficiently high α the second effect dominates. Put differently, a sufficiently high α will tilt the choice in favour of team production and this might happen even without synergy. Thus, overall, the choice between team and individual production crucially depends on the principal's inequity aversion (π) and the agent(s)' inequity aversion (α). If both π and α are positive and not too low, the principal will optimally choose team production, otherwise the principal will opt for individual production, without synergy.

The above result shows that even in the static setting, even without synergy, an inequity-averse principal might choose team production. Thus without going into a dynamic setting, in a static framework the existence of team production can be justified. This is an important distinction of this chapter compared to Che and Yoo (2001) which rationalized team production in terms of repeated interaction whereas we put forward an additional rationale, viz. the existence of social preferences.

Interestingly, if any one of principal's and agent(s)' inequity aversion becomes very low, i.e. any one effect of inequity aversion goes to zero, without synergy the principal will always prefer individual production. This is captured in the following corollary which is immediate from proposition 1.

Corollary 4.1:

(a). An inequity-averse principal interacting with self-regarding agent(s) will certainly prefer individual production over team production without synergy. This is a sufficient condition.

(b). A self-regarding principal interacting with an inequity-averse agent(s) will certainly prefer individual production over team production without synergy. This is a sufficient condition.

Proof:

(a). When $\pi > 0$ and $\alpha = 0$ the payoffs from individual production and team production will be $U_P^{IP} = q_2\left[R(1-\pi) - \frac{2c(1-2\pi)}{(q_2-q_0)}\right]$ and $U_P^{TP} = p_{11}\left[R(1-\pi) - \frac{2c(1-2\pi)}{(p_{11}-p_{01})}\right]$ respectively. Without synergy ($p_{11} \leq q_2$) we get $(p_{11} - p_{01}) < (q_2 - q_0)$ and therefore $U_P^{IP} > U_P^{TP}$. Thus, without synergy, an inequity-averse principal will certainly prefer individual production over team production.

(b). When $\pi = 0$ and $\alpha > 0$ we get $U_P^{IP} = \frac{q_2}{(1+2\alpha)}\left[R(1+\alpha) - \frac{2e}{(q_2-q_0)}\right]$ and $U_P^{TP} = \frac{p_{11}}{(1+3\alpha)}\left[R(1+\alpha) - \frac{2c}{(p_{11}-p_{01})}\right]$ respectively. Once again, with no synergy ($p_{11} \leq q_2$) we certainly get $U_P^{IP} > U_P^{TP}$ and therefore a self-regarding principal will certainly prefer individual production over team production. **QED**

The above result implies that, without synergy, for team production to be preferred over individual production both the inequity aversion of the agent and the principal needs to be non-trivially positive. Anyone having high inequity aversion and the other having low inequity aversion might not suffice for the optimality of team production over individual production in the absence of synergy and in that situation we get back the Che and Yoo (2001) result.

Given the above analysis we now go over to the situation where the principal is highly inequity-averse.

5.2.3. Case 2: $\pi \geq \frac{1}{2}$ holds.

In this situation, the principal will find it optimum to offer $w^* = \frac{R}{2}$ in case of individual production such that the loss from inequity aversion is completely eliminated. Since R is sufficiently large this contact will be incentive-compatible.[44] Thus the inequity-averse principal's payoff under individual production will be $U_P^{IP} = q_2\left[R - \frac{R}{2}\right] = \frac{q_2 R}{2}$. In case of team production, the principal will offer $W^* = \frac{R}{4}$ to both the agents such that at the optimum the effect of inequity is eliminated.[45] The principal's payoff under team production will be $U_P^{TP} = p_{11}\left[R - \frac{R}{2}\right] = \frac{p_{11}R}{2}$. Thus $U_P^{TP} > U_P^{IP}$ only if $p_{11} > q_2$. This implies that if the team has synergy only then a sufficiently inequity-averse principal will opt for team production over individual production and this is necessary as well as sufficient. Otherwise, a sufficiently inequity-averse principal will opt for individual production.

The above discussion can be summarized succinctly in our next result.

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[44] We need $R \geq \frac{4c}{(q_2 - q_0)}$ to hold.

[45] We need $R \geq \frac{4c}{(1-\alpha)(p_{11} - p_{01})}$ for this wage to be incentive compatible in case of team production.

Proposition 4.2:

With inequity-averse agent(s), a sufficiently inequity-averse principal will prefer team production over individual production if and only if the team has synergy. Otherwise the principal will prefer individual production.

5.3. Repeated Interaction:

Thus far we have assumed a static setting where the agents choose effort only once. In this section we consider the strategic interaction of the two agents in a dynamic setup. Specifically, we examine what happens when the agents choose efforts repeatedly (over infinite periods) where the agents can monitor efforts mutually. Similar to Che and Yoo (2001), in case of team production, we assume a trigger strategy for each agent which is: "start and keep playing 'work' until an agent shirks in a previous stage, in which case both play 'shirk' repeatedly thereon". For the sake of simplicity we assume that the agents have a common discount factor $0 < \delta \leq 1$.

Before proceeding further, three comments are warranted at this point which are also there in Che and Yoo (2001). First, we assume that the agents observe each other's efforts in each period due to their proximity. The principal can only observe whether the project succeeds or fails which is an imperfect signal of the agents' efforts and cannot directly communicate with the agents about their efforts. Second, in this dynamic set up the agents only interact through their effort decisions and we rule out side payments or side contracting between the agents. Third, the wage scheme is assumed to be 'memory-less' (Chiappori et.al. (1994)) in the sense that the wage scheme chosen initially applies to all subsequent periods.[46] This final assumption makes the comparison between individual production and team production easier. The rest remains the same.

[46] This might restrict the contract space, but this can be justified as an equilibrium response by the principal when she finds it impossible to commit to a long term contract. (For more see Che and Yoo (2001)).

Given the above, first consider the case where $\pi < \frac{1}{2}$ holds. The result of individual production will remain the same as in the previous section in each stage since there is a single agent and no strategic interaction exists. Therefore, in every stage, the wage offered will be $w^* = \frac{2c+\alpha R(q_2-q_0)}{(1+2\alpha)(q_2-q_0)}$ and the principal gets $U_P^{IP} = q_2\left[\frac{R(1+\alpha-\pi)}{(1+2\alpha)} - \frac{2c(1-2\pi)}{(1+2\alpha)(q_2-q_0)}\right]$ which is given in equation (4). But with repeated interaction among the agents the team production case will change.

In case of team production, two necessary conditions for the previously mentioned trigger strategy to be subgame-perfect given our structure are as follows: First it must be self-enforcing for both agents to shirk repeatedly given that the other agent shirks, i.e. {shirk, shirk} has to be a Nash equilibrium of the stage game. For this we need, $p_{00}\{w - \alpha(R - 3w)\} \geq p_{10}\{w - \alpha(R - 3w)\} - c$ to hold which implies:

$$w \leq \frac{c+\alpha R(p_{01}-p_{00})}{(1+3\alpha)(p_{01}-p_{00})} = \widetilde{w} \tag{7}$$

Second, each agent must not shirk when shirking is punished by repeated shirking by the other agent. This happens if $p_{11}\{w - \alpha(R - 3w)\} - c \geq (1-\delta)p_{01}\{w - \alpha(R - 3w)\} + \delta p_{00}\{w - \alpha(R - 3w)\}$ holds which in turn implies that the following must hold:

$$w \geq W^*(\delta) \equiv \frac{c+\alpha R[(p_{11}-p_{01})+\delta(p_{01}-p_{00})]}{(1+3\alpha)[(p_{11}-p_{01})+\delta(p_{01}-p_{00})]} \tag{8}$$

Condition (7) and (8) together gives the range of wage that can support $\{\text{work}, \text{work}\}^\infty$ as a subgame-perfect outcome in this dynamic team game. Given super-modularity $(p_{11} - p_{01}) > (p_{01} - p_{00})$ we see that $W^*(\delta)$ satisfies (7) and therefore the range is valid.

Given the above and the 'memory-less' wage scheme, the principal, in each period, maximizes

$$U_P^{TP} = p_{11}[R - 2w - \pi(R - 4w)] \tag{9}$$

Subject to $W^*(\delta) \leq w \leq \widetilde{w}$.

It is straightforward from (7) and (8) that $W^*(\delta)$ is the lowest possible wage that ensures $\{\text{work}, \text{work}\}^\infty$ as a subgame perfect outcome in this repeated interaction between agents and is therefore the optimal wage. [47] The optimum expected payoff of the principal will be

$$U_P^{TP}(\delta) = \frac{p_{11}}{(1+3\alpha)}\left[R(1+\alpha-\pi+\alpha\pi) - \frac{2c(1-2\pi)}{[(p_{11}-p_{01})+\delta(p_{01}-p_{00})]}\right] \quad (10)$$

Since $(p_{11} - p_{01}) < (p_{11} - p_{01}) + \delta(p_{01} - p_{00})$, optimal wage received by an agent under repeated setup is lower than what she gets under the static setup, i.e. $W^*(\delta) < W^*$ for $\delta > 0$. Also note that, given R sufficiently high, an increase in α will lead to an increase in $W^*(\delta)$. Comparing (10) and (6) one can easily check that the expected payoff of the principal under team production is higher in repeated setup than in the static setup. Thus team production becomes more favourable in the repeated setup. Also as $\Delta_1 + \delta\Delta_0 = (p_{11} - p_{01}) + \delta(p_{01} - p_{00})$ increases, $U_P^{TP}(\delta)$ increases implying that as the technology becomes more inter-dependent i.e. (Δ_0, Δ_1) increases, the attractiveness of team production increases under repeated interaction. Therefore, we can state our next proposition:

Proposition 4.3:

For a moderately inequity-averse principal

(a). Under dynamic team production, $\{\text{work}, \text{work}\}^\infty$ *is implemented with wage* $W^*(\delta)$ *which is lower than the wage* W^* *of static setup.*

(b). Given team production, the principal is better off under repeated setting than under the static setting.

(c). Fix the inequity aversion of the principal and the agents. Compared to the static setting, under repeated interaction the principal is more likely to choose team production over individual production and this holds irrespective of whether the team has synergy $(p_{11} > q_2)$ *or not* $(p_{11} \leq q_2)$.

[47] For all $0 \leq w < W^*(\delta)$, $\{\text{shirk}, \text{shirk}\}^\infty$ will be the sub-game perfect outcome of this repeated interaction.

(d). Given the memory-less wage scheme, more patient agents (higher δ) make team production attractive compared to individual production.

(e). Ceteris paribus, the principal will prefer less inequity-averse agent(s) even in the repeated framework and this holds for both individual and team production.

When the agents interact repeatedly, the fact that one can punish the other by repeated shirking when any one shirks, helps agents sustain cooperation. Put differently, the possibility that both agents can get the success wage with probability p_{00} which is much lower than either p_{11} or even p_{01} keeps them disciplined and the principal can implement by paying a lower wage. The more the agents care for the future, the lower is $W^*(\delta)$ and the better it is for the principal. The lower is p_{00}, the better is team production over individual production. That is, in case of sabotage ($p_{00} < q_0$), team production is relatively more likely over individual production and this supports Lazear (1989)'s conjecture that "sabotage possibility makes Relative Performance Evaluation ineffective" and similar to Che and Yoo (2001) we also get that if p_{00} is sufficiently low, team production (which is in essence similar to 'joint performance evaluation') is optimal.

Also since repeated interaction increases the principal's payoff from team production, with or without synergy, team production is more likely for a moderately inequity-averse principal. Therefore, in essence, repeated interaction of agents tilts the preference of the principal *relatively* towards team production and this holds across production technologies but for moderately inequity-averse principal. Finally with more patient players (increased δ) the principal can implement $\{\text{work}, \text{work}\}^\infty$ by paying a lower $W^*(\delta)$ and that increases the attractiveness of team production over individual production. Since patient players value the future more, ceteris paribus, cooperation in teams becomes more likely. Also the fact that such strategic interaction is absent in case of individual production and therefore δ does not affect the principal's payoff from individual production, makes team production attractive over individual production with increased δ.[48]

When the principal is sufficiently inequity-averse ($\pi \geq \frac{1}{2}$), the static analysis of individual production will remain and $w^* = \frac{R}{2}$ will be offered in every stage. The principal's payoff will be once again $U_P^{IP} = \frac{q_2 R}{2}$ in every period. In case of team production the same static optimal wage $W^* = \frac{R}{4}$ will be offered in every stage since the principal finds it optimal to remove inequity altogether. For the trigger strategy to be optimal we need the mild parametric restriction that $R < \frac{4c}{(1-\alpha)(p_{01}-p_{00})}$, otherwise {shirk, shirk} will not be a Nash equilibrium of the stage game.[49] [50] Once again, given $W^* = \frac{R}{4}$ being offered in every stage, $\{\text{work}, \text{work}\}^\infty$ will be the subgame-perfect outcome of this repeated interaction if $R \geq \frac{4c}{(1-\alpha)[(p_{11}-p_{01})+\delta(p_{01}-p_{00})]}$ holds and given $\delta > 0$, the range $\frac{4c}{(1-\alpha)[(p_{11}-p_{01})+\delta(p_{01}-p_{00})]} \leq R < \frac{4c}{(1-\alpha)(p_{01}-p_{00})}$ exists. Therefore, $\{\text{work}, \text{work}\}^\infty$ as a sub-game perfect outcome is achieved under the trigger strategy and the payoff of the principal will be $U_P^{TP} = \frac{p_{11} R}{2}$ in every stage. Therefore, the principal will choose individual over team production if and only if the team has synergy which is exactly similar to the condition of the static scenario. Thus for sufficiently inequity-averse principal the incentive for team production remains the same both under static and dynamic interactions.

[48] Once again this is due to the 'memory-less' wage scheme.
[49] This can be calculated from the incentive compatibility constraint of the agent(s).
[50] Given supermodularity $\frac{4c}{(1-\alpha)(p_{11}-p_{01})} < \frac{4c}{(1-\alpha)(p_{01}-p_{00})}$. So $R \geq \frac{4c}{(1-\alpha)(p_{11}-p_{01})}$ and $R < \frac{4c}{(1-\alpha)(p_{01}-p_{00})}$ together are possible (see footnote 22).

Proposition 4.4:

A sufficiently inequity-averse principal's incentive for team production remains the same under both static and dynamic interactions and will prefer team production over individual production if and only if the team has synergy.

Since a sufficiently inequity-averse principal prefers to remove inequity at the optimum, under both individual and team production, the wage is set accordingly. Thus, the effect of strategic interaction among the agents does not play any role in this scenario. As a consequence, we get back the results of our static model which is similar to Che and Yoo (2001) since the effect of social preferences is also minimized as well.

5.4. Concluding Observations:

In this chapter we examine how the choice of production organizational structure crucially depends on the social preferences of economic agents. Specifically we look at the choice of individual versus team production where the principal is inequity-averse with respect to the agent(s) and the agents are inequity-averse with respect to the principal. We showed that, in a static framework, a moderately inequity-averse principal interacting with an inequity-averse agent(s) might opt for team production even without team synergy. If the team doesn't have synergy then an inequity-averse principal interacting with self-regarding agent(s) will certainly choose individual production over team production. Similarly a self-regarding principal will definitely choose individual production over team production while interacting with inequity-averse agent(s) without synergy. Under such special cases the principal can only choose team production if and only if the team has synergy. On the contrary when the principal is sufficiently inequity-averse she will choose team production if and only if the team has synergy and this is a necessary and sufficient condition. Our results point to the fact that in organizations where the employer is inequity-averse, those might go for work teams even without the existence of team synergy. Thus this chapter provides an additional rationale for the empirically observed prevalence of team based production in many modern organizations in terms of the possible existence of social preferences. This is a crucial difference of our approach compared to Che and Yoo (2001). In a dynamic framework we show that for a moderately inequity-averse principal, ceteris paribus, team production is more attractive over individual production compared to the static framework. Thus this chapter predicts that employment practices that work well in short term organizations need not work well in long-term organizations. Long-term employment relationships call for team based production practices compared to short-term employment relationships. But for a sufficiently inequity-averse principal the attractiveness of team production remains the same under both static and dynamic interactions. Thus social preferences crucially affects the choice of team vis-a-vis individual production both in static and dynamic framework and this chapter contributes in this direction.

From an empirical point of view the prevalence of team based production now have an additional justification in terms of the existence of social preferences. Even without synergy, controlling for other factors, if team production is observed, one can possibly explore and justify it in terms of the existence of social preferences. A carefully crafted empirical study might throw some light on that.

A comment on ‘status-seeking’ principal deserves special mention. One can easily analyze the incentives of a status-seeking principal by assuming $\pi < 0$. A status seeking principal enjoys being ahead and therefore will always prefer to pay the agent(s) less. Thus for a status-seeking principal both the effects mentioned earlier work in the same direction and the principal will optimally set the wage such that the agent(s)’ incentive compatibility constraint binds. This, in essence, will be similar to the case of $< \frac{1}{2}$, i.e. the case of a moderately inequity-averse principal and similar results and intuitions will follow.

Finally, one can think of synergy in a different way also. A job might have two tasks, but the tasks does not have separate outcome signal, only a team signal is available. Given this, is it optimal for the producer to entrust a single agent to carry out both the tasks? Or is it optimal to entrust two separate agents to carry out a task each? If the tasks have strong complementarity, which one can view as 'synergy with a different interpretation', then hiring a single individual to perform both the tasks might be optimal. But if the tasks are substitutable, it might be optimal to hire two agents for two different tasks. So, given this interpretation, synergy might lead to individual production. But this is an entirely different perspective of synergy that we are talking about and this might lead to an opposite prediction. In this chapter synergy is defined as when the tasks are performed by two individuals is more productive than a single individual performing both tasks, i.e. $p_{11} > q_2$ and in both cases the aggregate effort is $e = 2$. So two individuals have a positive externality on each other's work and does a better job than one agent doing both. Put differently, a single agent putting in two units of effort is less efficient corresponding to two different agents putting in one unit of effort each with certain positive externality. This view of synergy leads to team production being optimal. Therefore, the alternative view of synergy mentioned above is interesting and a careful analysis of that constitutes our future research agenda.[51]

[51] We thank an anonymous referee for encouraging us to think and discuss about this alternative interpretation.

CHAPTER 6

CONCLUSIONS

The findings of the dissertation clearly indicate that the results suggested by the literature change if the principal is other-regarding in nature instead of a self-interested individual. The role of an other-regarding principal in agency problem has not been analyzed in detail before. Only a few studies have considered the principal to be other-regarding even though experimental results have shown the presence of other-regardingness in individuals. Initially, we have developed a principal-agent model with linear type of other-regarding function. The project outcomes are assumed to be discrete whereas in chapter 3 and 4 they are assumed as continuous. The model is later generalized from this closed version.

In the closed form, the other-regarding results are compared with the results of the benchmark where both the principal and agent are self-regarding in nature. In the benchmark case, for lower outside option, principal optimally shares the gross payoff equally if the project succeeds. For higher outside option participation constraint binds and the success wage is increasing with respect to the outside option of the agent. When the principal is spiteful and the agent is self-regarding, the wage offered and the optimal effort become lower than the self-regarding benchmark setup. When the principal and the agent both are considered as other-regarding, the optimal wage becomes weakly decreasing with respect to principal's spitefulness. In other words, a spiteful principal prefers to offer as low wage as possible as it gives him additional utility by being ahead of the agent in terms of payoff. The optimal wage is increasing with respect to the inequity averseness of the agent. The reason for this is: an inequity-averse agent on the other hand will prefer to reduce the payoff difference. The success wage of spiteful principal dealing with inequity-averse agent lies between the benchmark case of both self-regarding and only principal other-regarding case. Another interesting finding is that when the principal and the agent have exactly opposite other-regardingness, we get the self-regarding benchmark result of equal sharing of outcome of the project.

Two types of other-regardingness are considered - inequity-averseness and status-seeking (spiteful). By following the Englmaier and Wambach (2010) structure it is found that if the principal is non-linearly other-regarding then the optimal contract wage schedule is unlikely to be linear when effort is contractible. This result is in contrast with the result found in Englmaier and Wambach (2010) where the wage contract is linear when effort is contractible with a self-regarding principal. But the introduction of an other-regarding principal changes the results - wage schedule becomes linear if and only if the principal is linearly other-regarding. Englmaier and Wambach (2010) result of linear wage contract holds with contractible effort only with this specific condition. The wage offered by a status-seeking principal will be less than the wage offered by a self-regarding principal which will be even lower than the wage offered by a spiteful principal. When effort is non-contractible (a more realistic case), optimal contract for risk-averse agent is strictly increasing for all kinds of principal. Given the output level, the wage is decreasing with respect to the spitefulness parameter of the principal and increasing with respect to the inequity averseness parameter of the agent. An agent with infinite concern regarding the inequity-averseness will be offered an equal share of the success output by the principal. Holmstrom (1979) states that an agent's wage should ideally depend on the output level of the project and the wage should not contain any component which is not an indicator of effort choice of the agent. This result holds when both the principal and the agent have exactly opposite other-regarding preferences with same other-regarding functions. If they have different other-regarding preference structures, optimal wage schedule contains non-relevant information regarding the effort choice.

Following the Englmaier and Wambach (2010) model the principal agent model is generalized for multi-agents with continuous output. The principal compares the optimality of relative performance contract and team contract. The two agents are hired for two separate projects then if the wage of one agent increases (decreases) when the output of the other project rises then this type of contract is called team (relative performance) contract. This cross wage effect defines the nature of the contract. The principal compares her payoff with the payoff of the agents. The agent is inequity-averse vis-à-vis the principal and also vis-à-vis the other agent (peer comparison). The study suggests that with not so high cross wage effect, a not so high status seeking principal or an inequity averse principal will offer a contract which is increasing with respect to its own output. Holmstrom (1982) showed for self-regarding principal that when the agents' project outcomes are correlated, relative performance contracts are optimal. But when projects are technologically independent then an agents' pay should not depend on other agents' output. This doesn't hold if the agents and also the principal are other-regarding. Englmaier & Wambach (2010) results suggest 'team contract' is optimal when principal is self-regarding and agents are other-regarding and projects are technologically independent. We have observed a significant change in this result by introducing other-regarding principal. For a sufficiently status-seeking principal relative performance contracts can be optimal with no correlation in project outcomes. We observe that team contract is optimal for an inequity-averse principal and a self-regarding principal dealing with inequity-averse agents if own wage effects are not very high and projects are independent. On the other hand, under the same condition, with a sufficiently status-seeking principal a relative performance contract can be optimal if the agents' wages are far apart. The wages offered to the agents rise when the agents are more concerned about their payoff difference vis-à-vis the principal. If the agents are not highly concerned about their payoff difference vis-à-vis the principal, then an increase in status-seekingness of the principal will lower the wages for both the agents. Agents are better off with a more inequity-averse principal. The principal optimally removes the entire payoff difference by offering the agents equal wages if the agents are too much concerned about their own payoff differences. This result is similar to the result found in Englmaier and Wambach (2010). With a rise in peer comparison, the wage gap of the two agents is optimally reduced by the principal.

The principal compares two cases – hiring one single agent for a project or hiring two agents for a project. The principal has a choice to hire one agent (individual production) or two agents (team production). Che and Yoo (2001) have done a similar study and they have found that individual production is always preferrable if synergy is not present in team. But here our findings change when we introduce other-regardingness for both the principal and the agent(s). Our results suggest that an inequity-averse principal dealing with an inequity-averse agent will prefer team production over individual production even without synergy if and only if both of their inequity concerns are not very low. The principal having a high inequity-aversion and the agent having a very low inequity aversion will not suffice for the optimality of team production over individual production. Non-trivially positive inequity-aversion for both ensures team production to be optimal without synergy. With a sufficiently high project outcome, the optimal wage rises with an increase in inequity-averseness parameter of the agent(s) both in individual and team production. The analysis is done for static and dynamic framework since contracts usually last for more than one period. The repeated setup shows the performance of the contract in the long run. The principal is better off under the repeated setting than under the static setting. The wage offered in the repeated setup is comparatively lower than the wage offered under static setup. Under the repeated interaction setup, the principal is more likely to choose team production over individual production irrespective of the fact whether the team has synergy or not. A sufficiently inequity-averse principal's incentive for team production remains same under both static and dynamic interactions and will prefer team production over individual production if and only if the team has synergy. A sufficiently inequity-averse principal prefers to remove all payoff differences and the result of Che and Yoo (2001) for the optimality of team production only with synergy is reestablished.

The results found above explain the behaviour of human individuals in economic experiments. Social preference can change the nature of optimal contracts in principal-agent models. This is clear from our findings that the presence of other-regardingness in the principal's utility function not only changes the results in the closed form but in a generalized structure as well we get some new insights. This is an important dimension that most of research studies so far have not analyzed properly. By addressing this aspect more robust institutional contracts can be designed.

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