# Public-private partnerships, incomplete contracts, and distributional fairness – when payments matter

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**Abstract**

The German energy sector's transition toward the more distributed production of energy has given rise to various forms of decentralized energy production. Within the framework of decentralized infrastructure, the relation between the involved agents is often characterized by a high degree of social proximity. Thus, the spatial and social closeness usually emphasizes aspects of decision-making such as pro-social behavior that can have significant effects on the involved parties' response to agency problems and their investment incentives.

This essay applies behavioral economics' finding on so-called social preferences to fundamental insights from incomplete contract theory regarding economic agents' investment behavior. Specifically, it will be analyzed how a contractor's investment incentives develop in a public-private partnership setting given incomplete contracts when the contractor disposes of preferences for distributional fairness. It will be shown that the investment incentives of the contractor are significantly different from those of the standard model assuming neoclassical preferences. Another important finding is that in contrast to the standard model in which only the allocation of property rights can set different investment incentives, payments can also influence an economic agent's behavior when social preferences apply as the distribution of payments determines whether the psychological influences of envy or a sense of guilt are affecting the contractor.

**Keywords**

Incomplete contracts; public-private partnerships; fairness; social preferences; behavioral economics

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## List of abbreviations

| | |
|---|---|
| PPP | public-private partnership |
| PPPs | public-private partnerships |

## List of symbols

| | |
|---|---|
| $\alpha$ | parameter reflecting the extent of the aversion against disadvantageous distributional inequality ("sense of envy") |
| $B$ | (gross) benefit to society from running a specific infrastructure |
| $B_0$ | fixed basic benefit amount that arises when an infrastructure is finished |
| $\beta$ | parameter reflecting the extent of the aversion against advantageous distributional inequality |
| $C$ | total costs from running a specific infrastructure, borne by the actor who operates the infrastructure |
| $C_0$ | fixed basic cost that accrues when operating the infrastructure |
| $c$ | productivity parameter that has an influence on unproductive investments within the cost function $C$ of operating the infrastructure |
| $c(e)$ | function of unproductive investments that has an impact on the overall costs $C$ of operating the infrastructure (only relevant in the Hart (2003) model) |
| $e$ | unverifiable amount of unproductive investment by the contractor |
| $e^*$ | first-best/ optimal amount for unproductive investment by the contractor |
| $e^{\max}$ | possible maximum amount of unproductive investments contractor can make in a specific scenario |
| $\hat{e}$ | unproductive investments made by the contractor in the unbundling case without social preferences (as in the Hart (2003) model) |
| $\hat{\hat{e}}$ | unproductive investments made by the contractor in the PPP case without social preferences (as in the Hart (2003) model) |
| $\hat{e}_{PPPsp}$ | unproductive investments made by the contractor in the PPP case when social preferences are relevant |
| $\hat{e}_{Usp}$ | unproductive investments made by the contractor in the unbundling case when social preferences are relevant |
| $\gamma$ | productivity parameter that has an influence on productive investments within the cost function $C$ of operating the infrastructure |

| | |
|---|---|
| $\gamma(i)$ | function of productive investments that has an impact on the overall costs $C$ of operating the infrastructure (only relevant in the Hart (2003) model) |
| $i$ | unverifiable amount of productive investment by the contractor |
| $i^*$ | first-best/ optimal amount for productive investment by the contractor |
| $i^{\max}$ | possible maximum amount of productive investments contractor can make in a specific scenario |
| $\hat{\imath}$ | productive investments made by a contractor in the unbundling case without social preferences (as in the Hart (2003) model) |
| $\hat{\hat{\imath}}$ | productive investments made by the contractor in the PPP case without social preferences (as in the Hart (2003) model) |
| $\hat{\imath}_{PPPsp}$ | productive investments made by the contractor in the PPP case when social preferences are relevant |
| $\hat{\imath}_{Usp}$ | productive investments made by the contractor in the unbundling case when social preferences are relevant |
| $o$ | productivity parameter that has an influence on unproductive investments within the gross benefit function of the society $B$ |
| $o(e)$ | function of unproductive investments that has an impact on the overall benefit to society $B$ (only relevant in the Hart (2003) model) |
| $\omega$ | productivity parameter that has an influence on productive investments within the gross benefit function of the society $B$ |
| $\omega(i)$ | function of productive investments that has an impact on the overall benefit to society $B$ (only relevant in the Hart (2003) model) |
| $P_0$ | fixed payment for the construction of the infrastructure |
| $t$ | point in time with $t=[0, 1, 2]$ |
| $TC_{contr.}$ | total construction costs of the contractor |
| $U_{C_{PPP-SP}}$ | utility function of the contractor in the PPP case, with social preferences |
| $U_{C_{PPP-SP},P1}$ | utility function of the contractor in the PPP case, when public authority's net payoffs are higher than the contractor's (i.e. the "envy" case) |
| $U_{C_{PPP-SP},P2}$ | utility function of the contractor in the PPP case, when public authority's net payoffs are lower than the contractor's (i.e. the "sense of guilt" case) |

$U_{C_{UNB-SP}}$ utility function of the contractor in the unbundling case, with social preferences

$U_{C_{UNB-SP},U1}$ utility function of the contractor in the unbundling case, when public authority's net payoffs are higher than the contractor's (i.e. the "envy" case)

$U_{C_{UNB-SP},U2}$ utility function of the contractor in the unbundling case, when public authority's net payoffs are lower than the contractor's (i.e. the "sense of guilt" case)

$U_{Soc.}(e,i)$ the society's utility function (net benefit), reproducing the economic exchange between contractor and public authority and depending on the contractor's investments $e$ and $i$

$V_{C_{PPP}}$ net payoffs of the contractor in the PPP case; equal to the contractor's utility function without social preferences

$V_{C_{UNB}}$ net payoffs of a contractor in the unbundling case, equal to the contractor's utility function without social preferences

$V_{PA_{PPP}}$ net payoffs of the public authority in the PPP case

$V_{PA_{UNB}}$ net payoffs of the public authority in the unbundling case

## 1. Introduction

The transition of the energy sector toward the broader use of renewable energy sources has introduced new technologies, regulatory regimes, and business models; and led to a reconfiguration of governance strategies within urban as well as rural areas (Monstadt 2007).[1] These governance patterns involve a variety of stakeholders – for example, the administration as strategy and framework setter, local authorities that implement regional energy policy, established energy suppliers trying to adapt their business model, new energy companies entering the market, institutional and strategic investors, the industry as one of the main consumers, and citizens who are nowadays not only another important group of consumers but also urged to play a bigger role in energy decisions through various forms of participation mechanisms (e.g. Devine-Wright 2005; Yildiz 2013). Against this background, strategies and governance approaches such as the distributed generation of energy (e.g. Pepermans et al. 2005; Alanne and Saari 2006; Karger and Hennings 2009), re-municipalization of existing infrastructure (e.g. Hall et al. 2013; Becker et al. 2015), and development of business models allowing for the financial participation of citizens (e.g. Yildiz 2014; Höfer and Rommel 2015; Yildiz et al. 2015) have gained particular attention.

Among these strategies, public-private partnerships (PPPs) are also a relevant governance approach to realizing renewable energy projects (e.g. Martins et al. 2011). Particularly for developing countries, PPPs promise to provide relief to constraints such as insufficient government investments due to limited public budgets, difficulties in mobilizing financial resources among citizens, or limited interest from the private sector due to project finance risks, since PPPs can allocate project risks between several parties (Sovacool 2013). Decisive for the functioning and performance of public-private partnership (PPP) relationships are complex contractual agreements between the involved parties. Here, the institutional framework given by the underlying contracts affects the involved parties' behavior and investment incentives, and therefore determines the agreements' efficiency (Saussier et al. 2009).

The new institutional economics literature, particularly the strand on property rights theory, dedicates substantial work to the question of the design of the institutional setting of PPPs and its effect on the behavior of actors involved in a PPP (e.g., Hart et al. 1997; Shleifer 1998; Hart 2003). This essay contributes to this strand of litera-

[1] For further reading on socio-technical transitions such as the transition of the energy sector, see e.g., Smith et al. (2005), Meadowcroft (2009), and Foxon et al. (2010).

ture by analyzing the investment behavior of involved parties through a theoretical analysis model.

The distinctive feature of the approach presented here is the link to insights from behavioral economics. According to this research strand, some economic agents dispose of a preference set that is different from the assumptions of neoclassical economics, that is, their behavior is determined by so-called social preferences (e.g. Fehr and Schmidt 1999). By including preferences for distributional fairness among involved parties in the analysis, the model presented here aims to simulate a preference set that might for example be relevant in the context of decentralized infrastructure which is the result of tendencies in the renewable energy sector toward a more dispersed generation approach. Therefore, this paper relates to prior work from Fehr et al. (2008) who theoretically analyzed entities that are organized as partnerships such as law offices, consulting companies, and advertising agencies.

In order to analyze the effects of preferences for distributional fairness in PPPs, this essay is structured as follows: the following section provides an overview on fundamental insights from incomplete contract theory and its applications to PPPs, and describes briefly central findings from behavioral economics in order to provide a rationale on how to extend incomplete contract theory. Section 3 introduces the model, then in section 4 the analysis is conducted. Section 5 supports the theoretical analysis with a numerical example. Finally, this paper ends with concluding remarks and suggestions for further research.

## 2. Literature review

Economic theory offers a large number of explanatory models and analytical frameworks to address the various complex exchange processes that are subsumed under the term *economy* (Buchanan 1984). One of the most prominent domains within economic theory is the analysis of economic exchange through different organizational settings. Dating back to the seminal work of Ronald Coase (1937), often referenced under the headword “Theory of the Firm” numerous authors have analyzed and discussed coordination mechanisms ranging from market transactions to hierarchically organized entities (e.g. Alchian and Demsetz 1972; Williamson 1975). In this context, central questions arise about the reasons for the existence and use of specific coordination mechanisms given a specific economic exchange. Further questions address the effects of an institutional setting (e.g. the specification of property rights) on an economic agent's behavior within a specific organizational framework (Jensen and Meckling 1976).

The latter subject is particularly prominent in the literature under the name of incomplete contract theory. Sanford Grossman and Oliver Hart (1986) were among the first to analyze the relation between contracts, contractual incompleteness, the allocation of property rights, and the effects of this allocation on an economic agent's investment incentives. As it is practically impossible to write a contract that includes subject terms for all possible future states of nature, the allocation of property rights is a crucial element. Property rights assign control in those cases where the contract is not specified. Hence, in cases where the so-called hold-up problem[2] prevents economic agents from making investments, the allocation of property rights provides investment incentives for the owner. To sum up, the general finding from incomplete contract theory is that the economic agent "*whose investments are more important (in the sense of their marginal impacts on the default payoffs) should be the owner*" (Schmitz 2001: 11) of all assets relevant to the economic exchange. Through this allocation, a second-best equilibrium can be realized (e.g., Grossman and Hart 1986; Hart and Moore 1990; Hart 1995; Schmitz 2001).

The rationale underlying incomplete contract theory has also been applied to the question of privatization and PPPs (e.g., Laffont and Tirole 1991; Schmidt 1996; Hart et al. 1997; Hart 2003; see Schönfeld (2011) for a more detailed list with further explanations on the respective models). A general statement on theoretical insights on the allocation of property rights in the context of privatization and PPPs is difficult as the various models include specific scenarios with specific assumptions. Examples are the focus on the provision of public goods through PPPs (e.g. Besley and Ghatak 2001; Francesconi and Muthoo 2006) and the effects of various organizational models on the costs and service quality when realizing and operating infrastructure (Hart et al. 1997; Chalkley and Malcomson 1998; Hart 2003). Though a vague conclusion

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[2] The so-called hold-up problem describes a problem set in which an economic agent does not invest efficiently in an economic exchange. Short-term contracts and contractual incompleteness can prevent economic agents from making relation-specific investments as they fear that their share in the economic exchange's rents could be extracted by an opportunistically acting exchange partner who ex-post (i.e. after realizing the economic exchange that was agreed on in a contract) demands re-negotiations. In general, ex-post negotiations on the allocation of the exchange's rents would be efficient according to the Coase theorem (see e.g. Coase 1960 and Schweizer 1988 for necessary conditions for the Coase theorem to hold) but with the threat of being exploited, strategies to incentivize parties to join a relationship ex-ante have to be developed. In this context, the allocation of property rights represents a measure to induce ex-ante efficient investment incentives for an economic agent and to join an economic relationship as these property rights determine the bargaining power in the ex-post negotiations (Schmitz 2001).

is that the right to build and operate infrastructure leads to the internalization of the costs of operation by a contractor. Hence, a contractor would put significant efforts in reducing operating costs (and service quality) so that an ordering party has to consider to which extent it can specify the service quality. If the ordering party (i.e. the public authority) can specify well the required service quality, then it should assign both, construction and operation, to one party (Schönfeld 2011).

The previous descriptions highlighted the importance of property rights in an incomplete contract setting in which ownership serves as a device to respond to the threat of opportunistic behavior. Underlying to this threat are the assumptions from neoclassical economics that have their origin in a set of a priori notions on the behavior of agents opposed to an economic problem (e.g., an exchange with other agents). One central characteristic of this theory is that economic agents evaluate all existing (action) alternatives by the utility they expect from the outcomes of a specific decision whereby the utility is exclusively determined by monetary payoffs. Then, economic agents always decide for the alternative that maximizes their expected utility (Simon 1998). With recent trends toward a broader diffusion of experimental methods in economics and the growing influence of insights from other disciplines, particularly the cognitive sciences, the viewpoint is increasingly supported that the explanatory and predictive power of economic analysis can be improved by extending the standard assumption set from neoclassical economics. This development has led to the establishment of so-called behavioral economics, which defines its assumptions according to evidence generated by experiments, field studies, and research methods from cognitive sciences such as brain scans (Camerer and Loewenstein 2004).

An important strand within behavioral economics addresses the question of an economic agent's utility assessment and influencing factors besides monetary payoffs. According to this perspective, findings from experimental game theory (Roth et al. 1981; Güth et al. 1982; Binmore et al. 1985) suggest that some (but not all) economic agents do not behave in a self-interest maximizing manner but are also influenced by behavioral patterns such as reciprocity (e.g. Rabin 1993), altruism (e.g. Khalil 2004), or preferences for distributional fairness (e.g. Fehr and Schmidt 1999) (Fehr and Schmidt 2006). These patterns, so-called social preferences, are dependent on the context of the economic exchange. The framework of the exchange determines the character of social interactions, the economic agents' scope of action, and the way in which information is processed. Thus, in market-like organizational contexts in which relationships are characterized by rather loose personal contacts, social preferences play a subordinated role. In contrast, social interactions are rather tight in non-market settings so that social preferences are more likely to influence an economic agent's utility assessment and consequently his behavior (Bowles 1998).

The insights on social preferences are latterly incorporated into incomplete contract theory in order to analyze the investment incentives of ownership in contexts that are characterized by strong social ties between involved actors. In this regard, findings from theoretical and experimental analysis reveal that among agents with social preferences, ownership allocation schemes set different incentives than those in the standard model – that is, joint ownership sets higher incentives than concentration of ownership (Fehr et al. 2008), Findings in the context of PPPs that include insights on social preferences do not exist so far. However, actual business models and governance approaches in the energy sector (e.g. decentralization, citizen participation schemes) provide a framework in which social preferences might be relevant. Hence, the following section introduces a model in which the impact of social preferences on investment behavior in a PPP setting is analyzed.

**3. The model**

The model presented here has its roots in the Hart (2003) model which analyzes the effects of different ownership structures on the costs and benefits of PPPs. In fact, the presented model extends Hart's (2003) model by including preferences for distributional fairness. The scenario modeled here takes place in a decentralized context. As a consequence, a socially proximate relationship between the economic agents is assumed so that the involved agents dispose of preferences for distributional fairness (see also section 2 for a more detailed rationale to include social preferences in the analysis).

As in the original model of Hart (2003) two actors – a contractor (e.g., a construction firm) and an ordering party (e.g. the public authority) – are involved in an economic exchange. The purpose of their exchange is the construction and, as an additional option, the operation of a specific service (e.g., infrastructure, or a prison as in Hart's (2003) model, etc.).[3] Accordingly, the time line (**Fig.1**) covers three dates: the date when the underlying contract between the contractor and the ordering party is agreed

[3] In the following, the model will describe, analyze, and discuss a PPP scenario. Therefore, the wording is adapted to this purpose, i.e. the public authority is set as the "ordering party" and the underlying "service" is the construction (and the operation) of an infrastructure project.

on and signed (t=0), the date when the underlying service with its basic characteristics is delivered by the contractor (t=1), and a final date that marks the end of the operational phase (t=2) (Hart 2003).

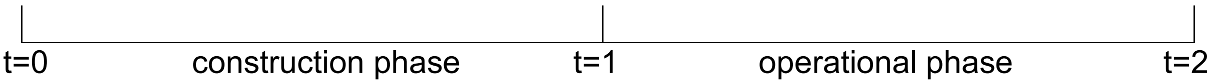


**Fig.1:** Time line of the analyzed economic exchange.
(Source: Author's design, adapted from Hart 2003).

The (construction) contract that is underlying to the provision of the infrastructure is incomplete (see e.g. Grosman and Hart 1986). That means the contract parties define basic elements of the required service but the constructor can still modify other specific details related to his service without violating the agreement between both parties. These specific details, $i \geq 0$ being the unverifiable amount of productive investment by the contractor and $e \geq 0$ being the unverifiable amount of unproductive investment by the contractor, depending on the decision of the constructor, cannot be verified by a third party and consequently cannot be contracted on, and form together the contractor's total construction cost $TC_{contr.} = i + e$. Furthermore, they are of particular importance as they influence the costs and benefits to society when the infrastructure is in use (Hart 2003). Accordingly, the costs and benefits of the operational phase in this model are defined as follows:

$$B = B_0 + \omega * i - o * e \qquad (1)$$

$$C = C_0 - \gamma * i - c * e \qquad (2)$$

with $\omega, o, \gamma, c$ being strictly positive so that the related terms are linear functions.[4]

Equation (1) represents the (gross) benefit $B$ that a society has from operating the infrastructure, measured in monetary terms. It comprises a fixed basic benefit $B_0$, a function of productive investments $\omega * i$, and a function of unproductive investments $o * e$. With regard to the benefit to society, productive investments $i$ raise the quality

[4] In the Hart (2003) model, the assumptions $\omega, o, \gamma, c > 0$, $\omega', o', \gamma', c' > 0$, $\omega'', \gamma'', c'' < 0$, and $o'' > 0$ apply. In this model, linear production functions were assumed for the sake of simplicity. As the model aims to show fundamental trends in the contractor's investment behavior when including social preferences, this simplification avoids problems regarding concavity of the utility function and changes that arise from the variation of the applying psychological effect.

of the service realized through the infrastructure and therefore the benefit to society. In contrast, unproductive investments $e$ reduce the quality of the service and therefore the overall benefit to society. Equation (2) represents the costs $C$ of operating the infrastructure. Here, the components are a fixed amount of basic costs $C_0$, a function of productive investments $\gamma * i$, and a function of unproductive investments $c * e$. Both types of investment, productive and unproductive investments, reduce the total costs (Hart 2003).

The objective function is to maximize the net benefit of the economic exchange (i.e. the society's net benefit) $U_{Soc.}(e,i)$. Hence, in the first-best scenario $i$ and $e$ are chosen to maximize the following equation:

$$U_{Soc.}(e,i) = B - C - TC_{contr.} = B_0 + \omega * i - o * e - C_0 + \gamma * i * + c * e - i - e \qquad (3)$$

In order to be consistent with the Hart (2003) model, the following additional conditions also apply:

$$\omega + \gamma > 1$$

$$c - o < 1.$$

Hence, we arrive at the socially optimal result (the "first-best") in the corner solutions where $i^* = Max[0; i^{\max}]$ and $e^* = 0$ (Hart 2003).

So far, this model and the related explanations are similar to the Hart (2003) model. The preferences for distributional fairness become important when considering the second-best scenario. The builder's investments cannot be verified and therefore cannot be contracted on. However, the contractor knows the exact amount of his costs $i$ and $e$. Consequently, the allocation of property rights (i.e., the assignment of the right to operate the infrastructure between $t = 1$ and $t = 2$) has an influence on the contractor's investment behavior (Hart 2003).

In the following, two cases will be distinguished, a first case in which the construction and the operation of the infrastructure are assigned to different actors ("unbundling" case) and another case, in which the infrastructure is operated by the same agent that constructed it ("PPP" case). These two cases are sub-divided into a case that describes the (neoclassical) standard model as in Hart (2003) and a model in which the contractor has preferences for distributional fairness.

### 3.1. The unbundling case

In the unbundling case, the contractor receives a fixed payment $P_0$ for the construction of the infrastructure and bears the costs for the investments $i$ and $e$. Hence, his net payoffs (that are equal to his utility when psychological effects do not apply) are

$$V_{C_{UNB}} = P_0 - i - e \tag{4}$$

and at date $t = 0$, the contractor's objective is to choose $i$ and $e$ to solve:

$$Max(V_{C_{UNB}}) = Max(P_0 - i - e). \tag{5}$$

The net payoffs of the commanding party (i.e., public authority) include the benefit to society $B$, the costs of operating the plant $C$, and the fixed payment $P_0$. Hence, the public authority's payoffs from operating the plant are:

$$V_{PA_{UNB}} = B - C - P_0 = B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e - P_0 \tag{6}$$

In the original paper of Hart (2003), the net payoff function of the public authority in the unbundling case $V_{PA_{UNB}}$ is slightly different as $P_0 = i + e$ is set. Underlying this equation is the assumption that there is competition in the market for contractors and therefore the public authority can set the fixed price $P_0$ for the service just high enough to cover the contractor's costs, the investments $i$ and $e$. However, in this model, it is assumed that there is no competition among contractors. In fact, the context of decentralized infrastructure that is set as a framework of this model reasons that there is only one contractor and consequently no competition. In return, the socially close context of the economic exchange results in preferences for distributional fairness among the involved parties.

Including preferences for distributional fairness changes the utility function of involved agents significantly. For the further course of the analysis, the utility function of the contractor is of particular interest. In reference to Fehr and Schmidt's (1999) approach to including preferences for distributional fairness in an economic agent's utility function, the utility function of a contractor with social preferences $U_{C_{UNB-SP}}$ is as follows:

$$U_{C_{UNB-SP}} = V_{C_{UNB}} - \alpha * \max\{V_{PA_{UNB}} - V_{C_{UNB}}, 0\} - \beta * \max\{V_{C_{UNB}} - V_{PA_{UNB}}, 0\} \tag{7}$$

with $\alpha$ reflecting the extent of the contractor's aversion to disadvantageous distributional inequality (i.e., "envy") and $\beta$ reflecting the extent of the contractor's aversion to advantageous distributional inequality (i.e., "sense of guilt"). Accordingly, the second term as a whole covers a reduction of the contractor's utility due to disadvantageous distributional inequality, and the third term a reduction of the contractor's utility due to advantageous distributional inequality. As in the Fehr and Schmidt (1999) model, both inequality parameters are $\alpha, \beta \geq 0$ where $\alpha, \beta = 0$ would imply that the contractor has preferences according to the standard (neoclassical) model. Furthermore, it is assumed that $\alpha \geq \beta$, which implies that in social comparisons, the aversion to disadvantageous distributional inequality is at least as high as the sense of guilt that arises when the analyzed agent (i.e., the contractor) is better off than his reference agent (Fehr and Schmidt 1999).[5]

### 3.2. The PPP case

In the PPP case, the contractor is allocated the rights to operate the infrastructure.[6] Hence, the contractor now internalizes the costs of the operation phase $C$ so that his net payoffs assuming standard (neoclassical) preferences (as in Hart 2003) include his fixed payment $P_0$ and the relevant cost item, the total operational costs $C(e,i)$ and the investments $i$ and $e$:

$$V_{C_{PPP}} = P_0 - C - i - e = P_0 - C_0 + \gamma * i + c * e - i - e \qquad (8)$$

Accordingly, the public authority's payoffs are determined by the benefit to society of realizing infrastructure $B$ and the fixed compensation $P_0$ that it has to pay to the contractor for his service to construct the infrastructure:

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[5] The Fehr and Schmidt (1999) model makes further assumptions on the inequality parameters. An example is the restriction of the range of the $\beta$-parameter to $0 \leq \beta < 1$, which is introduced in order to reflect that $\beta = 1$ implies an economic agent who would throw away some of his monetary payoffs in order to reduce advantageous inequality, which is not very plausible (Fehr and Schmidt 1999). Some of these additional assumptions as well as plausible numeric values for the inequality parameters $\alpha$ and $\beta$ will be discussed in section 4.3.

[6] In Hart's (2003) model, the contractor has either the possibility to operate the infrastructure by himself or sub-contract this service to a sub-contractor. As there is competition on the market of sub-contractors, the payments to the sub-contractor can be set equal to the costs of operating the infrastructure $C = C_0 - \gamma * i - c * e$. In the decentralized context of this model, it is simply assumed that the contractor provides the service by himself. Alternatively, one could also apply the same rationale as in the Hart (2003) model, i.e. the assignment to a sub-contractor, which is chosen among several alternatives in a competitive market.

$$V_{PA_{PPP}} = B - P_0 = B_0 + \omega * i - o * e - P_0 \tag{9}$$

As in the unbundling case, it is also necessary to determine the utility of the contractor, given preferences for distributional fairness. Again, differences regarding the distribution of net payoffs, either advantageous or disadvantageous, have a negative effect on the contractor's utility:

$$U_{C_{PPP-SP}} = V_{C_{PPP}} - \alpha * \max\{V_{PA_{PPP}} - V_{C_{PPP}}, 0\} - \beta * \max\{V_{C_{PPP}} - V_{PA_{PPP}}, 0\} \tag{10}$$

With the necessary net payoffs and utility functions defined, the effects of different ownership structures on the investment behavior of the contractor can now be analyzed.

## 4. Theoretical assessment of contractor behavior given preferences for distributional fairness

In the model of Hart (2003), the public authority has to consider a trade-off when making its decision. In the unbundling case, neither productive investments $i$ nor unproductive investments $e$ are made since the contractor does not internalize the social benefit $B$ nor the costs of the operation phase $C$. Regarding unproductive investments, $\hat{e} = 0$ corresponds to the first-best solution $e^* = 0$. However, $\hat{\imath} = 0$ represents an underinvestment in productive investments as the first-best here is the solution to the first-order condition $\omega'(i^*) + \gamma'(i^*) = 1$ where $i^* > 0$.[7] In the PPP case of Hart's (2003) model, the investment behavior of the contractor is significantly different. As the infrastructure's operating agent, the contractor now internalizes the costs of the operation phase $C$. Consequently, the contractor now invests in both, productive and unproductive investments. While it is clear that any investment in unproductive terms $e$ is sub-optimal from a social perspective ($\hat{e} > 0 \neq e^*$), a look at the first-order conditions ($\gamma'(\hat{\imath}) = 1$) reveals that the investments made in productive invest-

[7] As the Hart (2003) model does not limit its analysis to a setting with linear functions, the first-best is the solution to the first-order condition $\omega'(i^*) + \gamma'(i^*) = 1$ where $i^* > 0$. The analogous solution for the model presented here is $i^* = Max[0; i^{\max}]$ (see section 3).

ments are indeed $\hat{\imath} > 0$ but the amount is lower than in the first-best case (Hart 2003).[8]

According to the first-best solution analysis of the previous paragraph, the derived recommendation for action for public authorities is evident: If the characteristics of the asset underlying the economic exchange (here: the infrastructure) can be well specified and the quality of the service in the operational phase cannot, unbundling seems to be the better option as the PPP case would lead to an overinvestment in unproductive investments $e$, which has particularly negative consequences for the operational phase in the case that the service provided in the operational phase cannot be specified well or monitored through performance measures. Hence, the rationale for the PPP case is the opposite, that is, a PPP seems to be the better alternative when the service provided in the operational phase can be specified well but there are concerns regarding the specification of the characteristics of the underlying asset (Hart 2003).

In the following, it will be assessed how the contractor will behave, assuming he has preferences for distributional fairness. The analysis of the contractor's behavior given preferences for distributional fairness requires a case-by-case study since both scenarios, advantageous or disadvantageous inequality, cannot apply at the same time when the contractor makes his decision on investment levels. To determine whether the psychological effect from an advantageous or disadvantageous inequality influences the contractor's utility, the net payoffs to the contractor ($V_{C_{PPP}}$ or $V_{C_{UNB}}$) and to the public authority ($V_{PA_{PPP}}$ and $V_{PA_{UNB}}$) have to be compared in the respective cases. Accordingly, the influence of the fixed payment to the contractor $P_0$ is of high importance. Given that the other fixed components (i.e. $C_0$ and $B_0$) are exogenously given and not variable, the following analysis will show that $P_0$ is the main influence on the involved parties' payoffs. Hence, the payment $P_0$ for the contractor's services determines which psychological influence applies when deciding on his investment level, and therefore determines the shape of the contractor's utility function.

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[8] In the PPP case without preferences for distributional fairness, the second-best solution for the model presented here is the investment combination $\hat{\imath} = Max[0; i^{\max}]$ and $\hat{\hat{e}} = Max[0; e^{\max}]$ assuming that the conditions $\gamma > 1$, and $c > 1$ apply. Hence, the investment amount of productive investments in the PPP case corresponds to the first-best solution which is different from the Hart (2003) model where $i^* > \hat{\imath} > 0$. This is due to the fact that as a consequence of linear utility functions, only corner solutions are obtained.

Furthermore, fundamental to the hypotheses and following analysis in the respective cases is that the productivity parameters are in compliance with the conditions $\omega + \gamma > 1$, $c - o < 1$, $\gamma > 1$, and $c > 1$. These conditions are derived from the standard model of Hart (2003) (see also section 3). Hence, implicitly assuming that these conditions hold in the analysis assures that the results of the model including preferences for distributional fairness are comparable to the standard model's results.
The analysis in the next section will show that the variation in parameters can have a significant influence on the contractor's investment incentives as well. However, a comparison of these results with the Hart (2003) model's results would not be appropriate as in this case, the optima of the Hart (2003) model would change as well.

### 4.1. The unbundling case

#### 4.1.1. Case U1 – The public authority's net payoffs are higher than the contractor's in an unbundling setting

Assuming that the public authority's net payoffs are higher than the contractor's net payoffs, i.e. $V_{PA_{UNB}} > V_{C_{UNB}}$, the case of disadvantageous inequality ("envy") is relevant to the contractor when deciding on his investment in $t = 0$ so that the third term of equation (7) is equal to zero. Hence, the contractor's utility function is:

$$U_{C_{UNB-SP},U1} = V_{C_{UNB}} - \alpha * \{V_{PA_{UNB}} - V_{C_{UNB}}\} \qquad (11)$$

By substituting $V_{C_{UNB}}$ with equation (4) and $V_{PA_{UNB}}$ with (6), the contractor's utility function arrives at the following form:

$$U_{C_{UNB-SP},U1} = P_0 - i - e - \alpha * \{B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e - P_0 - P_0 + i + e\} \qquad (12)$$

where $V_{PA_{UNB}} > V_{C_{UNB}}$, i.e. $B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e - P_0 > P_0 - i - e$, which is equivalent to $B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e + i + e > 2P_0$.

Hence, the psychological effect of disadvantageous inequality is relevant if the difference of the gross benefit to society $B$ plus the invested amount of productive and unproductive investments minus the costs of operating the infrastructure $C$ is higher than twice the fixed payment to the contractor $P_0$.

In order to analyze the overall effect of preferences for distributional fairness on the contractor's utility and his investment incentives, a partial analysis of the effects of the respective investments on the contractor's utility is useful. Therefore, equation (12) is differentiated with respect to $i$ and $e$:

$$\frac{\partial U_{C_{UNB-SP},U1}}{\partial i} = -1 - \alpha * \{\omega + \gamma + 1\}$$
$$\Leftrightarrow \frac{\partial U_{C_{UNB-SP},U1}}{\partial i} = -1 + \alpha * \{-\omega - \gamma - 1\} \quad (13)$$

and

$$\frac{\partial U_{C_{UNB-SP},U1}}{\partial e} = -1 - \alpha * \{c - o + 1\}$$
$$\Leftrightarrow \frac{\partial U_{C_{UNB-SP},U1}}{\partial e} = -1 + \alpha * \{o - c - 1\} \quad (7.14.)$$

**Hypothesis U1:**

*In the unbundling case, the results of the Hart (2003) model are basically duplicated, i.e., the optimal combination of investments is* $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$ *when effects from disadvantageous distributional inequality apply. However, there can also apply a scenario (of productivity parameters) in which the optimal combination of investments includes unproductive investments, i.e.* $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$.

**Argument U1:**

From the results of the standard model as well as from equations (4) and (11), we see that any productive or unproductive investment will reduce the contractor's net payoffs. This implies that from the perspective of his own net payoffs, the contractor has no incentive to make either productive or unproductive investments.

Consequently, the only way for the contractor to have an incentive to invest in the unbundling case with a sense of envy initially applying is if there is a combination of investments whereby the increase in the utility through the psychological effect covers all losses from net payoffs. In order to realize this, there must be a combination of productivity parameters in which this effect is induced.

From equation (12) as well as from the partial analysis in equation (13) on the effects of an investment in $i$ on the distributional inequality, we know that there is no combination of productivity parameters in which the contractor has an incentive to invest in $i$ from a partial perspective. Any productive investment $i$ will increase the distributional inequality and therefore intensify the negative psychological influence on the contractor's utility. Thus, the psychological effect from an investment in $i$ will always be negative.

In contrast, we see from the equations (12) and the partial analysis in equation (14) that there exists a combination of productivity parameters where an investment in $e$ will reduce the distributional inequality among the involved parties and induce a positive psychological effect. If this positive psychological effect on the contractor's utility is higher than the negative effect of an investment in $e$ that arises due to the reduction of the contractor's net payoffs, then the contractor will invest a positive amount in unproductive investments $e$ so that the combination of optimal investments is $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$.

Technically speaking, unproductive investments serve in this case as a regulative measure in order to reduce the disadvantageous distributional inequality from the perspective of the contractor between him and the public authority. Consequently, these investment incentives are only relevant as long as the psychological effect from a sense of envy applies, i.e., as long as $V_{PA_{UNB}} > V_{C_{UNB}}$. Furthermore, we see from equations (12) and (14) that unproductive investments $e$ can only serve as a regulative measure when the negative effect from an investment in $e$ on the society's gross benefit $B$, which is determined by the productivity parameter $o$, is sufficiently high. Accordingly, the parameter $o$ must fulfill the condition $o > \frac{1}{\alpha} + (1+c)$, which is derived from equation (14). This condition is compatible with the parameter assumptions of the Hart (2003) model (see second to last paragraph in section 4) so that the optimal investment combination $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$ is a realizable solution in which differences from the Hart (2003) model only stem from including preferences for distributional fairness in the analysis.

For all other parameter scenarios, the combination of optimal investments in the unbundling case when a sense of envy applies is $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$, i.e., the envious contractor reproduces the behavior of a contractor where social preferences do not apply.■

#### 4.1.2. Case U2 – The public authority's net payoffs are lower than the contractor's in an unbundling setting

Assuming that the public authority's net payoffs are lower than the contractor's net payoffs (i.e. $V_{C_{UNB}} > V_{PA_{UNB}}$), the case of advantageous inequality ("sense of guilt") is relevant to the contractor at the point of decision so that the second term of equation (7) is equal to zero. Now, the contractor's utility function is:

$$U_{C_{UNB-SP},U2} = V_{C_{UNB}} - \beta * \{V_{C_{UNB}} - V_{PA_{UNB}}\} \quad (15)$$

Here again, $V_{C_{UNB}}$ can be substituted with equation (4) and $V_{PA_{UNB}}$ with (6) so that the contractor's utility function is:

$$U_{C_{UNB-SP},U2} = P_0 - i - e - \beta * \{P_0 - i - e - B_0 - \omega * i + o * e + C_0 - \gamma * i - c * e + P_0\} \quad (16)$$

where $V_{C_{UNB}} > V_{PA_{UNB}}$, i.e. $P_0 - i - e > B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e - P_0$, which is equivalent to $B_0 + \omega * i - o * e - C_0 + \gamma * i + c * e + i + e < 2P_0$.

In order to assess the investment incentives of the contractor in case U2, equation (16) is differentiated with respect to $i$ and $e$:

$$\frac{\partial U_{C_{UNB-SP},U2}}{\partial i} = -1 - \beta * \{-1 - \omega - \gamma\}$$
$$\Leftrightarrow \frac{\partial U_{C_{UNB-SP},U2}}{\partial i} = -1 + \beta * \{1 + \omega + \gamma\} \quad (17)$$

and

$$\frac{\partial U_{C_{UNB-SP},U2}}{\partial e} = -1 - \beta * \{-1 + o - c\}$$
$$\Leftrightarrow \frac{\partial U_{C_{UNB-SP},U2}}{\partial e} = -1 + \beta * \{c - o + 1\} \quad (18)$$

**<u>Hypothesis U2:</u>**

*In the unbundling case, when effects from advantageous distributional inequality apply and the productivity parameters are consistent with the Hart (2003) model, then* *only one equilibrium can exist where the contractor invests in productive investment and omits making unproductive investments, i.e.,* $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$*.*[9]

*Hence, the result when psychological effects from an advantageous distributional inequality apply is significantly different from the Hart (2003) model, i.e.,* $(\hat{\imath} = 0; \hat{e} = 0)$*, and can even reach the first best, i.e.,* $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$*, with* $\hat{\imath}_{Usp} = i^* = Max[0; i^{\max}]$ *if the differences in net payoffs are high enough that the contractor has to invest the maximal possible amount of productive investments in order to reduce the advantageous distributional inequality.*

**<u>Argument U2:</u>**

As the net payoffs do not change when the nature of the psychological effect changes, the contractor's net payoffs remain the same and will still decrease for every investment in $i$ and $e$. Hence, again the psychological effect determines whether the contractor has an incentive to invest.

Accordingly, it can be seen from equations (16) and (17) that the negative psychological effect will be reduced in any case through productive investments $i$ as the condition $\beta^* \{1+\omega+\gamma\} > 0$ holds for any combination of parameters $\gamma, \omega > 0$. Technically speaking, the second term in equation (17) implies that productive investments will reduce the advantageous inequality in payoffs in any case. Now, in order to induce incentives to invest, the beneficial effect on the contractor's utility from reducing the distributional inequality must cover the losses in net payoffs from an investment in $i$, i.e., $\beta^* \{1+\omega+\gamma\} > 1$ must hold. As elaborated earlier (e.g., second to last paragraph in section 4), it is assumed that the conditions $\omega+\gamma > 1$ and $\gamma > 1$ hold in order to provide a parameter set that is comparable to the Hart (2003) model. Thus, we know that if $\beta > 0.5$, then the condition $\beta^* \{1+\omega+\gamma\} > 1$ will be met. In this regard, we know from the seminal essay of Fehr and Schmidt (1999) on the effects of distributional fairness within an economic exchange that "$\beta = 0.5$ *implies that player i is just indif-*

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[9] Theoretically, various combinations of optimal investments can exist, depending on the productivity parameters. Here, possible optima are the combinations $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$, $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$, and in a special case a scenario where any combination $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} > 0)$ that implies a psychological effect equal to zero is optimal. However, the necessary combination of parameters leading to these investments is incompatible with the parameter values that underlie the Hart (2003) model and therefore remain disregarded.

*ferent between keeping one dollar to himself and giving this dollar to player j*" (Fehr and Schmidt 1999: 824). Consequently, it can be derived that in order to simulate a fair-minded contractor, a parameter value of $\beta > 0.5$ has to be assumed so that it is consequential that a fair-minded contractor who "suffers" from advantageous inequality will make productive investments $\hat{\imath}_{Usp} > 0$ as long as his sense of guilt is effective, i.e., as long as $V_{C_{UNB}} > V_{PA_{UNB}}$.

The analysis of unproductive investments is analogous. As the effect from an investment in $e$ on the contractor's net payoffs is negative, the psychological effect must cover these losses. Thus, from equation (18) we see that $c > \frac{1}{\beta} + \{o-1\}$ must hold. In order to assure the similarity with the Hart (2003) model's parameters, also the conditions $c - o < 1$ and $c > 1$ must be met. From the examination of these conditions, it can be seen that for $\beta > 0.5$ there can exist a parameter $c$ that meets the necessary condition $c > \frac{1}{\beta} + \{o-1\}$ without violating the other conditions $c - o < 1$ and $c > 1$. Thus, from a partial perspective, the contractor would theoretically have an incentive to make unproductive investments, i.e., $\hat{e}_{Usp} > 0$ as long as $V_{C_{UNB}} > V_{PA_{UNB}}$.

For the assessment of the overall investment incentives, both partial effects have to be compared. Possible optima can theoretically include the combinations $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$, $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$, $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$, and in a special case a scenario in which both investment types have the same effect on the contractor's utility, and therefore any combination of $(\hat{\imath}_{Usp} \geq 0; \hat{e}_{Usp} \geq 0)$ that completely eliminates the overall psychological effect is optimal.

Among these theoretically possible combinations $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$ is the only realizable optimum given the restrictions on the parameters that arise from the analogy to the Hart (2003) model. The rationale is as follows:

a) For the combination $(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$ to be the optimal solution, the effect on the contractor's utility from reducing the negative psychological influence through productive investments $i$ must be in a first step higher than the reduction of the contractor's net payoffs. This is the case as it was shown in the course of the partial analysis above for any combination of parameters that is consistent with the Hart (2003) model.

In addition the effect from reducing the psychological influence through productive investments in $i$ must be higher than the effect of unproductive investments on the psychological influence, i.e. $\beta^*\{c-o+1\}<\beta^*\{1+\omega+\gamma\}$. This condition is equivalent to $c-o<\omega+\gamma$. As the right side is $\omega+\gamma>1$ as in the Hart (2003) model and the left side of the inequation is $c-o<1$, the necessary condition $\beta^*\{c-o+1\}<\beta^*\{1+\omega+\gamma\}$ is met for any combination of parameters. Hence, there can exist an optimal investment combination with $(\hat{\imath}_{Usp}>0;\hat{e}_{Usp}=0)$. Here, the exact amount of $\hat{\imath}_{Usp}$ depends on the difference in payoffs between both agents. If the difference, which depends at the point of decision on the payment to the contractor $P_0$, is high enough, it can even result in an optimal investment combination $(\hat{\imath}_{Usp}>0;\hat{e}_{Usp}=0)$ where the contractor will invest $\hat{\imath}_{Usp}=i^*=Max[0;i^{\max}]$. Hence, the first-best will be realized.

b) The combination $(\hat{\imath}_{Usp}=0;\hat{e}_{Usp}=0)$ is not feasible as an optimal solution as the contractor always has incentives to invest $\hat{\imath}_{Usp}>0$ in any case (see above).

c) For the combination $(\hat{\imath}_{Usp}=0;\hat{e}_{Usp}>0)$ to be the optimal solution, the effect on the contractor's utility from reducing the negative psychological influence through unproductive investments must be higher than the effect of productive investments on the psychological influence. Hence, the parameters must meet the condition $\beta^*\{c-o+1\}>\beta^*\{1+\omega+\gamma\}$, which is equivalent to $c-o>\omega+\gamma$. As was shown in bullet point a) of this section, this condition cannot hold as $\omega+\gamma>1$ and $c-o<1$ must be met in order to be compliant with the Hart (2003) model. Thus, $(\hat{\imath}_{Usp}=0;\hat{e}_{Usp}>0)$ is not realizable.

d) The third theoretically possible combination is a special case where both psychological influences have exactly the same effect on the contractor's utility so that any combination of $(\hat{\imath}_{Usp}\geq 0;\hat{e}_{Usp}\geq 0)$ that eliminates the psychological effect is optimal. Accordingly, the necessary parameter combination for this scenario to be realized is $\beta^*\{c-o+1\}=\beta^*\{1+\omega+\gamma\}$. Here again, we know that this result cannot hold as $\omega+\gamma>1$ and $c-o<1$ must be met.

To summarize, the optimal investment $(\hat{\imath}_{Usp}>0;\hat{e}_{Usp}=0)$ is the only realizable combination. The exact amount of $\hat{\imath}_{Usp}>0$ can be regulated through payment $P_0$ to the contractor. The higher the advantageous inequality in payoffs, the more a fair-minded contractor will invest in order to reduce the discrepancy between him and the public authority. Thus, having full information on the productivity parameters and the aversion parameter $\beta$, the public authority can choose the payment $P_0$ so that the first-best result $(\hat{\imath}_{Usp} = i^* = Max[0; i^{\max}]; \hat{e}_{Usp} = e^* = 0)$ will be reached.■

### 4.2. The PPP case

#### 4.2.1. Case P1 – The public authority's net payoffs are higher than the contractor's in a PPP setting

As in case U1 (section 4.1.1.), it is assumed that the public authority's net payoffs are higher than the contractor's net payoffs, i.e. $V_{PA_{PPP}} > V_{C_{PPP}}$. As a consequence, the case of disadvantageous inequality ("envy" case) is relevant to the contractor at the point of decision so that the third term of equation (10) is equal to zero. Hence, the contractor's utility function is:

$$U_{C_{PPP-SP},P1} = V_{C_{PPP}} - \alpha * \{V_{PA_{PPP}} - V_{C_{PPP}}\}$$

By substituting $V_{C_{PPP}}$ with equation (8) and $V_{PA_{PPP}}$ with equation (9), the contractor's utility function is:

$$U_{C_{PPP-SP},P1} = P_0 - C_0 + \gamma * i + c * e - i - e - \alpha * \{B_0 + \omega * i - o * e - P_0 - P_0 + C_0 - \gamma * i - c * e + i + e\} \quad (19)$$

The relation between the payoffs of the involved agents is $V_{C_{PPP}} < V_{PA_{PPP}}$, i.e. $P_0 - C_0 + \gamma * i + c * e - i - e < B_0 + \omega * i - o * e - P_0$.

In order to have an impression on the effect of investments on the contractor's utility $U_{C_{PPP-SP}}$ from a partial analysis perspective, equation (19) is differentiated with respect to $i$ and $e$:

$$\frac{\partial U_{C_{PPP-SP},P1}}{\partial i} = \gamma - 1 - \alpha * \{\omega - \gamma + 1\}$$
$$\Leftrightarrow \frac{\partial U_{C_{PPP-SP},P1}}{\partial i} = \gamma - 1 + \alpha * \{\gamma - \omega - 1\} \qquad (20)$$
$$\Leftrightarrow \frac{\partial U_{C_{PPP-SP},P1}}{\partial i} = (1+\alpha) * \gamma - 1 + \alpha * \{-\omega - 1\}$$

and

$$\frac{\partial U_{C_{PPP-SP},P1}}{\partial e} = c - 1 - \alpha * \{1 - c - o\}$$
$$\Leftrightarrow \frac{\partial U_{C_{PPP-SP},P1}}{\partial e} = c - 1 + \alpha * \{c + o - 1\} \quad . \qquad (21)$$
$$\Leftrightarrow \frac{\partial U_{C_{PPP-SP},P1}}{\partial e} = (1+\alpha) * c - 1 + \alpha * \{o - 1\}$$

**Hypothesis P1:**

*In the PPP case, when psychological effects from disadvantageous inequality apply, several optimal investment combinations can result, depending on the productivity parameters, $\gamma, \omega, o$ and $c$. Assuming that the parameters are consistent with the Hart (2003) model, the possible optima include the combinations $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ (with the first-best combination also being possible), $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$, and $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$.*

**Argument P1:**

From the results of the standard model as well as from equation (19), we know that any productive or unproductive investment will increase the contractor's net payoffs as $\gamma * i - i > 0$ and $c * e - e > 0$, i.e., $\gamma > 1$ and $c > 1$. This implies that from the perspective of his own net payoffs, the contractor has an incentive to make the highest possible amount of productive and unproductive investments. Thus, it has to be examined in which way the psychological effect influences this incentive scheme.

From the partial perspective on productive investments $i$ in equation (20), it can be seen that the psychological effect is positive when $\gamma > \omega + 1$. Here, any investment in $i$ will reduce the distributional inequality among the involved parties and therefore raise the contractor's utility so that the contractor has an incentive to make productive investments $i$ as long as $V_{PA_{PPP}} > V_{C_{PPP}}$. In addition, the contractor can also have incentives to make productive investments $i$ despite a negative psychological influence if the increase in net payoffs is higher than the negative psychological effect, i.e., if $\gamma - 1 + \alpha * \{\gamma - \omega - 1\} > 0$.

The partial analysis of unproductive investments is analogous. Here, it can be seen from equation (21) that the psychological effect is positive when $c + o - 1 > 0$. As the parameters are such that they correspond to the standard model (e.g., $c > 1$, $c - o < 1$ ), this condition will always be met as $c > 1$ and does not violate the Hart (2003) model's conditions as long as $c - o < 1$ so that the contractor will always have an incentive to make unproductive investments $e$ in the PPP case as long as $V_{PA_{PPP}} > V_{C_{PPP}}$ from a partial perspective.

For the analysis of overall investment incentives and the identification of optimal investment combinations, the comparison of the overall effects (net payoffs and psychological effect) is decisive. As the partial analysis revealed from a partial perspective that $\hat{e}_{PPPsp} > 0$ when $c > 1$ and additionally that the contractor always has an incentive to invest in both types of investments from the perspective of his net payoffs, an optimal combination with $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} = 0)$ is not plausible from an overall perspective. Thus, it has to be analyzed whether the combinations $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$, $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$, and $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ are realizable.

a) Keeping in mind that the contractor has an incentive to make unproductive investments from a partial perspective, the first combination $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ is only feasible if the parameters are such that the partial effect from a productive investment is higher than the partial effect of an unproductive investment, i.e., if $\gamma - 1 + \alpha * \{\gamma - \omega - 1\} > c - 1 + \alpha * \{c + o - 1\}$, which is equivalent to the condition $\gamma > c + \frac{\alpha}{1+\alpha} * \{o + \omega\}$. This condition is compatible with the parameter set of the Hart (2003) model as the conditions from the standard model for $\gamma$ to hold are $\gamma > 1$ and $\gamma + \omega > 1$, so that the investment combination $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ is realizable. In addition, the contractor will always invest $\hat{\imath}_{PPPsp} = i^* = Max[0; i^{\max}]$, which implies that if for the parameter $\gamma$ the condition $\gamma > c + \frac{\alpha}{1+\alpha} * \{o + \omega\}$ holds, then the first-best solution will be achieved.

A combined investment in both types is in this case not relevant, as both psychological effects operate in the same direction but the positive effect from an investment in productive investments is higher. Hence, a combined investment in productive and unproductive investments would not be efficient assuming that the parameters are such that the condition $\gamma > c + \frac{\alpha}{1+\alpha} * \{o+\omega\}$ is fulfilled.

b) Underlying to the combinations $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$ and $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ is that the contractor has incentives to make unproductive investments rather than productive investments, i.e., $\gamma - 1 + \alpha * \{\gamma - \omega - 1\} < c - 1 + \alpha * \{c + o - 1\}$. In contrast to the previous case, the psychological effect from an investment in $i$ can be positive or negative. Thus, an additional distinction is necessary, which will explain why two different optimal combinations can result.

Assuming that the psychological effect from an investment in $i$ is positive, i.e., $\alpha * \{\gamma - \omega - 1\} > 0$, then the rationale is similar to the previous case. Here, the condition $\gamma - 1 + \alpha * \{\gamma - \omega - 1\} < c - 1 + \alpha * \{c + o - 1\}$ must be met, which is equivalent to the condition $c > \gamma + \frac{\alpha}{1+\alpha} * \{-\omega - o\}$. This condition is compatible with the parameter set of the Hart (2003) model as the conditions from the standard model for $c$ to hold are $c > 1$ and $c - o < 1$ so that the investment combination $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$ with $\hat{e}_{PPPsp} = Max[0; e^{\max}]$ is also one of the realizable optimal investment combinations implying a "worst-case" investment combination as the maximum amount of unproductive investments is realized while productive investments are omitted.

If the psychological effect of a productive investment $i$ is negative, i.e., $\alpha * \{\gamma - \omega - 1\} < 0$, then the analysis has to focus on the differences in payoffs and the maximum amount of investments that are possible, i.e. $[0; e]$ and $[0; i]$. The necessary condition remains the same, i.e., $c > \gamma + \frac{\alpha}{1+\alpha} * \{-\omega - o\}$ so that the contractor will make unproductive investments $e$ as long as $V_{PA_{PPP}} > V_{C_{PPP}}$. If the disadvantageous difference in payoffs between the contractor and the public authority is that high enough that the contractor can invest $\hat{e}_{PPPsp} = Max[0; e^{\max}]$ then the optimal combination of investments will be $(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$. If the contractor cannot invest $\hat{e}_{PPPsp} = Max[0; e^{\max}]$, then the contractor will make productive investments $i$ in order to increase the differences in payoffs. Through this, the contractor can in turn make more unproductive investments. Thus, the optimal combination of investments will be $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ where in an extreme case the investment levels $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$ and $\hat{e}_{PPPsp} = Max[0; e^{\max}]$ will be achieved, which is identical to the result of the Hart (2003) model with linear utility functions.[10] ■

### 4.2.2. Case P2 – The public authority's net payoffs are lower than the contractor's in a PPP setting

The final case of the analysis presented here is the PPP case where the public authority's net payoffs are lower than the contractor's net payoffs, i.e. $V_{C_{UNB}} > V_{PA_{UNB}}$. Accordingly, the psychological effect of advantageous inequality ("sense of guilt") is relevant to the contractor at the point of decision so that the second term of equation (10) is equal to zero. Hence, the contractor's utility function is:

$$U_{C_{PPP-SP},P2} = V_{C_{PPP}} - \beta * \{V_{C_{PPP}} - V_{PA_{PPP}}\}$$

Again, $V_{C_{PPP}}$ and $V_{PA_{PPP}}$ can be substituted with equations (8) and (9). Hence, the following form for the contractor's utility function results:

$$U_{C_{PPP-SP},P2} = P_0 - C_0 + \gamma * i + c * e - i - e - \beta * \{P_0 - C_0 + \gamma * i + c * e - i - e - B_0 - \omega * i + o * e + P_0\} \quad (22)$$

with $V_{C_{PPP}} > V_{PA_{PPP}}$, i.e. $P_0 - C_0 + \gamma * i + c * e - i - e > B_0 + \omega * i - o * e - P_0$, which is equivalent to $2P_0 > B_0 + \omega * i - o * e + C_0 - \gamma * i - c * e + i + e$.

For the partial analysis required to analyze the total effects, equation (22) is differentiated with respect to $i$ and $e$, leading to:

[10] The numerical example in section 5 will include the case where $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ in order to illustrate this particular scenario.

$$
\begin{aligned}
& \frac{\partial U_{C_{PPP-SP},P2}}{\partial i} = \gamma - 1 - \beta * \{\gamma - 1 - \omega\} \\
\Leftrightarrow\ & \frac{\partial U_{C_{PPP-SP},P2}}{\partial i} = \gamma - 1 + \beta * \{1 + \omega - \gamma\} \\
\Leftrightarrow\ & \frac{\partial U_{C_{PPP-SP},P2}}{\partial i} = (1-\beta) * \gamma - 1 + \beta * \{1 + \omega\}
\end{aligned} \tag{23}
$$

and

$$
\begin{aligned}
& \frac{\partial U_{C_{PPP-SP},P2}}{\partial e} = c - 1 - \beta * \{c - 1 + o\} \\
\Leftrightarrow\ & \frac{\partial U_{C_{PPP-SP},P2}}{\partial e} = c - 1 + \beta * \{1 - c - o\} \\
\Leftrightarrow\ & \frac{\partial U_{C_{PPP-SP},P2}}{\partial e} = (1-\beta) * c - 1 + \beta * \{1 - o\}
\end{aligned} \tag{24}
$$

**Hypothesis P2:**

*In the PPP case when psychological effects from disadvantageous inequality apply, several optimal investment combinations can result, depending on the productivity parameters, $\gamma, \omega, o$ and $c$. Assuming that the parameters are such that they reproduce the results of the Hart (2003) model, the possible optima include the combinations $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ (with the first-best combination also being possible) and $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$.*

**Argument P2:**

As in the case P1, the parameters are consistent with Hart's (2003) model so that the contractor's net payoffs increase with every productive and unproductive investment since $\gamma > 1$ and $c > 1$. Thus, from the perspective of his own net payoffs, the contractor has again an incentive to make the highest possible amount of productive and unproductive investments and it has to be analyzed how the psychological effect influences this incentive scheme.

From a partial perspective, the psychological effect of an investment in $e$ will be negative in any case as $\beta * \{1 - c - o\} < 0$ for $c > 1$. In addition, it can be also seen that the increase in the net payoffs will not be high enough to cover the losses from the negative psychological effect in any case, i.e. $c-1+\beta*\{1-c-o\}<0$ for any parameter combination that respects the conditions $c>1$ and $c-o<1$. Thus, the contractor does not have an incentive to make unproductive investments from a partial perspective.

Regarding productive investments, the partial analysis needs further distinctions as the psychological effect from a productive investment can be either positive if $\beta*\{1+\omega-\gamma\}>0$ or negative if $\beta*\{1+\omega-\gamma\}<0$. When including the effects of a productive investment on the net payoffs into the partial analysis, it can be seen that the contractor will always have an incentive to make productive investments $i$ since $\gamma-1+\beta*\{1+\omega-\gamma\}>0$ (which is equivalent to $\gamma-1>\beta*\{\gamma-1-\omega\}$) holds for any combination of parameters with $\gamma>1$, $\omega>0$, and $0\leq\beta<1$.

As the partial analysis revealed that the contractor will not have an incentive to make unproductive investments in any case and will always have an incentive to make productive investments when the parameters are consistent with the parameters of the Hart (2003) model, the optimal investment combinations $(\hat{\imath}_{PPPsp}=0;\hat{e}_{PPPsp}=0)$ and $(\hat{\imath}_{PPPsp}=0;\hat{e}_{PPPsp}>0)$ are not possible. $(\hat{\imath}_{PPPsp}=0;\hat{e}_{PPPsp}=0)$ cannot be realized as the partial analysis revealed that the contractor always has an incentive to invest $\hat{\imath}_{PPPsp}>0$, and $(\hat{\imath}_{PPPsp}=0;\hat{e}_{PPPsp}>0)$ cannot be realized as the necessary condition would be that the contractor has higher incentives to make unproductive investments than productive investments from a partial perspective, which is not possible as the partial incentive is $\hat{e}_{PPPsp}=0$. Thus, it has to be analyzed whether and under which conditions the combinations $(\hat{\imath}_{PPPsp}>0;\hat{e}_{PPPsp}=0)$ and $(\hat{\imath}_{PPPsp}>0;\hat{e}_{PPPsp}>0)$ are realizable.

a) As it is known from the partial analysis that the contractor has an incentive to make productive investments $i$ for any combination of parameters consistent with the Hart (2003) model, the optimal combination of investments $(\hat{\imath}_{PPPsp}>0;\hat{e}_{PPPsp}=0)$ can be realized through two scenarios.

   In the first scenario, the psychological influence for both types of investments is effective in the same direction. Hence, if the psychological effect from an investment in $i$ is negative, i.e. $\beta*\{1+\omega-\gamma\}<0$, and if the psychological effect from an investment in $e$ is also negative, i.e., $\beta*\{1-c-o\}<0$, which is given for any combination of parameters with $c > 1$, then the resulting optimal investment combination is $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ in any case.

In the second scenario, the psychological influence of an investment in $i$ is positive, and consequently is effective in the opposite direction of the psychological influence of an investment in $e$. Hence, the analysis has to focus on the differences in payoffs and the maximum amount of investments that are possible, i.e. $[0;e]$ and $[0;i]$. Here, the contractor will make productive investments $i$ as long as $V_{PA_{PPP}} < V_{C_{PPP}}$. If the advantageous difference in payoffs in favor of the contractor is high enough that the contractor will invest $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$, then the optimal combination of investments $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ *with* $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$, *i.e. the first-best, will be achieved.*

b) The optimal investment combination $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ is closely tied to the just described scenario. Here, again, both psychological influences are effective in opposite directions. However, in this case, the contractor cannot invest $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$ as the difference in payoffs is not high enough. Hence, the contractor will make unproductive investments $e$ in order to increase the differences in payoffs since he can in turn make more productive investments through this, so that the optimal combination of productive and unproductive investments will be $(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$. As in case P1 (see section 4.2.1.), a combination with $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$ and $\hat{e}_{PPPsp} = Max[0; e^{\max}]$ can be achieved, which is identical to the result of the Hart (2003) model assuming linear utility functions.■

With the theoretical analysis of the contractor's investment incentives completed, the following tables summarize the results and compare the findings of the model presented in this essay with the results of the standard model of Hart (2003), and then the next section illustrates the theoretical findings with a numerical example. Again, it has to be emphasized that the results derived in the actual model were developed assuming that the parameters are consistent with the Hart (2003) model.

| | Hart (2003) model (with linear functions) | Yildiz (2015) model | |
|---|---|---|---|
| | | $V_{C_{UNB}} < V_{PA_{UNB}}$ | $V_{C_{UNB}} > V_{PA_{UNB}}$ |
| Unbundling case | There exists only one optimal investment combination: $(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$ | There exist several optimal combinations depending on the productivity parameters:<br>a)<br>$(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} = 0)$ if $o < \frac{1}{\alpha} + (1+c)$<br>b)<br>$(\hat{\imath}_{Usp} = 0; \hat{e}_{Usp} > 0)$ if $o > \frac{1}{\alpha} + (1+c)$ | There exists only one optimal investment combination:<br>$(\hat{\imath}_{Usp} > 0; \hat{e}_{Usp} = 0)$ ; with $\hat{\imath}_{Usp} = i^* = Max[0; i^{\max}]$ possible if $P_0$ high enough.<br>This optimum is resulting, irrespective of the productivity parameters as long as the parameters are consistent with the Hart (2003) model. |

**Tab.1:** Summary of the model's results in the unbundling case and comparison with the Hart (2003) model.

(Author's design).

| | Hart (2003) model<br>(with linear functions) | Yildiz (2015) model | |
|---|---|---|---|
| | | $V_{C_{UNB}} < V_{PA_{UNB}}$ | $V_{C_{UNB}} > V_{PA_{UNB}}$ |
| PPP case | There exists only one optimal investment combination:<br><br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$<br><br>Note:<br>If linear functions as in the Yildiz (2015) model are applied, then the optimal combination of investments is<br>$(\hat{\imath}_{PPPsp} = Max[0; i^{\max}]; \hat{e}_{PPPsp} = Max[0; e^{\max}])$.<br>The condition to realize this optimum is $\gamma > 1$ and $c > 1$.<br><br>Otherwise, other optimal combinations in the PPP case of Hart (2003) model) can result. | There exist several optimal combinations depending on the productivity parameters:<br><br>a)<br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ if $\gamma > c + \frac{\alpha}{1+\alpha} * \{o + \omega\}$<br>$\hat{\imath}_{PPPsp} = i* = Max[0; i^{\max}]$ possible<br>b.1.)<br>$(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$ if $c > \gamma + \frac{\alpha}{1+\alpha} * \{-\omega - o\}$<br>and $\alpha * \{\gamma - \omega - 1\} > 0$; with<br>$e_{PPPsp} = Max[0; e^{\max}]$ possible<br>b.2.)<br>$(\hat{\imath}_{PPPsp} = 0; \hat{e}_{PPPsp} > 0)$ if $c > \gamma + \frac{\alpha}{1+\alpha} * \{-\omega - o\}$<br>and $\alpha * \{\gamma - \omega - 1\} < 0$; and the contractor can invest $\hat{e}_{PPPsp} = Max[0; e^{\max}]$<br>c)<br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ if<br>$c > \gamma + \frac{\alpha}{1+\alpha} * \{-\omega - o\}$ and<br>$\alpha * \{\gamma - \omega - 1\} < 0$; and contractor has to invest $\hat{\imath}_{PPPsp} > 0$ in order to move toward<br>$\hat{e}_{PPPsp} = Max[0; e^{\max}]$ | There exist several optimal combinations depending on the productivity parameters:<br><br>a.1.)<br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ if $\beta * \{1 + \omega - \gamma\} < 0$<br>with $\hat{\imath}_{PPPsp} = i* = Max[0; i^{\max}]$ possible<br><br>a.2.)<br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} = 0)$ if $\beta * \{1 + \omega - \gamma\} > 0$<br>and the contractor can invest<br>$\hat{\imath}_{PPPsp} = i* = Max[0; i^{\max}]$<br><br>b)<br>$(\hat{\imath}_{PPPsp} > 0; \hat{e}_{PPPsp} > 0)$ if $\beta * \{1 + \omega - \gamma\} > 0$<br>and contractor has to invest $\hat{e}_{PPPsp} > 0$ in order to move toward $\hat{\imath}_{PPPsp} = Max[0; i^{\max}]$ |

**Tab.2:** Summary of the model’s results in the PPP case and comparison with the Hart (2003) model.

(Author’s design).

## 5. Simulation of the contractor's behavior

In the following, a numerical example whose results are graphically visualized with the software Wolfram Mathematica displays the theoretical insights presented in the previous sections 4.1. and 4.2.

The numerical example starts with assigning values to the variables. The productivity parameters were chosen so that they replicate the results of the Hart (2003) model with linear functions. The values for the aversion parameters $\alpha$ and $\beta$ were derived according to the Fehr and Schmidt (1999) model. Here, as also addressed in section 4.1.2., Fehr and Schmidt (1999) elaborated on the range of the aversion parameters and discussed interpretations of different values. Thus, $\beta > 0.5$ implies an economic agent who disposes of a sense of guilt and suffers from advantageous distributional inequality. Regarding $\alpha$, it has to be stated that there is no upper bound on the sense of envy. In fact, assumptions about the distribution of preferences derived from the analysis of experimental results on the ultimatum game reveal that more than 40 per cent of the experiments' participants showed a behavior that corresponds to an $\alpha$ of higher than $\alpha \geq 1$ (Fehr and Schmidt 1999). According to this, the values of the variables are as follows:

$B_0 = 100$; $C_0 = 20$; $P_0 = 50$; $o(e) = e$; $c(e) = 1.5 * e$; $\gamma(i) = 1.5 * i$; $\omega(i) = i$; $\alpha = 1.5$; $\beta = 0.6$

When inserting these values into the net benefit function of the economic exchange (see equation 3), the following function results:

$$U_{Soc.}(e,i) = 100 + i - e - 20 + 1.5 * i * + 1.5 * e - i - e$$
$$\Leftrightarrow \quad U_{Soc.}(e,i) = 80 + 1.5 * i - 0.5 * e$$

Hence, it is clear that this function will be optimized when $i^* = Max[0; i^{\max}]$ and $e^* = 0$, which can be also seen in Figure 2 (**Fig. 2**).

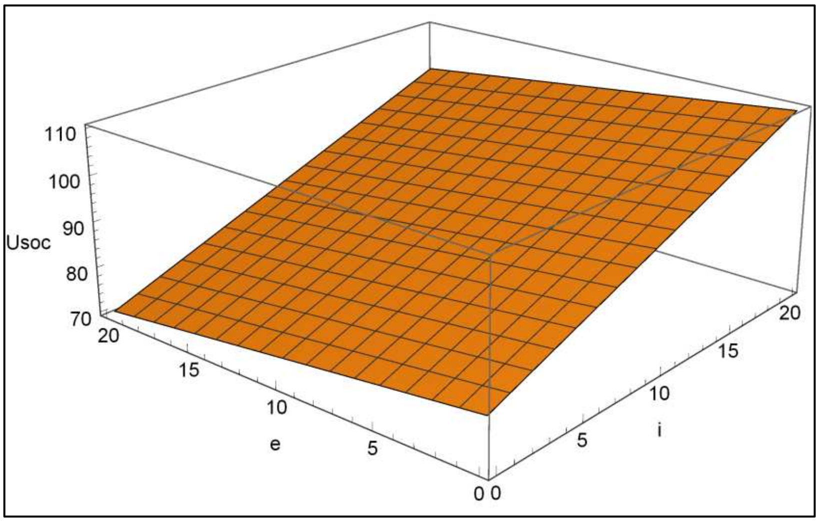


**Fig. 2**: 3D plot of the society's net utility function.
(Author's design, made with Wolfram Mathematica).

Figure 2 (**Fig. 2**) shows in a 3D plot the society's utility function (equation (3)) with the above defined values for the model's variables and for the interval $i \in [0;20]$ and $e \in [0;20]$. As predicted, the society's net utility is maximized (i.e., graphically the highest point of the plot) where $i^* = 20$ (i.e., $i^* = Max[0; i^{\max}]$) and $e^* = 0$.

With this first-best solution for the investment in mind, the following section will analyze the contractor's investment incentives given preferences for distributional fairness in the respective cases, starting with the unbundling case.

### 5.1. The unbundling case

Applying the numerical example to equations (4) and (6), we obtain the following results for the involved parties' net payoffs:

$$V_{C_{UNB}} = 50 - i - e \tag{25}$$

$$V_{PA_{UNB}} = 30 + 2.5 * i + 0.5 * e \tag{26}$$

The contractor's objective is to maximize his utility, which is in the standard model equal to his payoffs $V_{C_{UNB}}$. Hence, it is consequential that a utility maximizing contractor will not invest neither in $i$ nor in $e$, i.e., $\hat{\imath} = 0$ and $\hat{e} = 0$, as we can see from equation (25) that any further investment will reduce the contractor's payoffs. This result can also be shown graphically (**Fig.3**). Here, the highest point of the plane is at the combination of $\hat{\imath} = 0$ and $\hat{e} = 0$.

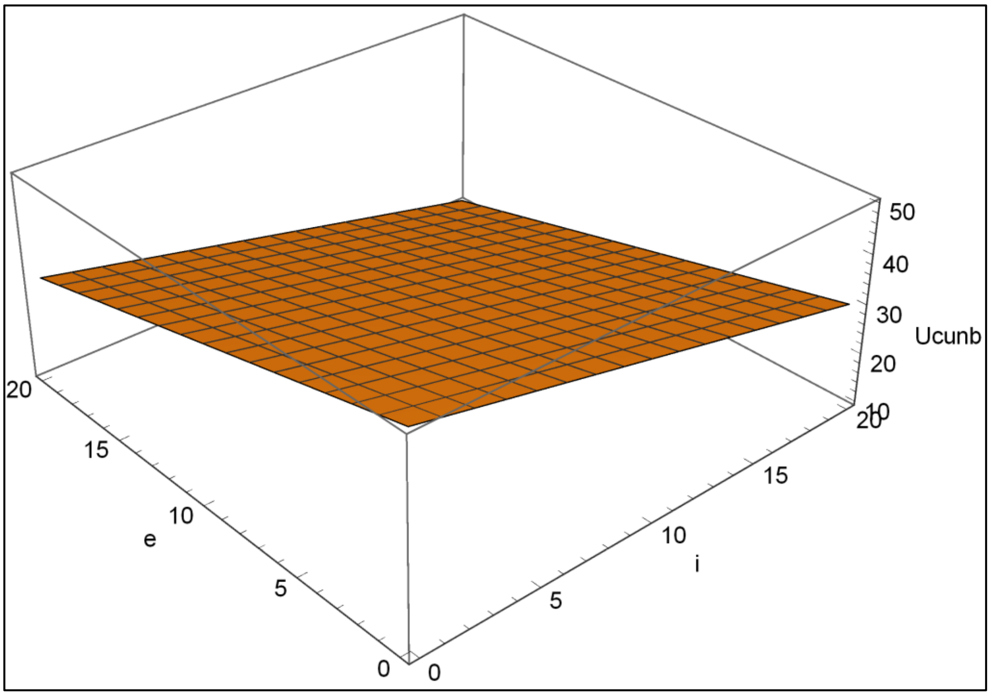


**Fig. 3**: 3D plot of the contractor's utility in the unbundling case in the standard model. (Author's design, made with Wolfram Mathematica).

Assuming that the contractor has preferences for distributional equality, his investment incentives change significantly.

When applying the numerical example to equation (7), the contractor's utility function with preferences for distributional equality is as follows:

$$U_{C_{UNB-SP}} = 50 - i - e - 1.5 * max\{-20 + 3.5 * i + 1.5 * e, 0\} - 0.6 * max\{20 - 3.5 * i - 1.5 * e, 0\} \quad (27)$$

From the terms in the brackets, it can be seen that for the numerical example above, the psychological effect from advantageous inequality applies at the point of decision as the term in the brackets of the second term (i.e., $-20 + 3.5 * i + 1.5 * e$), representing the psychological effect of envy, is below zero for the values of $i = 0$ and $e = 0$. In other words, the term in the brackets of the second term, i.e. $V_{PA_{UNB}} - V_{C_{UNB}}$, is below zero for the values of $i = 0$ and $e = 0$. Hence, the condition $V_{PA_{UNB}} < V_{C_{UNB}}$ applies, meaning that the contractor suffers from the psychological effect of advantageous inequality as long as $V_{PA_{UNB}} < V_{C_{UNB}}$ holds. Figure 4 (**Fig.4**) will show the depiction of the contractor's utility for the above defined numerical example from two different angles.

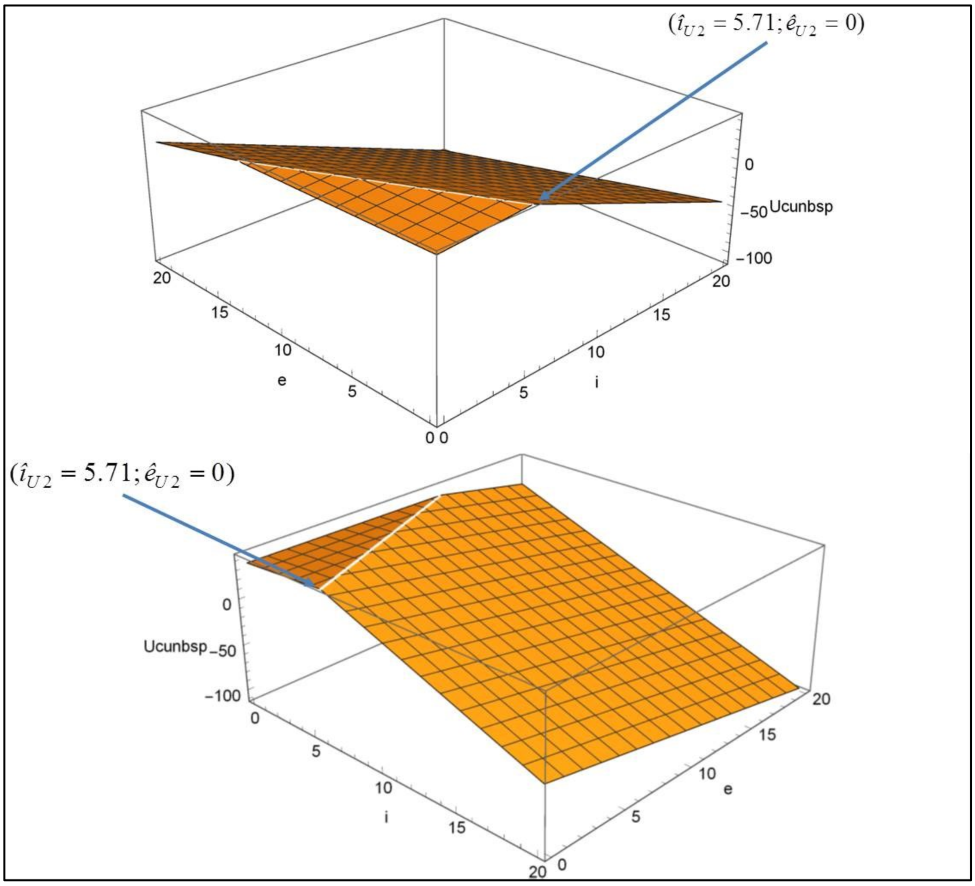


**Fig.4:** 3D plot of the contractor's utility in the unbundling case when a sense of guilt applies. (Author's design, made with Wolfram Mathematica).

From **Fig.4**, we see that, compared to the standard model, the applying sense of guilt induces investment incentives to the contractor. From equation (27), we see that any investment in $i$ will reduce advantageous inequality in payoffs, which raises the contractor's utility $U_{C_{UNB-SP}}$. As the positive effect on the contractor's utility from a reduction of advantageous inequality is higher than the loss of utility from the reduction in net payoffs, the contractor has incentives to make productive investments $i$ as long as the psychological effect from a sense of guilt applies. In addition, we also see that any investment in $e$ will likewise reduce advantageous inequality in payoffs, which raises the contractor's utility as long as the sense of guilt is relevant. However, regarding unproductive investments $e$, the positive effect on the contractor's utility from a reduction in advantageous inequality is lower than the loss of utility from the reduction in net payoffs. Hence, any investment in $e$ lowers in total the contractor's utility $U_{C_{UNB-SP}}$.

From this assessment, we know that the optimal combination of investments to maximize the contractor's utility can only be at the point where the maximal amount of productive investments $i$ is made before the vertex of the plane (i.e., the contractor's utility $U_{C_{UNB-SP}}$), i.e., $V_{C_{UNB}} = V_{PA_{UNB}}$, is reached. Hence, the optimal combination is $(\hat{\imath}_{Usp} = 5.71; \hat{e}_{Usp} = 0)$, which implies more productive investments than in the optimum of the standard model $(\hat{\imath} = 0; \hat{e} = 0)$. At the given combination of investment, we reach the vertex of the plane in **Fig.4.** This vertex represents the combination of investments $i$ and $e$ where the applying psychological effect is zero and afterwards changes from a sense of guilt to a sense of envy. When the applying effect changes, the negative psychological effect on the contractor's utility is intensified for any investment so that his utility will decrease. To summarize, the applying psychological effect of advantageous distributional inequality changed the contractor's incentives significantly as the optimal combination of investments now includes productive investments.[11]

As discussed in the theoretical assessment, a variation of the fixed payment $P_0$ to the contractor influences the optimal combination of investments as the payment $P_0$ determines how long a psychological effect persists. Figure 5 (**Fig.5**) will show the development of the contractor's utility when the payment $P_0$ is varied.

[11] The analysis on the planes (and therefore on the contractor's utility) run is only relevant for the above given numerical example. As elaborated in section 4.1, other parameter combinations can lead to scenarios where other investment combinations are optimal for the contractor.

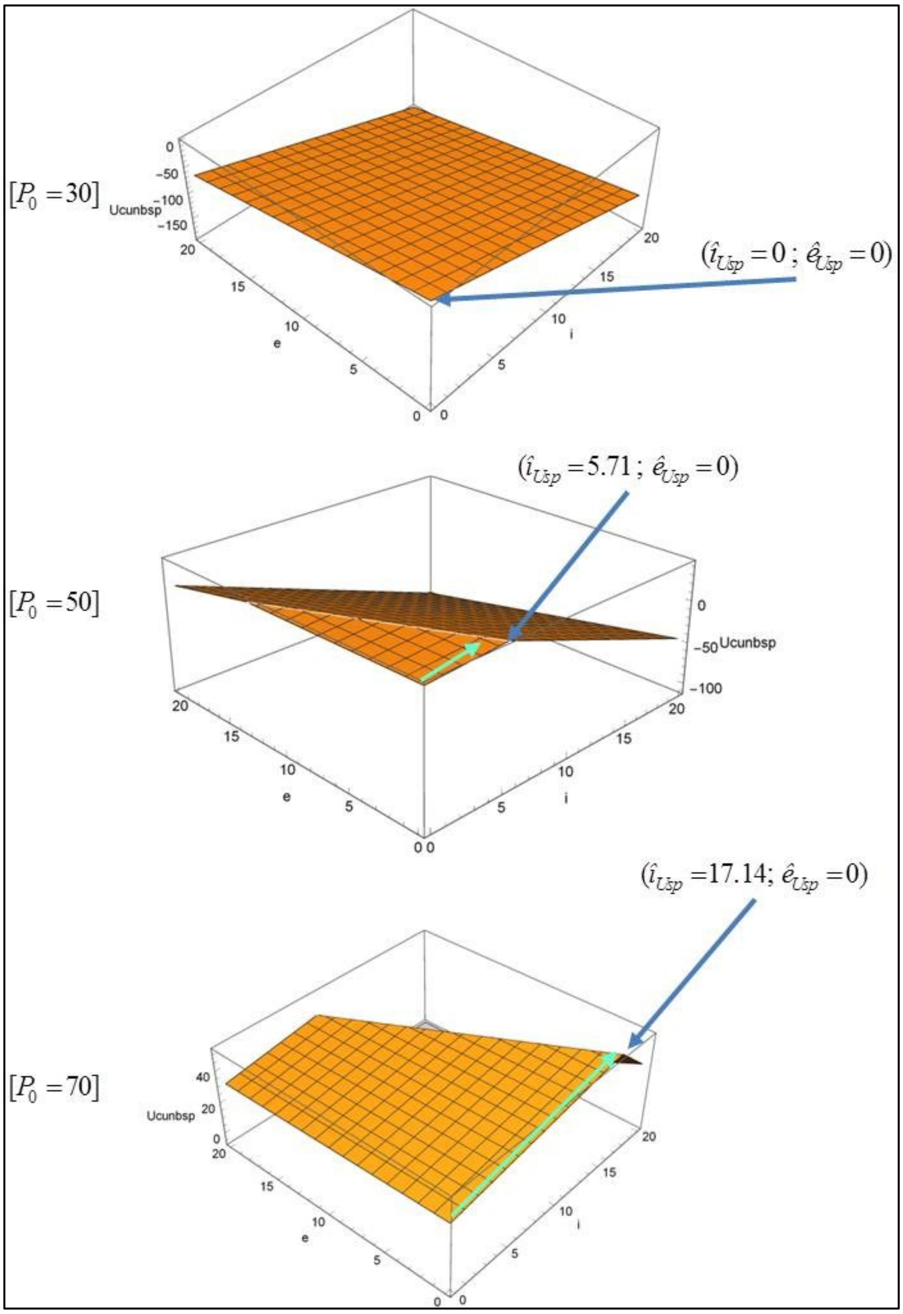


**Fig.5:** 3D plot of the evolution of the contractor's utility in the unbundling case when $P_0$ is varied. (Author's design, made with Wolfram Mathematica).

In the first (upper) illustration of **Fig.5**, the contractor's utility is illustrated when the payment $P_0$ for his service is $P_0 = 30$. Given this payment and all other parameters being the same as in the numerical example at the introduction of this subsection, his utility function changes to:

$$U_{C_{UNB-SP}} = 30 - i - e - 1.5 * max\{20 + 3.5 * i + 1.5 * e, 0\} - 0.6 * max\{-20 - 3.5 * i - 1.5 * e, 0\}$$

Here, it can be seen that the psychological effect from disadvantageous distributional inequality applies and that any productive or unproductive investment will reduce the contractor's utility. Hence, the optimal combination of investments is $(\hat{\imath}_{Usp} = 0\ ;\ \hat{e}_{Usp} = 0)$.

In the second (central) illustration of **Fig.5**, the contractor's utility is illustrated when the payment $P_0$ for his service is $P_0 = 50$. This case has already been discussed and the result was that the optimal combination is $(\hat{\imath}_{Usp} = 5.71; \hat{e}_{Usp} = 0)$. The light blue arrow shows how the optimal combination is shifted compared to the initial case ( $P_0 = 30$ ) as the psychological effects from a sense of guilt now apply. This incentivizes the contractor to make productive investments $i$ as long as the sense of guilt applies.

In the third (lower) illustration of **Fig.5**, the run of the contractor's utility is illustrated when the payment $P_0$ for his service is $P_0 = 70$. Here, his utility function changes to:

$$U_{C_{UNB-SP}} = 70 - i - e - 1.5 * max\{-60 + 3.5 * i + 1.5 * e, 0\} - 0.6 * max\{60 - 3.5 * i - 1.5 * e, 0\}$$

From the function term, it can be seen that the psychological effect from advantageous distributional inequality applies as in the previous case where $P_0 = 50$. However, for $P_0 = 70$, the distributional inequality is larger so that the contractor has a wider range to make productive and unproductive investments. As all other parameters of the numerical example are modified, the same rationale as for $P_0 = 50$ is applied. Hence, in the optimum, the contractor will not make unproductive investments and will invest as much as he can in productive investments $i$ as long as the sense of guilt is effective (i.e. as long as $V_{PA_{UNB}} < V_{C_{UNB}}$ ). Accordingly, the optimal combination of investments is $(\hat{\imath}_{Usp} = 17.14; \hat{e}_{Usp} = 0)$. The light blue arrow in the lower illustration shows again the shift from the original optimum (where $P_0 = 30$ ).

### 5.2. The PPP case

The basis for the upcoming analysis is again the involved parties' payoffs. Accordingly, through applying the numerical example to equations (8) and (9), we obtain the following results for the respective net payoffs:

$$V_{C_{PPP}} = 30 + 0.5 * i + 0.5 * e \quad (28)$$

$$V_{PA_{PPP}} = 50 + i - e \quad (29)$$

Again, the contractor's objective is to maximize his utility. Hence, in the standard model, the contractor's utility is equal to his payoffs $V_{C_{PPP}}$. From equation (29), we see that any investment in $i$ and $e$ will raise the contractor's payoffs so that a utility maximizing contractor will choose $\hat{\imath}_{PPP} = i^* = Max[0; i^{\max}]$ and $\hat{e}_{PPP} = Max[0; e^{\max}]$, which implies an overinvestment in unproductive investments $e$. Consequently, when plotting the contractor's utility for the interval $i \in [0;50]$ and $e \in [0;50]$, the combination of optimal investments in the PPP case will be $(\hat{\imath}_{PPP} = 50; \hat{e}_{PPP} = 50)$, as can be seen in figure 6 (**Fig.6**).

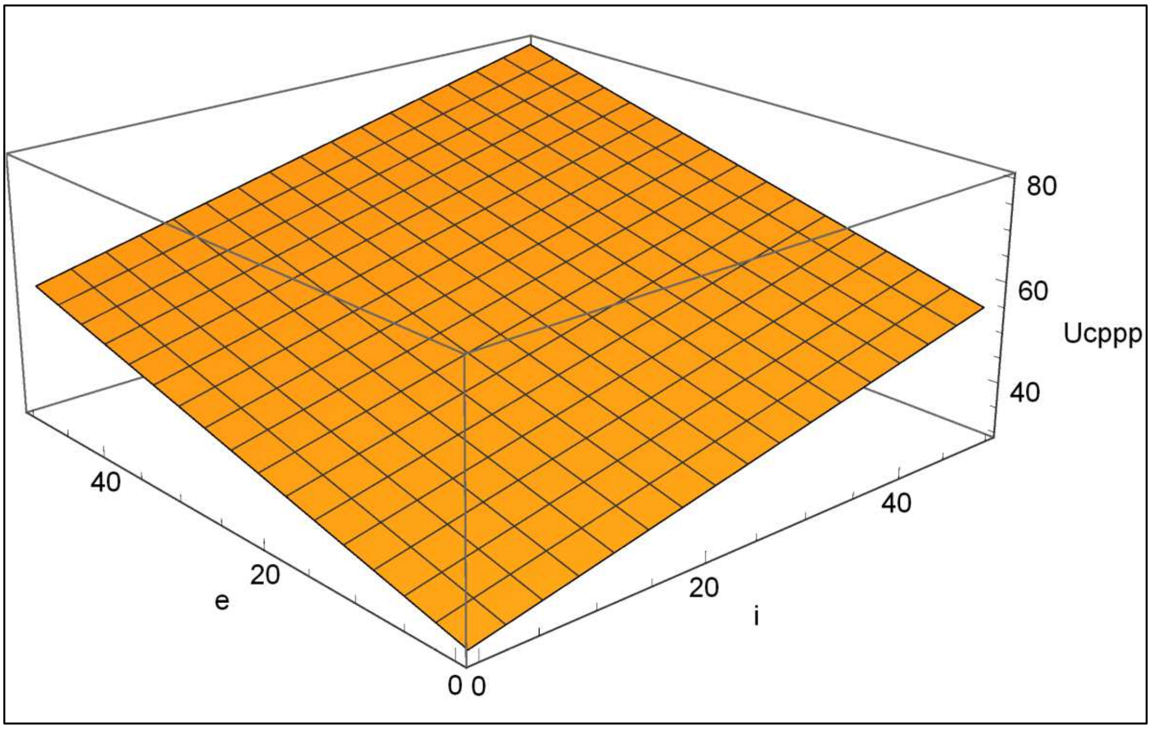


**Fig.6:** 3D plot of the contractor's utility in the PPP case in the standard model.
(Author's design, made with Wolfram Mathematica).

In analogy to the unbundling case, the contractor's investment incentives change significantly when he has preferences for a fair distribution of payoffs. Hence, applying the numerical example to equation (10) delivers the following utility function for the contractor:

$$U_{C_{PPP-SP}} = 30 + 0.5*i + 0.5*e - 1.5*\max\{20 + 0.5*i - 1.5*e, 0\} - 0.6*\max\{-20 - 0.5*i + 1.5*e, 0\} \quad (30)$$

Accordingly, we see from the utility function that a sense of envy will affect the contractor's utility at the point of decision as the term in the first bracket of the utility function $U_{C_{PPP-SP}}$, i.e., $\{20+0.5*i+1.5*e,0\}$, is positive for the starting values of the simulation, i.e., $i=0$ and $e=0$. The rationale underlying to this result is similar to the explanations in section 4.2.2. Figure 7 (**Fig.7**) displays the contractor's utility in the PPP case for the above defined numerical example when fairness preferences are effective.

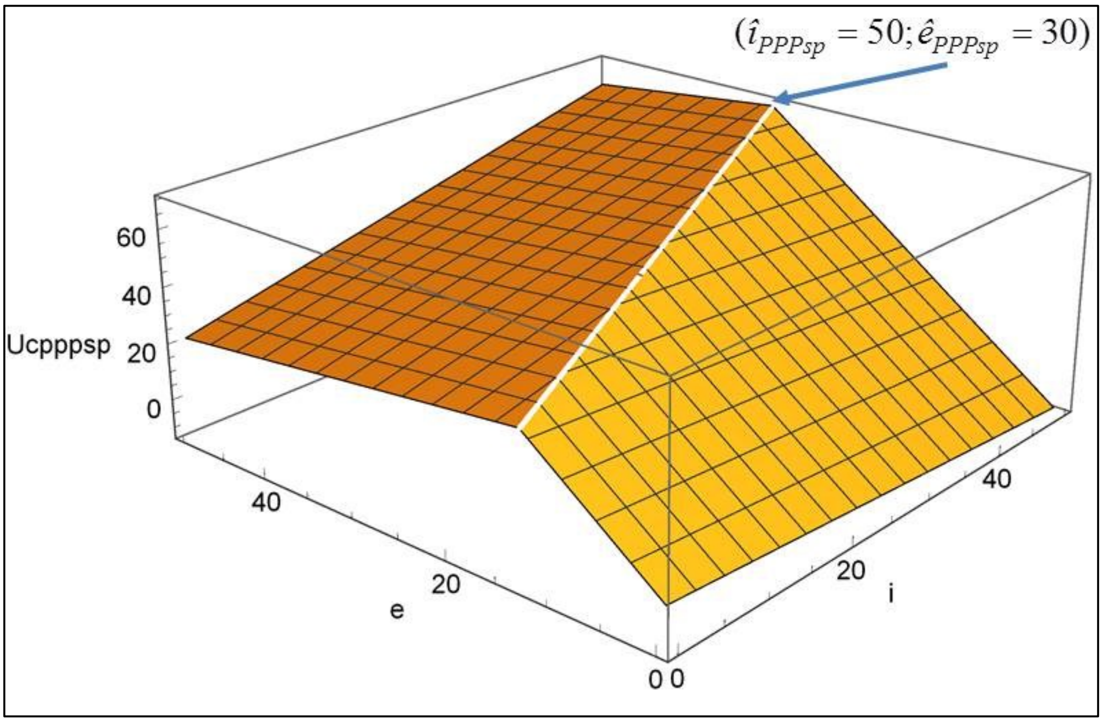


**Fig.7:** 3D plot of the contractor's utility in the PPP case when a sense of envy applies.
(Author's design, made with Wolfram Mathematica).

As can be seen in **Fig.7,** the optimal investment is $(\hat{\imath}_{PPPsp}=50;\hat{e}_{PPPsp}=30)$. This can be explained as any investment in $e$ will raise the contractor's net payoffs as well as reduce the disadvantageous distributional inequality as the contractor now operates the infrastructure and profits from the cost reduction (as the relevant productivity parameter is $c>1$), whereas the public authority's net payoffs are reduced (as $-o*e=-e<0$). Hence, it is optimal for the contractor to invest as much as possible in unproductive investments. Without any investment in $i$, this amount would be $\hat{e}_{PPPsp}=13.\overline{3}$.

The examination of the partial effects of an investment in $i$ reveals that a unit of productive investment $i$ has a positive effect on the contractor's net payoffs (as we also know from the standard model), but from equation (30) we also see that an investment in $i$ increases the disadvantageous inequality and consequently intensifies the negative psychological effect. As this negative effect on the contractor's utility is higher than the positive effect on the contractor's utility stemming from the increase in net payoffs that arise from an investment in $i$, the contractor would not have an incentive to make productive investments if it was based on a partial decision without any consideration of unproductive investments.

However, from an overall perspective including both types of investments simultaneously, the contractor has substantial incentives to make productive investments. The rationale is that any productive investment $i$ allows the contractor to make more unproductive investments $e$. As the overall effect from an investment in unproductive investments $e$ on the contractor's utility is higher than the effect of a productive investment, he chooses the combination where he can invest the most in unproductive investment $e$, i.e., $(\hat{\imath}_{PPPsp} = 50; \hat{e}_{PPPsp} = 30)$. Higher investments in unproductive investments in $e$ are suboptimal as here, effects from advantageous inequality would apply where investments in $e$ lower the contractor's utility (see equation (30)).

Similar to the numerical illustration of the unbundling case, a step-by-step variation of the fixed payment to the contractor $P_0$ also leads to an adjustment of the optimum as can be seen in figure 8 (**Fig.8**).

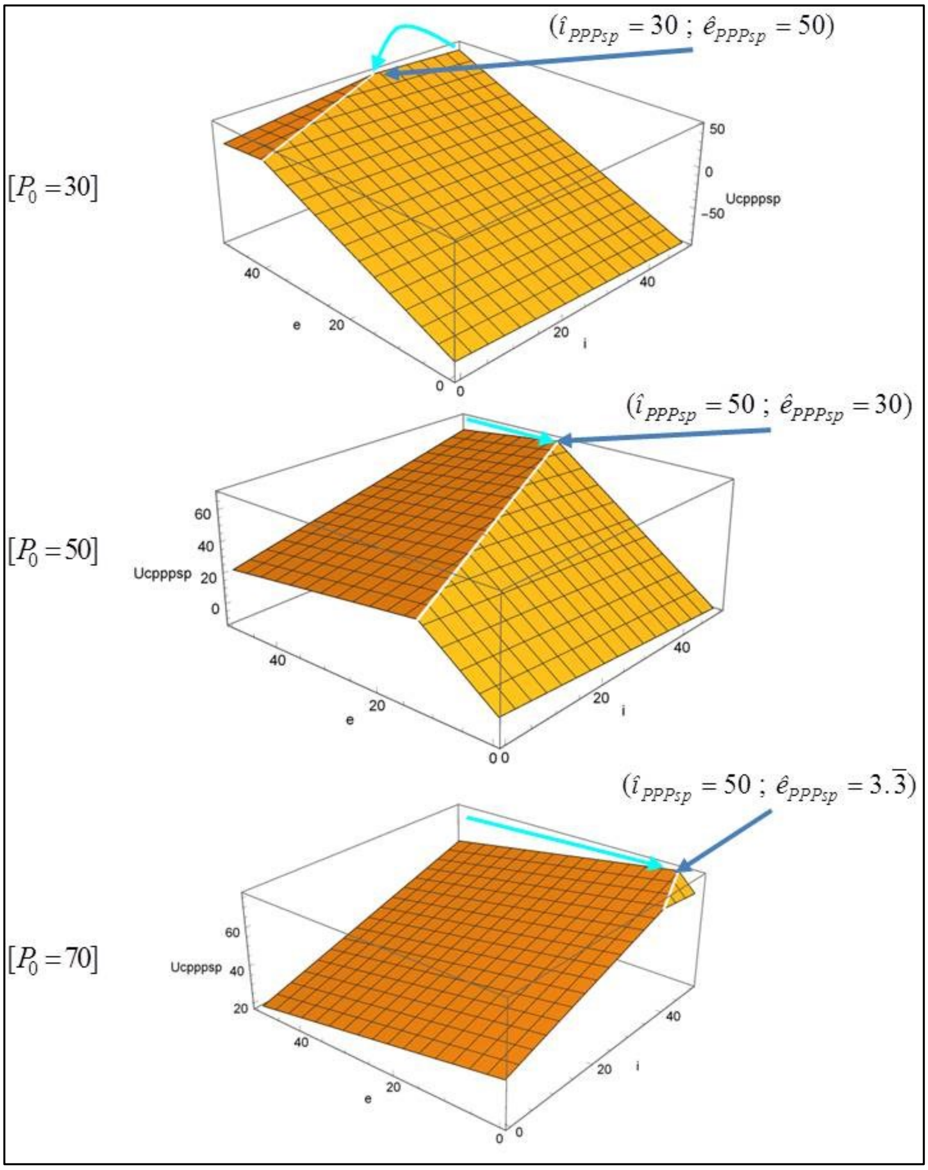


**Fig.8:** 3D plot of the evolution of the contractor's utility in the PPP case when $P_0$ is varied. (Author's design, made with Wolfram Mathematica).

In the first (upper) illustration of **Fig.8**, the contractor's utility in the PPP case is illustrated when the payment $P_0$ for his service is $P_0 = 30$. Given this payment and all other parameters being the same to the numerical example at the introduction of this subsection, his utility function changes to:

$$U_{C_{PPP-SP}} = 10 + 0.5 * i + 0.5 * e - 1.5 * \max\{60 + 0.5 * i - 1.5 * e, 0\} - 0.6 * \max\{-60 - 0.5 * i + 1.5 * e, 0\}$$

Here, it can be seen that the psychological effect from disadvantageous distributional inequality applies at the point of decision and that the contractor has an incentive to invest in unproductive investments $e$ from the net payoff and psychological perspective. When making only unproductive investments, the contractor could invest

$(\hat{\imath}_{PPPsp}=0;\hat{e}_{PPPsp}=40)$. However, through making productive investments in parallel, the contractor can "move" upwards on the vertex (where $V_{C_{PPP}}=V_{PA_{PPP}}$) of the plane and reach the combination of investments that maximizes his utility. Hence, the optimal investment combination when the payment to the contractor is $P_0=30$ is $(\hat{\imath}_{PPPsp}=30;\hat{e}_{PPPsp}=50)$. The light blue arrow in the upper illustration shows how the optimum is shifted compared to the standard model.

The second (central) illustration of **Fig.8** shows the already discussed case of the contractor's utility when the payment $P_0$ for his service is $P_0=50$. Here still, the sense of envy applies but the differences in net payoffs between both parties are lower than in the upper illustration so that the contractor makes more productive investments in order to invest the highest possible amount in unproductive investments. Hence, the optimal investment combination is at $(\hat{\imath}_{PPPsp}=50;\hat{e}_{PPPsp}=30)$.

In the third (lower) illustration of **Fig.8** the run of the contractor's utility is shown when the payment $P_0$ for his service is $P_0=70$. Here, his utility function changes to:

$$U_{C_{PPP-SP}}=50+0.5*i+0.5*e-1.5*\max\{-20+0.5*i-1.5*e,0\}-0.6*\max\{20-0.5*i+1.5*e,0\}$$

From the function term, it can be seen that the psychological effect from advantageous distributional inequality now applies at the point of decision. As we know from the analysis in section 4.2.2., the contractor will try to make as many productive investments as possible. Furthermore, as the psychological influence of productive and unproductive investments are effective in opposite directions, the contractor might consider making unproductive investments in order to increase the highest possible amount of productive investments. If the contractor were only to make productive investments, then the resulting combination before the vertex of the plane is surpassed would be at $(\hat{\imath}_{PPPsp}=40;\hat{e}_{PPPsp}=0)$. However, by investing a small amount in $e$, the contractor can make more productive investments so that he arrives at the optimal combination of $(\hat{\imath}_{PPPsp}=50\,;\,\hat{e}_{PPPsp}=3.\overline{3})$ for this case. The light blue arrow shows again how the optimum is shifted compared to the standard model. Furthermore, the total of **Fig.8** illustrates the evolution of the optimum by only varying the fixed payment to the contractor $P_0$.

This last example concludes the analysis of the implications of ownership and social preferences in a PPP setting with incomplete contracts. The following section will discuss the findings of the model presented here in the light of previous findings, particularly the Hart (2003) model, and add some concluding remarks.

## 6. Discussion and Conclusion

The analysis presented here provided new insights into the investment behavior of economic agents in a PPP setting with contractual incompleteness and social preferences, some of them being fundamentally different from previous insights from incomplete contract theory.

First of all, the analysis revealed that if the contractor in a PPP setting disposes of preferences for distributional equality, not only the distribution of ownership rights has an influence on the contractor's investment incentives but also payments. This is due to the influence the fixed payment – that is, the price for providing the service – has on whether the contractor feels a sense of envy or a sense of guilt. Consequently, the public authority can set investment incentives for productive investments in the unbundling case as well as in the PPP case. This finding is substantially different from the incomplete contract literature in general based on standard (neoclassical) theory in which only the distribution of ownership rights has an influence on an economic agent's investment incentives (e.g. Hart 1995).

The implications of these findings are that by appealing to fairness (e.g. through a "gentlemen's agreement") and ensuring that the contractor is better off, the public authority can induce investment effects in either case, unbundling and PPP. Hence, it is important for the public authority to ensure that it has enough funds to make payment for the contractor's construction service that makes him better off. In addition, the public authority (or the commanding party in general) can further influence the invested amount by varying its payments. Hence, if the public authority has complete information on the contractor's preferences and productivity parameters, it can choose an ownership form and make a payment so that the socially optimum first-best is reached, that is, the contractor invests the maximum amount of productive investments $i$ without any unproductive investments $e$.

On the contrary, if the public authority can foresee that it will not be able to pay a price that favors the contractor, a scenario can be realized in which the contractor only makes unproductive investments without any productive investments. This implies that an envious contractor might use unproductive investments as a measure to regulate “unfair” payments from the public authority. This behavior can also be observed in other contexts such as the provision of public goods or international climate negotiations. Here, parties might have a lower incentive for unilateral mitigation efforts when they feel they are being exploited by free-riders (e.g. Buchholz et al. 2014; Bolle et al. 2015).

When discussing these insights and the recommendations for action, it has to be considered that the model presented here is very simple and the results and recommendations are drawn through a casuistic approach. Nonetheless, the model helps to present a first impression of possible effects from social preferences in an incomplete contract setting.

In order to provide further insight on the behavior of economic agents in a decentralized investment scenario, further research could seek to simulate a PPP scenario and compare whether the observations in experiments are consistent with the theoretical predictions. In addition, these experiments could also serve to assess the aversion parameters. Analogous to Fehr and Schmidt (1999), the distribution of preferences could be analyzed according to the experimental results. This assessment in turn could be used in order to further develop the theoretical framework for the analyzed setting.

**7. Literature**


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