Team Composition & Conditional Cooperation: temporary agents, permanent agents or both?

Master Thesis

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Abstract

On the workplace agents differ in length of their contract. Nevertheless there is no extensive research on the optimal composition of teams regarding contracts. I will investigate theoretically the optimal team composition for different levels of conditional co-operators in society. Conditional co-operators are inclined to cooperate if other people also cooperate. In empirical research the existence of conditional co-operators is extensively discussed and proven. By adding renewable temporary contracts and mutual learning my analysis will be extended. I have found the following main results. If more than half of society consists out of conditional co-operators, two permanent agents is the optimal composition. If there are only few or no conditional co-operators in society, two temporary agents is the optimal composition. For shares of conditional co-operators in society in between, a mixed team is optimal.

Keywords: Team composition, Conditional Cooperation, Temporary contracts, Permanent contracts, Renewable contracts, Learning in teams

Content

1. Introduction

Teams are becoming more and more important in the structure of modern organizations (Hamilton et al., 2003). Using teams could be profitable if there are complementarities, if it facilitates specialization or if member learn from each other (Lazear, 1998). But, to accomplish well-functioning teams, the composition of a team is very important. Employees differ in characteristics, so it is important to think about how these different characteristics interact and influence the performance of the team. There are various studies in different scientific fields on the topic of team composition. An important question is whether it is more beneficial to have heterogeneous or homogeneous teams. There have been studies examining the effects of diversity in terms of gender (Davidsson, Steffens and Terjesen, 2012), Dufwenberg and Muren, 2005), age and experience (Davidsson et al., 2012), ethnic background (Hoogendoorn and Van Praag, 2012) and familiarity (Bel, Smirnov and Wait, 2015).

Another characteristic in which employees differ is the length of contracts. Some employees have a permanent contract (contract length indefinitely) and some employees have a temporary contract for only a year or a shorter amount of time (a fixed-term contract). Since the crisis (especially in The Netherlands), the public debate about temporary contracts has risen due to the increased usage and the situations in which temporary contracts are used. Despite this discussion, there is only limited (theoretical) research about the effect of contract length on cooperation behaviour in teams. Especially what the effects are if both types of contracts are present on the workplace is not extensively covered. Only Grund et al. (2015) provide experimental evidence from the lab which shows that more temporary members in a team leads to less cooperating behaviour in heterogeneous teams. For homogeneous teams (so either all permanent or temporary workers) there is evidence by Keser and Van Winden (2000) which shows that in temporary teams more free-riders are observed than in permanent teams.

In my thesis I want to study the cooperation behaviour in diverse teams theoretically. Besides differences in the duration of their contract, I will also consider differences in people's natural inclination to cooperate. If people have to work together in groups, people have different attitudes towards cooperation. This happens for example in sports (cycling), education (group projects) and of course on the workplace in teams. I will distinguish two different types: selfish (rational) agents and conditional co-operators. Selfish agents just provide the effort which is optimal for them. So, if it is optimal to shirk, they will shirk. Conditional co-operators have the characteristic that they put in high effort as long as the other worker has also exerted high effort. Proof of the existence of these conditional co-operators is found in a couple of lab experiments on public good games (e.g. Keser and Van Winden (2000) and Fehr et al. (2001)). The main objective of this paper is to examine which composition (in terms of length of contracts) is optimal for the cooperation behaviour of employees in teams for the possible shares of these conditional co-operators in society.

My first extension of this model considers an important characteristic of a temporary contract: the possibility to be extended for another fixed-term or to become permanent. Engellandt and Riphahn (2003) show empirically that an incentive effect of temporary contracts exists. If I would ignore this effect, I would underestimate the potency of temporary contracts on high productivity. There is also evidence that firms use temporary contracts as a screening device for permanent positions (Faccini, 2014). Hence, my model will incorporate contract extensions after high performance of the team.

As a second extension, I consider mutual learning. In most teams on the workplace, employees have the possibility to teach each other something, which increases the productivity of the other members. Hamilton et al. (2003) show that mutual learning increases the output of a team. Especially the most productive workers are influential in raising team productivity. I will include the option to teach each other something in my analysis and will examine what happens to the optimal composition if workers are going to do such teaching investments.

I have found the following main results. In the basic model, the composition of contract lengths has no big effect on the reached equilibrium. If more than half of society consists of conditional co-operators we end up in a high effort equilibrium, independent whether these agents are actually conditional co-operators. If less than half of society consists of conditional co-operators, we end up in a low effort equilibrium, except if both workers are conditional co-operators, then we end up in the high effort equilibrium.

If temporary contracts could be renewed and if less than half of society consists of conditional co-operators, composition of contracts lengths in a team becomes very important. If there are no or few conditional co-operators in society, two temporary workers is the optimal composition. For more than a few conditional co-operators in society (but less than half of society), a mixed team of one permanent worker and one temporary worker is the optimal composition. If more than half of society is a conditional co-operator a permanent team is optimal.

After the introduction of teaching possibilities it becomes more attractive to hire two temporary workers if society contains less than 50% conditional co-operators compared to hiring only one temporary worker. The reason for this is that two temporary workers ensure that contracts will be extended and investments will not be wasted.

The structure of this thesis will be as follows. In the next chapter I will give an overview of the related literature. In chapter 3, the basic model will be introduced and analysed. In chapter 4 the addition of renewable contracts will be investigated. In chapter 5 I will consider learning in teams. In chapter 6 I will finish my analysis by combining these extensions. I will conclude in chapter 7.

2. Related literature

In this chapter I will discuss the most important related literature on the topics that I will cover.

2.1 Conditional cooperation

Conditional cooperation is an important subject in my paper. But what is actually conditional cooperation? According to Fehr, Fischbacher and Gachter (2001) conditional co-operators are people who are willing to contribute more to a public good the more others contribute. This conditional cooperation could be due to altruism, reciprocity or some other fairness preference. They tested in a lab experiment whether conditional co-operators actually exist. The authors used a public good game in a one-shot variant in which subjects could state what their contribution will be conditional on the contribution of the other members (by using the strategy-method). In a team of 4, each subject had the possibility to divide 20 units between themselves and to invest in a public good. This public good multiplies the money invested in with 1,6. The resulting amount will be divided by the 4 subjects in the team, so the individually rational amount if it would be a one-shot game is to invest 0. The results are as follows. 30%

is selfish (rational) and does not contribute anything. 50% of the subjects were a conditional co-operator, which means that they (almost) match the contribution of the other member. Cherry et al. (2008) did the same public good game to test whether there is a difference in conditional cooperation across cultures. They did this by executing this experiment at 3 different continents (in Austria, Japan and the United States). They find a significantly higher number of conditional co-operators in the United States compared to Austria and Japan (80,6% versus 44,4% and 41,7% respectively). Also the average conditional contributions are higher in the U.S. compared to Austria and Japan.

So, these papers show that for conditional co-operators it is very important what other people contribute to determine their own contribution. In these controlled lab experiments there is no hidden information about the value of the public good. Moreover, the authors used the strategy-method, so subjects choose for every contribution of another subject what their contribution would be. So facing new information could not be an incentive to contribute more. Keser and Van Winden (2000) define this behaviour as reactive conditional cooperation. The authors state that reactive behaviour is behaviour in a public good game which is oriented towards the average behaviour of the other group members. This is also called reciprocity.

Until now, we have defined this type of conditional cooperation and provided lab evidence of this behaviour. But is it also observed in the field? In the field it is less easy to qualify whether the possible effect is due to conditional cooperation or a reaction on extra information of high contributions. But the advantage of field evidence is off course greater external validity. The first field study I want to consider is a field experiment by Frey and Meier (2003). This study investigates whether the decisions of students at the University of Zurich to contribute to two social funds are dependent on the contributions of other students. 1000 students received the information that a relative high percentage contributed to the social funds and 1000 students that a relative low percentage contributed in previous years. Students made their donations anonymously. The willingness to contribute increased if a higher percentage contributed. Especially people who are not inclined to donate are influenced by a high relative high percentage of contributors. Students who are inclined to donate are less influenced by a relative low percentage contributors.

Another study in the field is a natural field experiment by Heldt (2005). He used data of a Swedish ski resort about the voluntary contributions to a ski-track funding. The ski-track had the characteristics of a public good, so pure self-interested people had only limited incentives to contribute to the fund. His results could not reject the existence of conditional cooperation: if subjects are provided with information about contribution levels of other people, they are significantly more likely to contribute. The results of these two field experiments are extra evidence of conditional cooperation, but it is hard to rule out the theory of information provision.

Empirical research does also consider another type of conditional cooperation: future-oriented conditional cooperation. If people are future-oriented, cooperation is dependent on the subjects' perception of future interaction (Keser and Van Winden, 2000). This means that people are also conditional cooperative if they believe that other people are going to contribute. If people are going to contribute based on the believe that other people are contributing, there is no extra information about the value of the contribution. Thus, if we find evidence for this behaviour this could rule out the theory of information provision.

The first evidence on this theory is provided by Frey and Torgler (2006). They used a survey in various European countries to investigate the effect of conditional cooperation on tax morale. They find that tax morale is strongly influenced by the beliefs about the behaviour of other taxpayers. If taxpayers believe that others pay their taxes, their tax morale is higher than if they believe that others do not pay their taxes. This means that decisions about tax evasion are made based on the expected behaviour of other taxpayers. This implies that the probability of detecting tax evasion and the degree of punishment are not crucial on the behaviour of taxpayers. So, if people believe that most people pay their taxes honestly, people are inclined to pay their taxes to.

Smith (2011) provides even stronger evidence of this type of conditional cooperation in a lab experiment. He investigated the effect of identity on contributions in a public good game. Identity was created by a team-building activity and teams were composed exogenously differing in number of subjects who did the same team-building activity. Team members who share the same identity as the majority of the group contributed more compared to team members who share the same identity as the minority of the group. This difference in contribution was mainly due to the perception of the behaviour of other team members. So if subjects believed that other members are going to contribute more, they were more inclined to contribute themselves. Thus, identity had an indirect effect on the contributions of team members. If identity was created, subjects had higher beliefs about contribution behaviour of other team members. This provides very strong evidence on the existence of conditional cooperation.

Now we have shown that conditional cooperation actually exists, we could think about the reasons why this happens. Is it just a natural instinct or could we think of a rational reason for conditional cooperation?

Akiyama et al. (2011) did a study on conditional cooperation by using neuroeconomics. By using a lab experiment on the prisoner's dilemma game, they examined the neural and psychological bases of conditional cooperation. The participants were matched with players whose action history was good, bad or unknown. Participants matched with players with a good or unknown history were more inclined to cooperate than if they were matched with players with a bad history. The authors find 2 systems that provide the basis for conditional cooperation. The posterior cingulate cortex and the left orbital medial pre-frontal cortex taught the participants to cooperate, because of social and long-term monetary rewards. The posterior cingulate cortex plays a key part in our intrinsic control networks. The left orbital medial pre-frontal cortex is usually linked with categorizing judgements by comparing it to a similar past experience. These regions of the brain cause the natural impulse to cooperate. So, this is an explanation for the cooperation part of conditional cooperation. The right dorsolateral pre-frontal cortex inhibited the motivation to cooperate if participants were matched with players with a bad history. The right dorsolateral pre-frontal cortex is very important for the planning, organization and regulation in the brain. This brain region holds back the natural inclination to cooperate if people have to interact with people who did not tend to cooperate in the past. This is a neural explanation of the conditional part of conditional cooperation. This mechanism rules out the theory that cooperation triggers something in the brain which causes conditional cooperation. It is the other way around. Refusing to cooperate hampers the natural impulse to cooperate.

Now we have some idea how this mechanism works. But is there also a rational explanation of conditional cooperation? Guttman (2013) used a theoretical model to explain the existence of conditional cooperation. He modelled the voluntary contribution to a public good as a multi-period game, in which players contribute conditional on the contributions of other players in the previous round. In the first and second (and last) period every player can choose their contributions, but for the second period they also choose a ''matching rate'', a contribution based on the contribution of the other players in the first round. In the main part of the paper, complete information about matching rates is assumed. In equilibrium the stable matching rate is 1, implying only perfect conditional co-operators in society. This is an explanation for conditional cooperation, but all our evidence until now is found in one-shot settings. This study considered a multi-period game, in which I believe it could be rational to contribute a positive amount. I do not think that in an one-shot setting, without any strategic considerations, a rational/selfish argument exists to contribute.

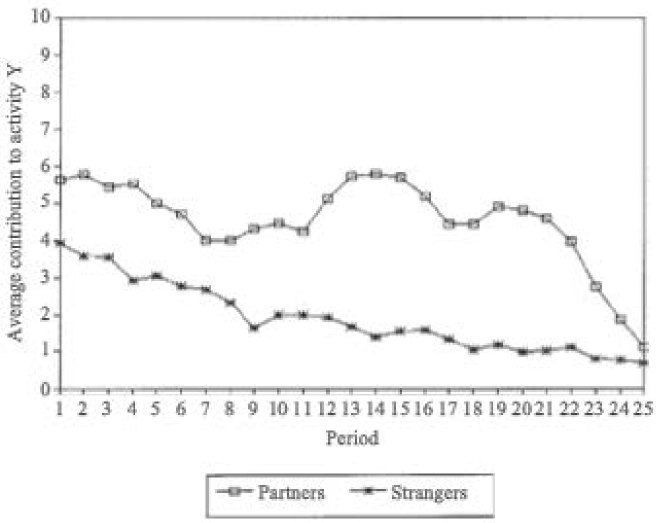
Most interactions in reality in which conditional cooperation plays a factor are actually settings in which agents are going to interact for a higher number of periods. In these situations conditional cooperation interacts with strategic considerations. For selfish people the existence of conditional co-operators can already make it profitable to co-operate to benefit from reciprocal behaviour. In the next subchapter we are going to consider cooperation behaviour in situations with multiple periods.

2.2 Permanent versus temporary contracts

This subchapter covers two important components of my study. First I will discuss cooperation behaviour of permanent and temporary workers in a team. Next I will deal with the reason renewable temporary contracts exist and the effect of these contracts on temporary workers and firms. I will finish with discussing whether contracts affect the interaction between agents and principals.

Keser and Van Winden (2000) did a similar public good game as Fehr et al. (2001). But in this experiment instead of just one round, 25 rounds are considered. Two different treatments were considered. Subjects could stay all 25 periods in the same team (the ''partner''-setting), or they switch every period into a new team of 4 subjects (the ''stranger''-setting). The latter case could be seen as 25 one-shot games. Future-oriented conditional cooperation could be the case if people expect positive contributions by other subjects. In these games there could also be some reciprocal behaviour, because observing that other subjects contribute could lead to contributions in later periods. But being reciprocal in the next period does not reward the same people, so this might diminish motivation for reciprocal behaviour. In the partner treatment in which subjects are matched all 25 periods, stronger behaviour could be expected. In the first couple of rounds, investing in the relationship could be expected by subjects. This implies that future-oriented conditional co-operators could anticipate on this behaviour by contributing on a high level. The same logic holds in the final periods. Investment into the relationship could not be expected anymore, future-oriented conditional co-operators anticipate on this by reducing their contribution levels. In this setting I expect stronger reactive conditional cooperation than if people are matched every round with somebody else. In this case reciprocal behaviour benefits the same people who cooperated in the previous periods. Thus, even in the final periods I expect higher contributions than in the stranger treatment due to reciprocal behaviour.

There results show, as expected, significantly higher contributions in the partner treatment than in the stranger treatment:



[1]

Especially the behaviour in the first period had a big impact on the average contributions of the team in the next periods. Three explanations could explain this effect. High contributions in the first round could just be made by people who are inclined to contribute on a high level and they follow-up with this behaviour in next periods. Another explanation is that high contributions in the first round could shape believes about contribution levels by other subjects in the team, or shape believes about average contributions by all subjects.

[1] From Keser and Van Winden (2000).

This explains why this effect is also found in the stranger treatment. This argument relates to reputation building. Subjects in the partner setting could try to build a reputation that they could be trusted in next periods. Even without conditional co-operators this theory could support positive contributions by selfish subjects.

Another study that compares contribution levels of permanent and temporary agents in a team is done by Grund, Harbring and Thommes (2015). They look at public good contributions of permanent and temporary workers in a lab experiment. They used the same public good game as Fehr et al. (2001). The difference with Keser and Van Winden (2000) is that they also consider mixed groups. A team can consist out of 1, 2 or 4 temporary worker. Permanent workers will stay all 10 periods in the team, but temporary workers will change teams every round. They find that there are higher contributions in teams with fewer temporary workers. This is caused by significantly lower contributions by temporary workers compared to permanent workers, but contributions of permanent workers are also lower in a mixed team compared to an entirely permanent team. The latter observation could be due to lower beliefs about contribution levels of other permanent members in mixed teams compared to permanent teams or beliefs. Beliefs of temporary workers about other temporary members is higher in an entirely temporary team than in mixed teams. This could be an explanation for higher contribution levels of temporary members in unmixed teams.

These studies suggest that contribution levels are lower in teams with temporary workers, compared to teams consisting of permanent members. My theoretical model will study the optimal composition of the team if conditional co-operators exist. This will be investigated in a multi-period setting.

The discussed studies so far ignore a very important aspect of temporary contract: the possibility that contracts get renewed. Now I want to consider the reason why temporary contracts could be beneficial for firms and workers.

Engellandt and Riphahn (2003) examine empirically whether temporary contracts have a significant positive effect on effort levels compared to permanent contracts. They show that temporary workers exert significantly more effort. Temporary workers have a 60% higher probability of working overtime (unpaid) compared to workers with a permanent contract. This gives an important argument for the existence of temporary contracts. But why are people going to exert more effort? The authors argue that this effect could be due to asymmetric information on employee characteristics. The decision whether a contract gets extended will be based on observable information: the performance of the worker. This provides incentives for workers to signal that they are of a good type by exerting high effort.

Other research on this topic is provided by Faccini (2014). He reviews the position and the effects of temporary contracts. The study provides a framework to consider how temporary contracts affect productivity, hiring practices, wage differentials, career prospects and welfare. He argues that temporary contracts have significant positive effects on welfare. The use of temporary contracts leads to a permanent decrease in unemployment. The paper also provides evidence that firms use temporary contracts as a screening device for permanent positions. This theory explains the high mobility rates into permanent employment of temporary workers.

A study by Devicienti et al. (2011) support this theory as well. They investigate among labour market entrants in Italy whether people with a temporary contract flow into permanent employment. They find that having a temporary contract provides a significantly higher probability of earning a permanent contract compared to people who do not have a job.

But do principals treat temporary agent the same as permanent agents? This is investigated by Angelova, Güth and Kocher (2011) if temporary and permanent agents both exist in a team or group. Theoretically they show that behaviour should be the same. Their experimental results show that temporary workers earn significantly lower wages in teams compared to permanent workers (fixed wages and piece rates). They suggest that this behaviour is due to reciprocity of the permanent agents. Principals expect that permanent agents are going to exert more effort in later periods, to return the favour of high wages. If information about contracts is disclosed, agents are treated more equally by the principal. This could be due to a distaste of reciprocal agents for discrimination.

We can conclude that there is considerable support for the theory that temporary contracts are used as a screening device. After high performance, temporary contracts will be renewed or turned into a permanent contract. In my first extension of the model, I will consider the effects of renewable contracts on effort level and optimal composition.

2.3 Team composition

In previous research optimal team composition has been covered before. Especially the question whether homogeneous teams or heterogeneous teams are optimal. We already discussed the results of Grund, Harbring and Thommes (2015). They showed that for both temporary and permanent agents, contributions are higher in homogeneous teams than in mixed teams. In this subchapter I will examine whether this is also the case for other characteristics.

The first study I want to discuss is by Davidsson, Steffens and Terjesen (2012). The authors investigate whether the optimal new venture team composition is heterogeneous or homogeneous. They test for three characteristics: sex, age and experience. They find positive effects of more heterogeneous teams for age and experience (no effect for sex) on the long-term performance. On the short-term, they expected worse outcomes for more heterogeneous teams, but this did not turn out to be the case.

So, we have found positive effect of heterogeneous teams regarding age and experience, but no effect for gender. Still I expect that gender could have an impact on the decisions made by a team. This is investigated by Dufwenberg and Muren (2005). They did an experiment to test the difference in decision-making in various gender compositions in a team. In this experiment groups of three people divide a sum of money between themselves and a fourth person. The money allocated to the group is divided equally. They find that teams with a female-majority are more generous and also chooses most often the equal distribution between the 4 participants. We can conclude that gender composition affects the decisions made by teams. Depending on the goal of an organization it could be more beneficial to have a diverse team or a homogeneous team.

Another study on diversity in teams is done by Hoogendoorn and Van Praag (2012). They examine, by using a field experiment, whether there is an effect of ethnic diversity in a team on the performance. They studied an entrepreneurship program at an international business study in The Netherlands. Average team size is between 12 and 10 during the experiment. The paper finds evidence of a positive effect of ethnic diversity on performance if at least half of the team is ethnic diverse. Their results suggest that this could be due to more mutual learning in the team.

Thus, for age, experience and ethnicity we find unambiguous positive effects of more diverse teams on performance. This implies that it is important to take these effect into account by thinking about team composition. For gender there is no unequivocal answer on the question whether more or less heterogeneous teams are optimal. If the objective of a firm is to be more generous in making decisions, more females in a team is a good choice.

The next study (by Bel, Smirnov and Wait, 2015) considers whether more familiar teams are more productive. This topic is related to the discussion about temporary and permanent contracts, because agents with a permanent contract are more familiar with the firm and with other team members. The authors study by using a theoretical model the optimal composition of people who have worked together before (incumbents) and less familiar workers (newcomers). Incumbents are more productive in relation to effort, but the surplus of collaboration is also higher (because they have worked together before). Making a contract on the division of surplus is not possible, so this implies that there could be more incentives at newcomers to provide high effort. Thus, not always the most productive workers are the optimal team composition. True productivity should be considered by the principal to compose the optimal team.

The last study (by Mello and Ruckes, 2006) that I will cover, studies whether diversity in teams is beneficial in general. The authors study team composition from the perspective of information collection. More heterogeneous teams have more various information, so they get to better decisions if this information is honestly disclosed. They find that especially in very uncertain environments and if the stakes are high it is beneficial to have less correlated information and hence heterogeneous teams are more efficient. If there is a team leader it is better if he is not very involved in the topics discussed. The authors suggest that this is good for communication. If the authority of the leader is too big, there might be a threat of replacement in case of conflict what could lead to less information disclosure.

3. The model

I will start with a simple model to show what the behaviour of cooperative and selfish agents will be in the case without learning possibilities. Agents in a team can have permanent or temporary contracts. *Temporary contracts (T)* last for 3 periods. *Permanent contracts (P)* last for an undefined period of time *t* (but longer than a temporary contract plus an optional extension[2]). Each period, agents work in teams of 2 agents. Three team compositions are possible: a team with two P agents (PP), a team with two T agents (TT) and a mixed team with one P agent and one T agent (PT). A principal is responsible for the composition of the team. The principal has an interest (could be indirect or direct) in choosing a composition which reaches the highest expected productivity of the team. The principal cannot observe the effort levels of individual agents. I will compare the optimal composition of the principal with the preferences of T and P agents to check whether there is a conflict of interests. It could be the case that agents could affect the contract length of their co-worker or put pressure on the contract length decision of the principal.

Total productivity of the team Q_t equals:

$$Q_t = (e_1 + e_2)k. \tag{1}$$

In this equation e_1 and e_2 are the effort levels of agent 1 and agent 2, respectively. k is the productivity factor of this effort. The agents' utility function is:

$$U_i = w - \frac{1}{2}e_i^2. \tag{2}$$

In which *w* is the wage of the agents:

$$w = \frac{1}{2}Q_t. \tag{3}$$

There are two types of agents. The probability that an agent is a *Conditional Co-operator (CC)* is equal to π and the probability that an agent is *Selfish (S)* is equal to 1-π. This probability (besides knowing their own type) is known by both agents. The characteristic of a Conditional Co-operator is that he will provide *first best effort (FB)* as long as the other agent has never exerted a lower effort level than FB. If the other agent has exerted a lower effort than FB, he will do his *individually rational (IR) level of effort* in all future periods. The natural behaviour of an S agent is that he will do what is best for his own utility. So, he will do his individually rational level of effort, unless if it is profitable to mimic the behaviour of the CC. I assume that there are no recruitment cost if people are hired randomly (so probability π that the hired

[2] Extendable contracts will be covered in the next chapter.

agent is a CC agent). The principal has the possibility to recruit a CC for sure in exchange for recruitment costs *r*. These recruitment costs could be dependent on the scarcity of CCs.

By assumption the strategy of a CC is already determined. If he observes a lower effort level than FB, he will do his IR level of effort in all future periods. For S agents we need to determine what their optimal behaviour is. To find this Nash-equilibrium I will focus on the case in which S agents play trigger-strategies. This implies that I will look for an equilibrium where everyone plays FB, until someone has ever played something else in the past, after which they will simply maximize their stage-game pay-off (by playing IR).

1.1 First best efforts and one-shot efforts

Now we can determine FB and IR levels of effort. To determine the FB level of effort we need to maximize the total utility ($U_1 + U_2$) with respect to e_1.

$$\frac{d(U_1 + U_2)}{de_1} = k - e_1 = 0 \rightarrow e_1 = e_2 = k. \tag{4}$$

In this way, the externality of effort on the other agent is internalized in the effort decision. Individually, it is rational to only take into account own benefits of effort. In this case we need to maximize U_1 with respect to e_1.

$$\frac{dU_1}{de_1} = \frac{1}{2}k - e_1 = 0 \rightarrow e_1 = e_2 = \frac{1}{2}k. \tag{5}$$

There are 4 possible utility scenarios. Both agents could provide FB effort ($U = \frac{1}{2}(k + k)k - \frac{1}{2}k^2 = k^2 - \frac{1}{2}k^2 = \frac{1}{2}k^2$) or IR effort ($U = \frac{1}{2}\left(\frac{1}{2}k + \frac{1}{2}k\right)k - \frac{1}{2}\left(\frac{1}{2}k\right)^2 = \frac{1}{2}k^2 - \frac{1}{8}k^2 = \frac{3}{8}k^2$). Agent 1 could provide FB effort and agent 2 IR effort ($U = \frac{1}{2}\left(k + \frac{1}{2}k\right)k - \frac{1}{2}k^2 = \frac{3}{4}k^2 - \frac{1}{2}k^2 = \frac{1}{4}k^2$) and vice versa ($U = \frac{1}{2}\left(\frac{1}{2}k + k\right)k - \frac{1}{2}(\frac{1}{2}k)^2 = \frac{3}{4}k^2 - \frac{1}{8}k^2 = \frac{5}{8}k^2$).

1.2 Results

Our next step is to find the equilibrium. If there is a T worker in the team the total number of periods of interaction between the agents is always 3, so it is most easy to start with determining the optimal behaviour of S agents in a PT and TT team. We can now solve by using backward induction what the optimal strategy is when both agents have exerted FB effort in all periods until the current period. Note that the characteristics of all agents (except their type) are the same so that the behaviour of S agents will be the same in equilibrium. Thus, in the third and last period a CC will play FB and we need to determine what the optimal response is to the different strategies of an S agent. If an S agent is going to provide IR in the last period, providing IR effort, instead of providing FB effort, is optimal if:

$$\pi \cdot \frac{5}{8}k^2 + (1-\pi)\,\frac{3}{8}k^2 \geq \pi \cdot \frac{1}{2}k^2 + (1-\pi)\frac{1}{4}k^2. \tag{6}$$

This condition always holds. So if the strategy of a S agent is to provide IR effort, if in the first two periods both agents have provided FB effort, it is optimal to exert IR effort (as a S agent). But, what is optimal if the strategy of an S agent is to provide FB effort? Providing IR effort instead of providing FB effort is optimal if:

$$\pi \cdot \frac{5}{8}k^2 + (1-\pi)\,\frac{5}{8}k^2 \geq \pi \cdot \frac{1}{2}k^2 + (1-\pi)\frac{1}{2}k^2. \tag{7}$$

Also this condition always holds. If the other agent is always going to play FB (independent of the type) it is optimal to do IR in the last period. We can conclude that it is always optimal for an S agent to do IR in the last period, independent of the strategy of another S agent. Now we need to determine what is optimal in the second period for an S agent if both agents have exerted FB in the first period, knowing that all S agents will play IR in the last period. If the strategy of an S agent is to provide IR effort it is optimal to provide IR effort instead of FB effort if:

$$\begin{aligned}\pi\frac{5}{8}k^2 + (1-\pi)\frac{3}{8}k^2 + \frac{3}{8}k^2 \\ \geq \pi \cdot \frac{1}{2}k^2 + (1-\pi)\frac{1}{4}k^2 + \pi\frac{5}{8}k^2 + (1-\pi)\frac{3}{8}k^2.\end{aligned} \tag{8}$$

And this solves for:

$$\pi < \frac{1}{2}. \tag{9}$$

If the strategy of an S agent is to provide FB effort it is optimal to provide IR effort instead of FB effort if:

$$\frac{5}{8}k^2 + \frac{3}{8}k^2 \geq \frac{1}{2}k^2 + \pi\frac{5}{8}k^2 + (1-\pi)\frac{3}{8}k^2. \tag{10}$$

And this also solves for $\pi < \frac{1}{2}$. Thus, independent of the strategy of an S agent it is optimal to provide IR effort if $\pi < \frac{1}{2}$ and FB effort if $\pi \geq \frac{1}{2}$ in the second period. We can now check what the optimal behaviour is in the first period in both cases. If $\pi < \frac{1}{2}$, S agents know that they are going to play IR in the second and third period. If the strategy of an S agent is to provide IR effort it is optimal to provide IR effort instead of FB effort if:

$$\pi \cdot \frac{5}{8}k^2 + (1-\pi)\,\frac{3}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2 \geq \pi \cdot \frac{1}{2}k^2 + (1-\pi)\frac{1}{4}k^2 + \pi \cdot \frac{5}{8}k^2 + (1-\pi)\,\frac{3}{8}k^2 + \frac{3}{8}k^2. \tag{11}$$

Gives $\pi < \frac{1}{2}$, which holds in this case. If the strategy of an S agent is to provide FB effort it is optimal to provide IR effort instead of FB effort if:

$$\frac{5}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2 \geq \frac{1}{2}k^2 + \pi \cdot \frac{5}{8}k^2 + (1-\pi)\,\frac{3}{8}k^2 + \frac{3}{8}k^2. \tag{12}$$

Also gives $\pi < \frac{1}{2}$, which holds in this case. So if $\pi < \frac{1}{2}$, S agents will play IR in all three periods. CCs will play FB in the first period and IR in the second and third period if matched with an S agent and FB in all three periods if matched with a CC.

What is the optimal behaviour in the first period if $\pi \geq \frac{1}{2}$? If the strategy of an S agent is to provide IR effort it is optimal to provide IR effort instead of FB effort if:

$$\pi\frac{5}{8}k^2 + (1-\pi)\frac{3}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2 \geq \pi \cdot (\frac{1}{2}k^2 + \frac{1}{2}k^2 + \frac{5}{8}k^2) + (1-\pi)(\frac{1}{4}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2). \tag{13}$$

Gives $\pi < \frac{1}{3}$. We already know that $\pi \geq \frac{1}{2}$, so this condition does not hold. If the strategy of an S agent is to provide FB effort it is optimal to provide IR effort instead of FB effort if:

$$\frac{5}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2 \geq \frac{1}{2}k^2 + \frac{1}{2}k^2 + \pi\frac{5}{8}k^2 + (1-\pi)\frac{3}{8}k^2. \tag{14}$$

Gives $\pi = 0$. We already know that $\pi \geq \frac{1}{2}$, so this condition does not hold. So if $\pi \geq \frac{1}{2}$, S agents will play FB in the first 2 periods and IR in the last period and CCs will play FB in all 3 periods.

For two of the three possible compositions, the equilibrium is now determined. For the PP team the equilibrium is similar. The behaviour in the second last period is still crucial. In the case of $\pi < \frac{1}{2}$, the benefits and costs of providing FB effort are in every period the same (independent of the number of periods), because the agents infer from backward induction that in the next period exerting IR is optimal. In the case of $\pi \geq \frac{1}{2}$, S agents are going to exert FB effort in the second last period. In the preceding periods the benefits of providing FB are even bigger, because by providing IR they will also lose the utility of the cooperation periods before the last period. Thus, in the case of $\pi \geq \frac{1}{2}$, the equilibrium will be to provide FB in all periods but the last for both types of players. In the last period S agents will provide IR and CCs will provide FB. In the case of $\pi < \frac{1}{2}$, S agents will exert IR in all periods, a CC will provide FB in the first period and IR in all other periods if matched with an S agent and FB in all periods if matched with another CC.

1.3 Optimal team composition

We can now look at the optimal team composition. I will start with the optimal combination of contracts in a team. In the case of $\pi \geq \frac{1}{2}$, in the last period there is a probability of not ending up in the FB equilibrium (in all other periods both players will exert FB). So it is beneficial for the principal to hire agents for a high number of periods, since this will lead to the situation that this last period accounts for a smaller part of the average productivity. Since a PP team interacts always for a higher number of periods than the other two compositions, the PP team is optimal. If the contract length of P workers can be determined by the principal, a longer contract is more profitable. If $\pi < \frac{1}{2}$ the opposite holds, because the first period is always equal or better in productivity compared to all next periods. If the highest average productivity is the objective, it is beneficial for the principal if the agents interact for a low number of periods. This implies that a PT or TT composition is optimal. In this case, preferences of agents about the composition are the same as the preferences of the principal.

The next step is to consider what the optimal composition is, if the composition of types can be affected by the principal too. So, in which cases does the principal have relative the most incentives to recruit a CC worker? If $\pi \geq \frac{1}{2}$ every CC worker instead of an S worker leads to an increase in productivity of $\frac{1}{2}k^2$ in the last period, and no increase in productivity in all other periods. In addition, there is already a big probability that the agent is a CC worker (because $\pi \geq \frac{1}{2}$). In the case of $\pi < \frac{1}{2}$, there are relative more incentives. In this case the minimal increase in productivity is also $\frac{1}{2}k^2$, but this increase happens with a bigger probability (because now $\pi < \frac{1}{2}$). On top of this, there is also a probability by recruiting one or two (in this case probability is 1) CC workers that the productivity is doubled compared to a team of two S agents. So in a situation with scarcer CC workers there are 2 extra incentives to recruit a CC worker:

- Because the CC workers are scarcer there is a lower probability to hire a CC worker by luck.
- Because of the nature of the equilibrium recruiting a CC worker has a bigger effect on the expected outcome if CC workers are scarce.

4. Renewable contracts for temporary agents

The first extension of the model will be the possibility that the contract of a T worker gets extended. I will assume that if both agents provide FB effort in all periods the contract of the temporary worker will be extended for *s* periods (contracts can be extended only once). If the contract of a T worker does not get extended, his utility will be 0 and he will get replaced by a new T worker. For a PP team there will be no differences. For a TT and PT team the equilibrium will change. If P workers are matched with a T worker I assume that the contract of a P worker will last for infinity. This is just a simplifying assumption to make analysis easier.[3]

4.1 Results

I will start with considering a situation when the team consists of a T worker and a P worker and $\pi \geq \frac{1}{2}$. The equilibrium without contract extension will be that both workers will provide FB effort until the last period and then S workers will switch to IR effort and CC workers will exert FB effort. P-S workers have no incentives to provide FB effort in the last period, because

[3] This is just a simplifying assumption. If they are matched with another P worker, contracts last for a definite number of periods, longer than 3 + s periods.

if their co-worker provides IR effort, it is better to also provide IR effort and if he provides FB effort he will extract the rents of the work relationship by providing IR effort. There are no benefits of contract renewal, because only the rents will be delayed. T workers know this but P-CC workers are still going to provide FB effort, so there is still a probability that the contract will be extended if he provides FB effort (π). Now, what are the costs and benefits of a temporary worker if he provides FB effort? Costs in the last period before the extension:

$$\pi \cdot \frac{1}{8}k^2 + (1-\pi)\frac{1}{8}k^2 = \frac{1}{8}k^2. \tag{15}$$

Benefits after the extension (he knows for sure that the other agent is a CC):

$$\pi\left(s \cdot \frac{1}{2}k^2 + \frac{1}{8}k^2\right) = \pi \cdot s \cdot \frac{1}{2}k^2 + \pi \cdot \frac{1}{8}k^2. \tag{16}$$

So T workers will provide FB effort in the last period if:

$$\pi \cdot s \cdot \frac{1}{2}k^2 + \pi \cdot \frac{1}{8}k^2 > \frac{1}{8}k^2. \tag{17}$$

This could be rewritten as:

$$\pi > \frac{1}{1 + s \cdot 4}. \tag{18}$$

And this always holds because $\pi \geq \frac{1}{2}$ and $s \geq 1$. Hence, we have shown that T agents are willing to exert FB effort in the third period, if $\pi \geq \frac{1}{2}$.

The next step is to consider the situation when $\pi < \frac{1}{2}$. Then the equilibrium without contract extension is to provide IR effort from the first to the last period. What will be the equilibrium with contract extension? We should again start in the last period what the strategy of a T worker will be if all periods till so far have delivered FB effort. His strategy is to provide FB effort if $\pi > \frac{1}{1+s\cdot 4}$. So if this condition does not hold we are back in the regular IR equilibrium in all periods. If this condition holds the P worker wants to do FB effort in the second period because:

$$\frac{1}{2}k^2 + \frac{5}{8}k^2 \geq \frac{5}{8}k^2 + \frac{3}{8}k^2. \tag{19}$$

And also in the first period the utility of doing FB is higher compared to exerting IR (knowing that the agent will also do FB in the second period):

$$\frac{1}{2}k^2 + \frac{1}{2}k^2 + \frac{5}{8}k^2 \geq \frac{5}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2. \tag{20}$$

So if $\pi > \frac{1}{1+s\cdot 4}$ holds T workers will provide FB in all periods before the renewal and after the renewal FB until the last period and then IR. P workers will provide FB until the last period before the renewal and then IR.

We can conclude that if $\pi > \frac{1}{1+s\cdot 4}$ we arrive in an interesting equilibrium. Also if $\pi < \frac{1}{2}$ T agents are willing to exert FB effort after the contract extension, because due to the renewal of the contract, information about the type of the P worker has been revealed.

Until now I have implicitly assumed that the new worker has no extra information from the fact that the last workers contract did not get extended. But it is realistic to assume that a new worker has information about whether the job was done before by someone else or whether it is a totally new job. If this is the case the equilibrium does not require to change. The fact is that I assumed that a contract can only be extended once, so a replacement of a T worker does not mean that the P worker shirked in the last period (and so that he is S), but could also be due to the end of the second contract. But, does the equilibrium change if we also drop this assumption? If in this case the contract of a T worker does not get extended, a new T agents knows that the P worker is S. For a CC this information does not change his behaviour. An S agent will change his behaviour, because he knows that the other worker is not willing to exert FB in the third period for sure. The first step in establishing the new equilibrium is determining the behaviour of a P agent if the last T contract did not get renewed due to the behaviour of the P worker. His utility if he provides FB effort in the first period (and optimal effort in the other 2 periods based on the observed type of his co-worker):

$$\pi \cdot \left(\frac{1}{2}k^2 + \frac{1}{2}k^2 + \frac{5}{8}k^2\right) + (1-\pi) \cdot \left(\frac{1}{4}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2\right) = k^2 + \pi \cdot \frac{5}{8}k^2. \tag{21}$$

His utility if he provides IR in the first period:

$$3 \cdot \left(\frac{3}{8}k^2 + \frac{3}{8}k^2 + \frac{3}{8}k^2\right) + \pi \cdot \frac{1}{4}k^2 = \frac{9}{8}k^2 + \pi \cdot \frac{1}{4}k^2. \tag{22}$$

Thus, Providing FB effort for the P worker is optimal if:

$$k^2 + \pi \cdot \frac{5}{8}k^2 \geq \frac{9}{8}k^2 + \pi \cdot \frac{1}{4}k^2. \tag{23}$$

This solves for $\pi \geq \frac{1}{3}$. Now we need to check whether the behaviour of the P worker is going to change at the first matched T worker if $\pi \geq \frac{1}{3}$. If he exerts FB effort in the third period at the first matched T worker his total utility each three periods is equal to:

$$3 \cdot \frac{1}{2}k^2 = \frac{3}{2}k^2. \tag{24}$$

The utility after shirking in each cycle is already determined[4] ($k^2 + \pi \cdot \frac{5}{8}k^2$), so we can calculate the level of π for which P agents are going to shirk in the last period.

$$k^2 + \pi \cdot \frac{5}{8}k^2 \geq \frac{3}{2}k^2. \tag{25}$$

And this is the case for $\pi \geq \frac{4}{5}$. Hence, we can conclude that the equilibrium does not change for $\pi \geq \frac{4}{5}$ and $\pi < \frac{1}{1+s \cdot 4}$. In the latter case, the observation of no contract extension could also be due to low effort of the T worker. For $\frac{1}{1+s \cdot 4} < \pi < \frac{4}{5}$ the P worker will provide FB in the final period of every cycle. So, if both assumptions do not hold we arrive in a different equilibrium for these values of π. If one of these assumptions hold, the equilibrium will stay the same. From now on, I will assume that contracts can only be extended once.

Now consider the situation of 2 T workers in a team. First the situation with $\pi \geq \frac{1}{2}$. Then FB in the last period will be optimal if:

$$\frac{1}{2}k^2 + s \cdot \frac{1}{2}k^2 + \ \pi \cdot \frac{1}{8}k^2 > \frac{5}{8}k^2. \tag{26}$$

And this always holds. As we have seen before, this also means that in the first 2 periods both players will provide FB effort. Now the situation with $\pi < \frac{1}{2}$:

$$\frac{1}{2}k^2 + s \cdot \frac{3}{8}k^2 + \ \pi \cdot \frac{2}{8}k^2 > \frac{5}{8}k^2. \tag{27}$$

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[4] The one-off benefits of shirking in the last period at the first matched agent are negligible if there is an infinite number of cycles, so these are not taken into account.

And this also always holds. Only after the extension the equilibrium will be IR instead of FB in all periods before the last one. So with 2 T workers in a team both contract will always be extended in equilibrium.

4.2 Optimal team composition

I will start with considering which composition is beneficial for the different types of workers. It is clear that T workers always want to be matched with another T worker. In that case they are always sure that their co-worker will not shirk and so their contract will be extended. If they are in a team with a P worker their contract will only be extended if matched with a CC worker. But, what is best for a P worker? Working in a PP team or a PT team? For an S worker it is definitely optimal to work with a T worker. If $\pi > \frac{1}{1+s\cdot 4}$ they can profit from the incentive effect on T workers of contract renewal possibilities, if they work hard. If $\pi < \frac{1}{1+s\cdot 4}$, they are more often matched with a new worker and have more opportunities to extract the rent of shirking in the first period (because PP workers contracts are longer than 3 + *s*).

For a CC worker it is less simple. They do not choose to take advantage from the incentive effect of T workers. This means that if $\pi \geq \frac{1}{2}$, it is more profitable to be in a PP team, because there will be shirked at most only once (in the last period). In a PT team all temporary workers will shirk in the last period after the renewal (if it is an S agent). So this will happen in expectation more often. In the case of $\pi < \frac{1}{2}$ it will depend in general on *s* whether the P worker will prefer a PP or PT team. If $\pi > \frac{1}{1+s\cdot 4}$, the T worker will always exert high effort in the periods before the contract renewal, but he will only do this after the contract extension if he is a CC worker. So if *s* is high the P worker will more likely prefer a PP team. The opposite holds if $\pi < \frac{1}{1+s\cdot 4}$. In this case contract will never be extended, unless the T worker is a CC. Now the periods after the renewal are very lucrative and the P worker will more likely prefer a PT team if *s* is high. Because a high *s* makes it more likely that $\pi > \frac{1}{1+s\cdot 4}$ happens (and that $\pi < \frac{1}{1+s\cdot 4}$ does not happen) we can conclude that in most cases a P-CC worker prefers to work with a P worker.

We have now determined what the optimal composition is for the agents themselves, but maybe more interesting is what the most profitable composition for the principal is. If $\pi \geq \frac{1}{2}$, the equilibrium with 2 P workers is already very interesting, because both workers will provide FB effort at least until the last period, so because contracts of PP workers are longer than 3 + s, this is a better expected outcome than two T workers.[5]

If $\pi < \frac{1}{2}$, but $\pi > \frac{1}{1+s\cdot 4}$, two P workers is not a very interesting scenario, because the expected outcome will be low (only if both workers are CC they will provide FB effort in all periods). Two T workers will provide high effort in the periods before the renewal, but will end up in the same equilibrium as two PP workers after the renewal. The last alternative is a PT team. In this case both workers will provide high effort in the first 2 periods. In the last period before the renewal the T worker will provide high effort, and the P worker only if he is a CC. After the renewal the T worker knows that the P worker is a CC and will also arrive in a good equilibrium. If the P worker is S we are still in a pretty desirable outcome. So in this case the expected productivity is the highest in a PT team.

If $\pi < \frac{1}{2}$ and $\pi < \frac{1}{1+s\cdot 4}$, a PP team still does not lead to a desirable outcome. Now in case of a PT team contracts will only be extended if both workers are CCs, and this is not likely to happen because π is low. So, also in this case we end up in low equilibria. If we hire two T workers, at least before the contract extension efforts will be high and thus is this the most desirable outcome in this case.

We have seen what happens after the introduction of different lengths of contracts and renewal possibilities. In the desirable case of $\pi \geq \frac{1}{2}$ we remain in the same situation of hiring two P workers. In the scenario of a high enough π to let the incentive effect of possible contract renewal still exist if a T worker is matched with a P worker, we establish with this composition that we never arrive anymore in the undesirable outcome. This does not happen anymore, because information about the type of the P worker is released if the contract is extended. Even if the P worker is S for sure we are still in a better outcome than without T workers.

If π is such that T workers are not anymore motivated by the contract extension effect (if matched with a P worker), a PT team is no longer better than a PP team. In this case we end

[5] If contracts of PP workers are the same length as 3 + s, a team of two T workers gives the same outcome in terms of productivity.

up in a better situation if we choose for a TT team. T workers are always willing to exert high effort if matched with another T worker, even if there exist no CCs at all. This results in the outcome that at least before the contract renewal both workers provide high effort. After the contract renewal, the contract renewal incentive does not exist anymore and we arrive in the undesirable outcome.

After establishing the new equilibria, we can now examine in which cases the principal has relative the most incentives to recruit a CC worker. If $\pi \geq \frac{1}{2}$ we remain in the same equilibrium as without T workers and renewable contracts, in which there was only a small incentive to recruit a CC worker. If $\pi > \frac{1}{1+s\cdot 4}$ (but $\pi < \frac{1}{2}$), the PT composition is optimal. Recruiting a T-CC worker gives a probability of $1 - \pi$ that this has no effect on the outcome (if P is S, we do not arrive in the periods after the contract extension, and a T worker already always does FB in the periods before the renewal). With probability π the P worker is CC and we arrive in the periods after the renewal. If T would be S, he would also have the information that P worker is a CC, and would already provide FB until the last period. Thus, recruiting only has a positive effect on the last period after the contract extension, if the P worker is CC. If we recruit a P-CC worker this has a bigger effect on the outcome. In this case we can be sure that the contract will be renewed and that the information that P is a CC will be released to the T worker. This results in the equilibrium that the P worker will do FB in all periods, and the T worker FB in all periods but the last (in the last period only if he is CC). So recruiting a P-CC worker is a very attractive possibility in this case. If $\pi < \frac{1}{1+s\cdot 4}$, recruiting a CC worker only has an effect after the contract renewal. This effect is small if the other agent is S, but big if the other agent is CC (productivity will be doubled). So especially recruiting 2 CC workers is lucrative in this case. Note that recruitment costs could increase if CC workers become scarcer.

4.3 Optimal length of contract renewal and effects on team composition

So now we have determined which compositions are chosen under the different conditions. Our next question is: what to do with *s* if this can be determined by the principal. It is important to note that the conditions are also dependent of *s*. This means that by adjusting *s* the principal can also choose which composition is optimal (if *s* is higher $\pi > \frac{1}{1+s\cdot 4}$ is more easy satisfied). So, we will look at the different scenarios. If $\pi = 0, \pi < \frac{1}{1+s\cdot 4}$ is always satisfied and we arrive in the case in which *s* has a negative effect on the average productivity. If in this case *s* could be determined by the principal it should be as small as possible (so *s* = 1). Relatively high πs are positive for the PT composition, because the output will be high if the contract is extended, relative to the TT composition, in which output is always lower (after contract renewal) than in the PT composition. So for relative high values of π the PT composition is more beneficial and this composition is even more lucrative for higher values of *s*. So the principal fixes *s* such that $\pi > \frac{1}{1+s\cdot 4}$ at least holds (and higher is better). In fact, if $\pi > 0$ and *s* can take on any value, the PT equilibrium is always better than the TT equilibrium. The PT equilibrium can in this case always be reached. Proof that even under $\pi = 0$, PT is optimal (but cannot be reached) follows.

Average productivity PT composition:

$$\frac{2 \cdot (k+k)k + \left(\frac{1}{2}k + k\right)k}{3} = 1\frac{5}{6}k^2. \tag{28}$$

Average productivity TT composition (*s* = 1 is optimal):

$$\frac{3 \cdot (k+k)k + \left(\frac{1}{2}k + \frac{1}{2}k\right)k}{4} = 1\frac{3}{4}k^2. \tag{29}$$

π has a bigger positive effect on the average productivity of a PT team than a TT team, so the difference will only be larger if π is positive (and will become a feasible result).

We can conclude that for all cases if $\pi < \frac{1}{2}$ (except $\pi = 0$), PT is the desirable team composition, because we always arrive in an acceptable equilibrium with a probability π of ending up in a very good equilibrium. So, the principal benefits from the ''selfish'' behaviour of the P-S worker, which results in the fact that only the contract of the T worker will be extended if the P worker is of the good type. The principal can, in turn, put *s* very high, because the T worker knows that the P worker is CC if the contract gets extended and will provide FB in all periods until the last after the renewal and will also provide FB in the last period if he is a CC himself.

So if s can be fixed, recruitment costs are not too high and $\frac{1}{2} > \pi > 0$, we end up in very interesting equilibrium which looks a lot like the equilibrium if $\pi \geq \frac{1}{2}$. This is due to the fact that the effort decision of the P worker is pivotal and a P-CC is only willing to do FB in the last period before the contract renewal, which lead to the crucial release of information.

4.4 Discussion

These results are under the simplifying assumption which states that the outside utility of a T worker is equal to 0. This is off course not realistic, but putting another value on it is also not justified. By using a parameter, the results will be more abstract and less easy to interpreted. So, the contract extension possibility effect is in reality smaller than in this model. If teams can be composed by the principal, this does not affect the case of $\pi \geq \frac{1}{2}$ (there will be no T workers). In the case of $\pi < \frac{1}{2}$, the sub-conditions changes: $\frac{1}{1+s\cdot 4}$ will increase. If s cannot be fixed, π should be larger for the contract renewal incentive to exist (in a PT team). Also, it cannot be the case any longer that T workers in a TT team are always willing to play FB in all periods. It might be that s should be larger than 1 to satisfy this behaviour. If s could be fixed, this has no effect on the PT equilibrium (because s can always be fixed such that the condition holds). In the TT equilibrium (if $\pi = 0$) s should still be fixed as low as possible.

5. Learning in teams

The next extension is the possibility to teach the other agent something. In a model like this in which you can only change the general productivity (also if the level of teaching is the same) learning does not change the effort decisions. We will have to change the model slightly to consider the effect of learning/teaching possibilities. I want to study a situation in which both agents can raise the productivity of his team member by teaching on his own cost. Every period, both agents have the option to teach the other agent something before they choose their effort levels. The absolute level of learning will stay the same (and so the relative level of learning decreases). The utility function and the wage will stay the same and the total productivity changes to:

$$Q_t = e_1(k + n \cdot \theta) + e_2(k + m \cdot \theta). \tag{30}$$

n is the number of times agent 2 teaches something to agent 1 and *m* is the number of times agent 1 teaches something to agent 2. ϑ is the return to learning and *c* are the costs of teaching the other agents something. The next step is to look what happens to the effort levels and utilities. FB effort will become:

$$\frac{d(U_1 + U_2)}{de_1} = k + n \cdot \theta - e_1 = 0 \rightarrow e_1 = e_2 = k + n \cdot \theta. \tag{31}$$

And IR effort will change to:

$$\frac{dU_1}{de_1} = \frac{1}{2}k + \frac{1}{2}n \cdot \theta - e_1 = 0 \rightarrow e_1 = e_2 = \frac{1}{2}k + \frac{1}{2}n \cdot \theta. \tag{32}$$

The utility of agent 1 if both agents put in FB effort is $U = \frac{1}{2}(k + n \cdot \theta)^2 + \frac{1}{2}(k + m \cdot \theta)^2 - \frac{1}{2}(k + n \cdot \theta)^2 = \frac{1}{2}(k + m \cdot \theta)^2$ and if both agents exert IR effort: $U = \frac{1}{4}(k + n \cdot \theta)^2 + \frac{1}{4}(k + m \cdot \theta)^2 - \frac{1}{8}(k + n \cdot \theta)^2 = \frac{1}{4}(k + m \cdot \theta)^2 + \frac{1}{8}(k + n \cdot \theta)^2$. The other utilities in the other 2 scenarios are: if $e_1 = FB$ and the other agent exerts $e_2 = IR$, $U = \frac{1}{2}(k + n \cdot \theta)^2 + \frac{1}{4}(k + m \cdot \theta)^2 - \frac{1}{2}(k + n \cdot \theta)^2 = \frac{1}{4}(k + m \cdot \theta)^2$ and if $e_1 = IR$ and other agent exerts $e_2 = FB$, $U = \frac{1}{4}(k + n \cdot \theta)^2 + \frac{1}{2}(k + m \cdot \theta)^2 - \frac{1}{8}(k + n \cdot \theta)^2 = \frac{1}{2}(k + m \cdot \theta)^2 + \frac{1}{8}(k + n \cdot \theta)^2$.

5.1 The equilibrium after learning

Now we can consider the total trade off with backward induction. I will assume that players play the same trigger-strategies as without learning. Thus, if an agent did not invest into the productivity of the other agent, he will not get punished by the other agent in effort level. In chapter 5.3 I will discuss why this could also be expected. Both agents are not always identical anymore, so this will change the method slightly. I will first consider the situation without contract extension possibilities and with the PT and TT compositions. Determining the equilibria in the second and third period are the same as in chapter 3.

In the third and last period the optimal strategy will be still to always exert IR effort:

$$\pi \cdot (\frac{1}{2}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2) + (1-\pi)(\frac{1}{4}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2) \geq \pi \cdot \frac{1}{2}(k + m \ \cdot \theta)^2 + (1-\pi)\frac{1}{4}(k + m \ \cdot \theta)^2. \quad (33)$$

In the second period agent 1 will do FB effort if (assuming player 2 plays FB, results are the same if player 2 plays IR):

$$\frac{1}{2}(k + m \ \cdot \theta)^2 + \pi \cdot (\frac{1}{2}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2) + (1-\pi)(\frac{1}{4}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2) \geq \frac{1}{2}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2 + \frac{1}{4}(k + m \ \cdot \theta)^2 + \frac{1}{8}(k + n \ \cdot \theta)^2. \quad (34)$$

And this solves for:

$$\pi \cdot \frac{1}{4}(k + m \ \cdot \theta)^2 \geq \frac{1}{8}(k + n \ \cdot \theta)^2. \quad (35)$$

The condition for agent 2 will similarly become:

$$\pi \cdot \frac{1}{4}(k + n \ \cdot \theta)^2 \geq \frac{1}{8}(k + m \cdot \theta)^2. \quad (36)$$

So if $m = n$ we are in the same equilibrium ($\pi \geq \frac{1}{2}$).[6] But if $m \neq n$ we arrive in a different equilibrium. We are then in the FB equilibrium if $\pi \cdot \frac{1}{4}(k + m \ \cdot \theta)^2 \geq \frac{1}{8}(k + n \ \cdot \theta)^2$ and $\pi \cdot \frac{1}{4}(k + n \ \cdot \theta)^2 \geq \frac{1}{8}(k + m \cdot \theta)^2$. We are in the IR equilibrium if $\frac{1}{8}(k + n \ \cdot \theta)^2 > \pi \cdot \frac{1}{4}(k + m \ \cdot \theta)^2$ and $\frac{1}{8}(k + m \ \cdot \theta)^2 > \pi \cdot \frac{1}{4}(k + n \ \cdot \theta)^2$. But we should determine what happens if $\pi \cdot \frac{1}{4}(k + m \ \cdot \theta)^2 \geq \frac{1}{8}(k + n \ \cdot \theta)^2$, but $\frac{1}{8}(k + m \ \cdot \theta)^2 > \pi \cdot \frac{1}{4}(k + n \ \cdot \theta)^2$ and

[6] In this model we arrive in the same equilibrium if both agents have invested into each other's productivity as often as the other agent, compared to the basic model without investment possibilities. I also considered another way of investing to check whether we always arrive in such equilibria, in a model like this with trigger-strategies. I considered the way of investing used by Dur and Sol (2010), in which investing means giving attention to the other agent. This investment leads to altruism towards the other agent (so the other agent will care about your wage). Also in this case, if both agents have invested the same amount of attention to the other worker, the equilibrium does not change in the context of my model.

the opposite variant. So is doing FB in the second period still optimal if agent 2 is doing IR effort?

$$
\begin{aligned}
&\pi \cdot (\frac{1}{2}(k+m\ \cdot \theta)^2 + \frac{1}{2}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2) \\
&\qquad + (1-\pi)(\frac{1}{4}(k+m\ \cdot \theta)^2 + \frac{1}{4}(k+m\ \cdot \theta)^2 \\
&\qquad + \frac{1}{8}(k+n\ \cdot \theta)^2) \\
&\qquad \geq \frac{1}{4}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2 + \pi \cdot \frac{1}{4}(k+m\ \cdot \theta)^2 \\
&\qquad + \frac{1}{4}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2.
\end{aligned} \tag{37}
$$

This results in:

$$\pi \cdot \frac{1}{4}(k+m\ \cdot \theta)^2 \geq \frac{1}{8}(k+n\ \cdot \theta)^2. \tag{38}$$

And this holds. If agent 2 is exerting FB in the first period, then it is obviously optimal for agent 1 to do FB. So the last thing we need to check is whether agent 2 is willing to do FB in the first period (assuming agent 1 is providing FB).

$$
\begin{aligned}
&\frac{1}{2}(k+m\ \cdot \theta)^2 + \frac{1}{2}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2 + \frac{1}{4}(k+m\ \cdot \theta)^2 \\
&\qquad + \frac{1}{8}(k+n\ \cdot \theta)^2 \\
&\qquad \geq \frac{1}{2}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2 + \frac{1}{4}(k+m\ \cdot \theta)^2 \\
&\qquad + \frac{1}{8}(k+n\ \cdot \theta)^2 + \frac{1}{4}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2.
\end{aligned} \tag{39}
$$

Gives:

$$\frac{1}{2}(k+m\ \cdot \theta)^2 \geq \frac{1}{4}(k+m\ \cdot \theta)^2 + \frac{1}{8}(k+n\ \cdot \theta)^2. \tag{40}$$

And this holds, because both doing FB should lead to higher utility than both doing IR. So if 1 of the 2 conditions holds, the agent which condition holds will do FB until the last period and the other agent will do FB in the first period and IR in the second and third period. As in chapter 3, in a PP team the equilibrium in the last 3 periods is the same. If it is optimal to provide FB in one of those periods it is also optimal to provide FB in all previous periods (if no one has shirked yet). By shirking they will lose all cooperation periods, so this is not optimal. Also, if the optimal strategy is to shirk in the three last periods, it is also optimal to shirk in all previous periods. The relative benefits of providing FB will not increase in previous periods, so the strategy stays the same (assuming same level of investing).

5.2 The effect on utilities

The next step is to look at what happens with productivity and utility after an investment. It is easy to see what happens to the utilities. If the agent is playing FB investing in the other leads to an increase from $\frac{1}{2}k^2$ to an utility of $\frac{1}{2}(k + m \cdot \theta)^2$ if the other is also exerting FB and increases from $\frac{1}{4}k^2$ to $\frac{1}{4}(k + m \cdot \theta)^2$ if the other is exerting IR. In these expressions is no n present. So if you are providing FB, investment from the other in your productivity has no effect on your utility. If you are doing IR effort and the other one is providing FB effort, utility will increase from $\frac{5}{8}k^2$ to $\frac{1}{2}(k + m \cdot \theta)^2 + \frac{1}{8}(k + n \cdot \theta)^2$ and if the other agents provides IR then utility increases from $\frac{3}{8}k^2$ to $\frac{1}{4}(k + m \cdot \theta)^2 + \frac{1}{8}(k + n \cdot \theta)^2$. In these expressions there is an effect (although smaller than investing yourself) from being invested in. Still, being invested in could be positive for the invested in, because investing increases the probability that the respective agent is exerting FB effort and creates a better pay-off if you provide IR effort (and so more incentives to switch to IR effort).

I will finish this part by analysing my conclusions. Investing in the other agent leads to the effect that the investor is more likely to do FB, but the other team member is less likely to do FB. Investing increases the value of the cooperative equilibrium, so investing gives more incentives to sustain this equilibrium. If the other invests in you, you are less likely going to exert FB effort, because the utility of shirking has increased and the utility of providing FB effort has not changed. But this does not necessary mean that your expected effort is lower (because FB and IR effort both increases due to the investment of the other). This behaviour is due to the nature of the trigger-strategies, which is played by the agents. Intuitively without considering strategies I would expect that someone is never going to reduce effort if his productivity increases, because he can always at least do the same effort as without the investment and receive a higher pay-off. But because the other player plays a trigger-strategy, the necessary effort to let your team member still provide FB effort, increases. And so, if doing

FB is still optimal after the investment, the utility of the invested in will stay the same. Thus, maybe the opposite of what intuitively was expected: most of the benefits from investing go to the investor. Our next step is to consider when agents are going to invest.

5.3 The investment decision

If there are multiple investment possibilities it is very hard to determine the equilibrium, because investment leads then also to an option to invest at the next investment possibility (and that leads to a next option). So to determine an investment equilibrium I assume that investment is only possible once, before the first period. I will look at the case without contract extension. The externality of investing is very small (and exists only when exerting IR), so I expect that in the case of only investing once, externalities will not play a role in the strategies of both players. In fact, there are no strategic considerations possible, because after this simultaneous investment decision there are no investment decisions left. Besides that, is punishment in effort impossible (in FB equilibria both agents do not care about investments of the other agents and in IR equilibria switching to lower effort levels is not the expectation). So agents will only compare the benefits of investment with the costs. Costs are equal to c. So there are 2 types and 2 equilibria (assuming that the investment does not change the equilibrium), so 4 investment decisions. Starting with an S agent in the situation of $\pi \geq \frac{1}{2}$. If there are 1 or 2 temporary workers in the team, there are $t = 3$ periods. If 2 P workers are matched, the number of periods left before the first period is equal to t, so this will result in similar but more general conditions. First 2 periods will always be FB and the last period will be the (IR, IR) or (IR, FB) equilibrium, so investment will happen if:

$$(t-1)\cdot\left(\frac{1}{2}\theta^2 + k\theta\right) + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta + \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \tag{41}$$

If the agent is a CC, then the expected behaviour will be FB in the first 2 periods of both agents and (FB, IR) or (FB, FB) in the last period. This does not lead to other returns to investment so the same condition holds. If $\pi < \frac{1}{2}$ and the agent is S, then the agent will do IR in all t periods with a π probability of FB effort of the other agent in the first period:

$$t\cdot\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) + \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \tag{42}$$

In this case the utility increase for a CC agent is bigger, because if the agent would be matched with another CC agent all periods will be FB effort:

$$t \cdot \left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) + t \cdot \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \qquad (43)$$

We can conclude a couple of things. First of all, in a PP team there are more incentives to invest, compared to the other two compositions, because the agents interact for a higher number of periods and hence have more benefits of investing in their co-worker. Second, own type does not matter for the investment decision in all compositions if $\pi \geq \frac{1}{2}$. Only the decision (and thus the type) of the other agent affects the return to investing. Lastly, if $\pi < \frac{1}{2}$, own type could have a big effect on the investment decision. This is the case if the agents' own type is CC. If in this case the other agent is also a CC, we arrive in the high equilibrium instead of the low equilibrium in all periods. This also has a big effect on the investment decision of the CC.

6. Combining renewable contracts & learning

The next step is to consider what happens to the behaviour in the last period of a P worker in a PT team if contracts of temporary workers could be extended. For the other two compositions, investment does not make a difference if contracts could be extended. In case of two permanent agents, contracts will never be extended and in case of two T workers, contracts will always be extended (independent of investments).

Without investment we have already seen that P workers will never provide FB effort in the last period. After investment this is not necessary anymore the case. So we need to determine when P is willing to do FB in the last period. If P is exerting FB in the last period, T is obviously also willing to do FB.

Let's first consider the case of $\pi \geq \frac{1}{2}$. For simplifying reasons I assume that investment is only possible at the first matched agent (for a permanent worker). Otherwise we would get a lot of conditions which will not make the results more interesting. If P is exerting IR in the last period, the contract of the T agent will not be renewed and the P worker will be matched with another T agent. This means that investments into each other are wasted.

If P is exerting IR in the last period his utility for the periods the contract lasts (with contract extension) is equal to:

$$\frac{5}{8}k^2 + \frac{5}{8}\theta^2 + \frac{10}{8}k\theta + s \cdot \frac{13}{24}k^2. \tag{44}$$

The last term is the average utility in the situation without investment multiplied by the number of periods if the contract would be extended (for comparison reasons):

$$\frac{\frac{1}{2}k^2 + \frac{1}{2}k^2 + \frac{5}{8}k^2}{3} = \frac{13}{24}k^2. \tag{45}$$

Utility if exerting FB in last period:

$$\frac{1}{2}k^2 + \frac{1}{2}\theta^2 + k\theta + (s-1) \cdot \left(\frac{1}{2}k^2 + \frac{1}{2}\theta^2 + k\theta\right) + \frac{3}{8}k^2 + \frac{3}{8}\theta^2 + \frac{6}{8}k\theta + \pi \cdot \left(\frac{2}{8}k^2 + \frac{2}{8}\theta^2 + \frac{4}{8}k\theta\right). \tag{46}$$

So if the following condition holds, P will do FB in the last period:

$$s \cdot \left(\frac{1}{2}\theta^2 + k\theta\right) + \pi \cdot \left(\frac{1}{4}k^2 + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > \frac{1}{4}k^2 + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta + s \cdot \frac{1}{24}k^2. \tag{47}$$

If $\pi < \frac{1}{2}$ (but $\pi > \frac{1}{1+s\cdot 4}$) this condition will change. Utility if P exerts IR in last period will remain the same, but the utility of exerting FB in the last period will decrease. This is because we are now in the low equilibrium after the contract renewal (since $\pi < \frac{1}{2}$).

$$\frac{1}{2}k^2 + \frac{1}{2}\theta^2 + k\theta + s \cdot \left(\frac{3}{8}k^2 + \frac{3}{8}\theta^2 + \frac{6}{8}k\theta\right) + \pi \cdot \left(\frac{1}{4}k^2 + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right). \tag{48}$$

So if the following condition holds, P will do FB in the last period:

$$s \cdot \left(\frac{3}{8}\theta^2 + \frac{3}{4}k\theta\right) + \pi \cdot \left(\frac{1}{4}k^2 + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > \frac{1}{8}k^2 + \frac{1}{8}\theta^2 + \frac{1}{4}k\theta + s \cdot \frac{1}{6}k^2. \tag{49}$$

If $\pi < \frac{1}{1+s\cdot 4}$ this condition will slightly change. Utility if P exerts IR in last period will become (if FB in the first 2 periods):

$$\frac{5}{8}k^2 + \frac{5}{8}\theta^2 + \frac{10}{8}k\theta + s \cdot \frac{3}{8}k^2 + \pi \cdot s \cdot \frac{1}{12}k^2. \tag{50}$$

The last 2 terms are determined as follows. The P worker will earn always at least $\frac{3}{8}k^2$, because he is always doing IR (second to last term). He also has a probability π that the other worker is a CC and this increases the pay-off in the first period with $\frac{1}{4}k^2$. Divided by the 3 periods every cycle lasts this is equal to $\frac{1}{12}k^2$.

If the P agent exerts FB in the last period his utility will remain the same. The condition in this case becomes:

$$\begin{aligned} s \cdot \left(\frac{3}{8}\theta^2 + \frac{3}{4}k\theta\right) + \pi \cdot \left(\frac{1}{4}k^2 + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) \\ > \frac{1}{8}k^2 + \frac{1}{8}\theta^2 + \frac{1}{4}k\theta + \pi \cdot s \cdot \frac{1}{12}k^2. \end{aligned} \tag{51}$$

So if this condition holds, P and T will do FB until the last period (before the extension). If this condition does not hold, P and T will do IR from the first period. This condition is more easily satisfied because the P worker will not extract the rent anymore from the next worker willing to do FB until the last period (because $\pi < \frac{1}{1+s\cdot 4}$), so he has more reasons to let the contract be extended.

Now we have determined which equilibria change if contracts could be renewed after investment. We already discussed that PP & TT equilibria will not change after investment. But we have seen that in the case of a PT team, P agents could be willing to exert high effort in the third period. Even in the scenario with few CCs ($\pi < \frac{1}{1+s\cdot 4}$) investment could improve the equilibrium from a situation in which both agents are going to exert IR to an equilibrium in which both agents have incentives to provide high effort. This is due to the fact that investments are wasted if the team separates.

6.1 Optimal team composition

The last step is to consider whether the principal is making other composition decisions if agents are going to invest in each other. If $\pi \geq \frac{1}{2}$, a PP team still gives a higher productivity than a PT or TT team, independent of whether condition (47) holds. So if $\pi \geq \frac{1}{2}$ investment by both agents does not change the composition decision. If $\pi < \frac{1}{2}$, but $\pi > \frac{1}{1+s\cdot 4}$, PP still leads to the equilibrium in which both agents are doing maximum 1 period FB, unless they are both CC and in that case they will exert all periods FB. If condition (49) holds, the P worker (in a PT team) will always do FB in the last period and this effort decision will not provide information anymore about his type. So, after the contract extension we are back in the low equilibrium. In a TT team, the contracts of the T workers will always be extended. After the renewal we arrive in the same low equilibrium. This means that after investment the PT and TT composition are equivalent and better than the PP equilibrium (for the principal and the agents) if condition (49) holds. If condition (49) does not hold, still TT is always better than PP, so the PP composition will never be chosen. But whether TT or PT gives the higher productivity is not directly clear. Productivity if the PT composition is chosen:

$$2\cdot 2(k+\theta)^2 + \frac{3}{2}(k+\theta)^2 + \pi\cdot\frac{1}{2}(k+\theta)^2 + \pi\cdot s\cdot 2(k+\theta)^2 - \pi\cdot(1-\pi)\frac{1}{2}(k+\theta)^2 + (1-\pi)\cdot s\cdot\frac{11}{6}k^2. \tag{52}$$

First term is the productivity in the first 2 periods (both agents are doing FB). Second term is the productivity in the third period if the P worker is S. Third term is the extra productivity if the P worker is CC in the third period. Fourth term is the productivity after the renewal (so if the P worker is CC). Fifth term is the loss in productivity in the last period after the renewal if the T worker is S. Last term is the average productivity if the contract is not renewed (so if the P worker is S) multiplied by the number of periods the contract would have been extended. Productivity if the TT composition is chosen:

$$3\cdot 2(k+\theta)^2 + s\cdot(k+\theta)^2 + \pi^2\cdot s\cdot(k+\theta)^2 + 2\cdot\pi\cdot(1-\pi)\cdot\frac{1}{2}(k+\theta)^2. \tag{53}$$

The contract will always be extended in a TT team, so the first term is the productivity in the periods before the renewal. Second term is the productivity after the renewal if both agents are S. The third term is the extra productivity after the renewal if both agents are CC. The last term is the extra productivity after the renewal if 1 of both agents is CC. So if the following condition holds the principal will choose for a PT team and if it does not hold he will choose a TT composition.

Notice that in the same scenario without investment, the productivity of a PT was always bigger. This is not always the case anymore, because if the contract does not get extended, the extra productivity of the investment after the renewal will get wasted. Productivity if the PT composition is chosen:

$$\pi \cdot s \cdot 2(k+\theta)^2 + (1-\pi) \cdot s \cdot \frac{11}{6}k^2 + \pi^2(k+\theta)^2 > \frac{1}{2}(k+\theta)^2 + s \cdot (k+\theta)^2 + \pi^2 \cdot s \cdot (k+\theta)^2 + \pi \cdot \frac{1}{2}(k+\theta)^2 + \pi \cdot (1-\pi)\frac{1}{2}(k+\theta)^2. \tag{54}$$

If $\pi < \frac{1}{1+s\cdot 4}$, PP is still not a desirable composition. If condition (51) holds, the contract of the T worker in a PT team will always be extended, so the PT composition is again equivalent to the TT composition. If condition (51) does not hold, the PT composition results in the low equilibrium. In a TT team at least both agents do FB in the first 3 periods, before arriving in the low equilibrium.

6.2 The investment decision

Now we can determine whether the agents are going to invest. We already calculated when P workers are going to invest if $\pi \geq \frac{1}{2}$ (and so composition is PP):

$$(t-1) \cdot \left(\frac{1}{2}\theta^2 + k\theta\right) + \frac{1}{4}\theta^2 + \frac{1}{2}k\theta + \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \tag{55}$$

Agents are not more likely going to invest if the team is composed differently. For the scenario if $\pi < \frac{1}{1+s\cdot 4}$, it is also not that complicated and similar to what we did before. T-CC workers will invest if:

$$3 \cdot \left(\frac{1}{2}\theta^2 + k\theta\right) + s \cdot \left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) + s \cdot \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \tag{56}$$

And T-S workers will invest if:

$$3 \cdot \left(\frac{1}{2}\theta^2 + k\theta\right) + s \cdot \left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) + \pi\left(\frac{1}{4}\theta^2 + \frac{1}{2}k\theta\right) > c. \tag{57}$$

The assumption is that the principal will choose TT in all cases (if condition (51) holds PT is equivalent to TT). Agents are not more likely going to invest if the team is composed differently.

For the scenario if $\pi < \frac{1}{2}$, but $\pi > \frac{1}{1+s\cdot 4}$, it is more complicated, because by investing and providing FB in the last period by the P worker, the equilibrium changes. Stating these investing conditions for all the different sub-cases and types will not give us any extra information, so I will not make it more complicated than necessary. Most important is that we check whether these equilibria hold if we compare their incentives to invest (just as we did in the first 2 scenarios). If condition (49) holds, agents are not more likely to invest in a PP team than in a TT or PT team, so this equilibrium holds. If condition (49) & (54) do not hold, agents have relative the most incentives to invest in a TT team, so this equilibrium holds. If condition (49) does not hold, but condition (54) holds, we have a problem. Agents are most likely to invest in a TT team, but most optimal for the principal is to compose a PT team. If the workers will invest in both cases, he should still choose for a PT team. Same holds if the workers will not invest in both cases. If agents are going to invest in a TT team but not in a PT team we should check whether condition (54) still holds after adjusting the productivity in the PT team. Productivity if the PT composition is chosen becomes:

$$2\cdot 2k^2+\frac{3}{2}k^2+\pi\cdot\frac{1}{2}k^2+\ \pi\cdot s\cdot 2k^2-\pi\cdot(1-\pi)\frac{1}{2}k^2+(1-\pi)\cdot s\cdot\frac{11}{6}k^2. \tag{58}$$

So PT is optimal if:

$$2\cdot 2k^2+\frac{3}{2}k^2+\pi\cdot\frac{1}{2}k^2+\ \pi\cdot s\cdot 2k^2-\pi\cdot(1-\pi)\frac{1}{2}k^2+(1-\pi)\cdot s\cdot\frac{11}{6}k^2 > 3\cdot 2(k+\theta)^2+s\cdot(k+\theta)^2+\ \pi^2\cdot s\cdot(k+\theta)^2+2\cdot\pi\cdot(1-\pi)\cdot\frac{1}{2}(k+\theta)^2. \tag{59}$$

7. Conclusion

In this paper I investigated in three different situations the effect of team composition on the equilibrium outcome. The first situation is if contracts of temporary agents could not be extended. If more than half of society is a conditional co-operator, the optimal composition is two permanent agents and we end up in a lucrative equilibrium. If there are not enough conditional co-operators, the optimal team composition is at least one temporary worker and we end up in a low equilibrium.

The second situation is if contracts of temporary workers can be extended if the team performs well enough. If more than half of society is a conditional co-operator we already end up in a very lucrative equilibrium with just two permanent workers, so temporary workers are not required. If less than half of society is a conditional co-operator, but if there are still quite a lot of conditional co-operators in society, the optimal composition is one permanent worker and one temporary worker. This is because permanent workers are only willing to do high effort in the last period if he is a conditional co-operator and temporary workers are always willing to do high effort in all periods (because there are enough conditional co-operators in society to make it worthwhile). Although the temporary worker knows that selfish permanent workers are going to do low effort, the temporary worker has still enough incentives to do high effort. This is called the contract extension incentive. By putting in high effort he will at least have the probability that his co-worker is a conditional co-operator that he will not lose his job. If there are only a few or no conditional co-operators in society, temporary workers are not anymore motivated to do high effort, because the probability that their contract will be extended is too small. In this case, it is best to hire two temporary workers. If temporary workers are matched with another temporary worker, they are always motivated by the contract extension incentive, because they are in the same situation.

After investment in each other's productivity in the team there are no changes to the equilibria in the case with a lot of conditional co-operators in society and the case with a few or no conditional co-operators in society. Respectively an entirely permanent team and an entirely temporary team are still the optimal compositions. For the case with quite a lot conditional co-operators in society, the equilibrium might change to an entirely temporary team if the permanent member in the team is not willing to put in high effort in the last period before the renewal. By using backward induction this will result in less motivation to invest in teaching. If the difference in motivation to invest is too big compared to an entirely temporary team, there will be situations in which it is better to compose an entirely temporary team.

According to lab evidence by Cherry et al. (2008), the United States has significant more conditional co-operators compared to Austria and Japan (80,6% versus 44,4% and 41,7% respectively). This implies that based om my theory, I expect more permanent members in teams in the United States compared to Austria and Japan, if maximizing effort is the objective.

There could also be other reasons to use temporary workers in a team. This could facilitate specialization by agents. It could be interesting to extend this model by adding generalists and specialists and check whether temporary or permanent agents become more beneficial for the principal.

There are also some limitations on this theoretical research paper. I focused on trigger-strategies. Especially if permanent workers are going to interact for a high number of periods, other strategies could also be expected. There could for example be limited punishment. If someone shirks the other agent shirks for a limited number of periods instead of punishment in all future periods. Another important remark is the decisive behaviour of the permanent worker on the contract renewal of the temporary worker. If his position would be less pivotal, the sooner the contract of a temporary worker will be renewed after high effort of the temporary worker and other equilibria will be reached.

The most interesting result is the fact that a mixed team is optimal if there are quite some conditional co-operators. Permanent workers are going to take advantage of the contract renewal incentive for temporary workers (and this is beneficial for the principal). I am curious to see whether this effect would also appear in empirical research.

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