CITY UNIVERSITY LONDON

Department of Economics
School of Social Sciences

Infrastructure Contracts: Trust and Institutional Updating

Xeni Dassiou[1]
City University

Jon Stern[2]
City University

Department of Economics
Discussion Paper Series
No: 08/06

CCRP Working Paper No.12
December 2008

1 Department of Economics, City University, Northampton Square, London, EC1V 0HB, x.dassiou@city.ac.uk
2 Department of Economics, City University, Northampton Square, London, EC1V 0HB, jon.stern.1@city.ac.uk

Infrastructure Contracts: Trust and Institutional Updating*

Xeni Dassiou and Jon Stern
Dept. of Economics, City University,
Northampton Square, London EC1V 0HB, U.K.
CCRP, City University
x.dassiou@city.ac.uk† and jon.stern.1@city.ac.uk

December 14, 2008

Abstract

This paper discusses trust and trust perceptions in infrastructure contracts and supporting institutions. We focus on perceptions of the trustworthiness of the government purchasers of infrastructure services by the supplying companies and by the governments themselves. In particular, we allow for trust updating and trust misalignments which may give rise to 'undertrusting' and 'overtrusting'. The core of the paper sets out a game theoretic model of contracts with dynamic adjustment of trust perceptions, which we use to explore the impact of trust misalignment both on economic efficiency (measured by expected welfare) and on investment levels. We explore flexible contracts with and without pre-payments, rigid contracts (which do not allow for post-investment renegotiation) and hybrid contracts. We then compare the efficiency of the flexible contracts to that of hybrid contracts using as a criterion the expected welfare implications of each contract. The model is used to shed light on current issues on the sustainability of private investment infrastructure contracts in developed and in developing countries, including the role of regulatory institutions..

JEL classification: D02, C78, L14, L51, L78, L97

Keywords: Contracts, infrastructure, institutions, regulation, trust

*The authors wish to thank Chris Bolt, Stephen Littlechild, Francesc Trillas, Chris Walters, and the participants of the Paris December 2007 PPP conference, the Gran Canaria January 2008 CCRP City Workshop, and the Berlin INFRADAY October 2008 conference, for many useful and constructive comments on earlier versions of this paper. We are also particularly grateful to an anonymous referee whose numerous comments and suggestions pushed us to re-think many points in our model and analysis. The usual disclaimer applies.

†Corresponding author.

1 INTRODUCTION

In this paper, we investigate trust issues in infrastructure contracts, the viability of such contracts and the role of regulation and institutions in general for affecting these contracts[1]. More specifically, we focus on how well aligned are trust perceptions between buyers and sellers of infrastructure services, as well as on absolute levels of trust. It turns out from our analysis, that both the degree of mutual alignment/misalignment and the evolution of trust perceptions between suppliers and purchasers are each of major importance. Infrastructure investments install very long-lived, sunk assets and the services that they provide are typically highly politically sensitive (electricity, water, transport, etc.). In consequence, the critical issue for effective and sustained delivery is how to ensure adequate trust between the supplying entity and the government. The latter (or its proxy) purchases the output and provides the legal underpinnings, including possible regulatory arrangements. These issues are always important for private infrastructure investment, but are particularly important, firstly, for riskier investments; and, secondly, for infrastructure investment in difficult institutional environments as are frequently found in developing and transition countries.

In practice, we observe a wide range of institutional arrangements to support private investment in infrastructure. This range includes, at one end of the spectrum, licensed suppliers operating on infinite length contracts supervised by a regulatory agency (where the term 'contracts' includes licences and indefinite infrastructure franchises). This is the electricity and telecom regulatory model. At the other end of the spectrum, are fixed length concession contracts with no external supervisory body other than the commercial courts (as with many toll road contracts and many PPP contracts). There are also many hybrid models which combine contracts with regulatory or other forms of external regulation/arbitration etc. in various ways (e.g. UK railways, the London Underground and many others). As argued later, contracts and regulation are better regarded as complements rather than substitutes[2]. It is worth pointing out that infrastructure contracts – like long-term contracts between companies - can be found with various degrees of external contract resolution and with varying degrees of renegotiating flexibility both in terms of tariff and similar changes and for post-investment renegotiation[3].

In this paper, we explicitly introduce a measure for the quality of the in-

[1] In particular we investigate the role of external agencies - regulatory agencies or similar - can have in sustaining trust in infrastructure contracts. Contracts in our paper refer to legally binding agreements that involve investment as well as operation and management. These include all concession contracts with investment obligations, UK regulatory licences and US infinite duration franchises, but exclude French aftermage/lease and similar contracts without investment obligations. They also exclude PPPs except for those where there is an external regulatory entity in place (like the London Underground PPPs).

[2] See Stern (2003), Bolt (2003 and 2007). These both discuss the issues arising from the perspective of a regulated industry. Athias and Saussier (2006) discuss these issues arising from the perspective of concession contract design.

[3] See Athias and Saussier (2006) for evidence on this for toll road concessions and Menard and Saussier (2002) for water supply arrangements.

stitutional and regulatory conditions that prevail in the environment where the contract is to be implemented. This is a variable that covers the aspects of country governance that most directly impact on the likelihood that the contract will be fairly administered and enforced and that any contract disputes will be resolved in an impartial manner. Apart from the presence of a regulatory or quasi-regulatory entity, this most obviously concerns issues to do with the rule of law, the reliability and timeliness of law courts, and levels of probity (and corruption) in public life[4].

We present and report the results of a game theoretic model which includes not just the contract and the relevant institutional framework, but also the potential for renegotiation and contract modification (including regulatory review). Hence, following Menard and Saussier (2002), we consider the relative merits of different types of contractual arrangements. In addition, we explicitly consider the role of pre-agreed revision and renegotiation clauses, following the evidence of Athias and Saussier (2006) on the way that they are frequently used in toll road concession contracts. Our model introduces trust alignment and perception issues into this framework.

We adopt a game theoretic approach to these issues starting from a consideration of alternative types of contract. We first develop a typology of contracts building on Athias and Saussier who distinguished between flexible contracts, which explicitly allow for contract renegotiations after investments have been made; and rigid contracts, which set fixed contract terms before the investments are made and do not allow for subsequent term changes or renegotiation. We then develop hybrid models which are constructed by introducing a variable for the probability of renegotiating a fixed contract after the investment has taken place.

We integrate the discussion of contracts with that of regulation on the basis that external regulators can allow simpler contracts, easier dispute resolution and, in particular, more readily agreed contract renegotiation. This perspective arises from Laffont (2005), Guasch and Straub (2006) as well as Stern (2003).

The measure of trustworthiness on which we focus is the probability that the contract between the buyer and the seller will be enforced, taking the simplest dimension of enforcement, i.e. whether or not the buyer pays the firm in full according to the terms of the contract. With trust misalignment, the perception that the buyer will be paid in full can differ between buyers and sellers and each can differ from the maximum level of one. We explore a range of contractual and institutional arrangements that can reduce this perception gap and/or help guarantee payment. These may take a variety of forms from (a) insurance type arrangements (for example World Bank regulatory risk guarantees) to (b)

[4] Specialist regulatory or similar external agencies may be given some of the responsibilities for these issues, but within a legal framework under which appeals and possibly implementation would be done by the local courts. Of course, countries may decide to establish independent regulatory or similar agencies as a way of *signalling* to investors their commitment to fair dealing on infrastructure contracts and investment. Such policy signalling devices were advocated by the World Bank and others in the 1990s but actually go back to medieval times for trade courts, as shown in Greif (2006).

some form of explicit pre-payment contracts (see, for instance, Braynov and Sandholm, 2002). Essentially in our model, the term 'prepayment' is interpreted broadly and can mean any facility that provides an almost "as good as in your pocket money" to the buyer and/or the seller.

The paper sets out the formal modeling relationship between trust perceptions and different contractual arrangements. We do this by constructing a bargaining model between the buyer and the seller using a framework based on Nash bargaining, where the dynamic responses are generated by Bayesian updating. We compare the expected welfare and the expected investment levels from each of our contractual types with those from a benchmark incentive-compatible contract, and we use these expected welfare and investment comparisons to evaluate the appropriateness in different circumstances of different contract forms. These provide a framework within which we can evaluate the importance of external regulatory and of pre-payment/guarantee arrangements.

In section 2 we address the question of whether concession contracts are substitutes or complements and we introduce the key concepts used in our modelling. This is followed by section 3 where we set out the formal framework of our model. We consider the relative merits of alternative forms of flexible contracts and rigid contracts in addressing the problems posed by variations in the perceived levels both of trust misalignment and of the absolute values of these trust perceptions. Finally, we draw our conclusions in section 4. We include as appendices (a) a discussion of relevant cases on OECD and developing countries and (b) a mathematical appendix.

2 CONCESSION CONTRACTS REGULATION AND TRUST CONCEPTS

In this section, we firstly provide a summary literature review of the relationship between contracts and external regulatory entities and then we introduce the key concepts used in our model.

2.1 Infrastructure Contracts and External Regulation

From around the mid-1980s, there was a strong push towards developing regulatory agencies as the key way in which trust could be established for countries privatising their utilities or wishing to expand private investment. Hence, it was suggested that establishing such agencies was a way of assuring infrastructure investors that countries were now trustworthy.

Proponents of this view failed to give sufficient weight to:

(i) the degree to which governments would intervene into regulatory decisions;

(ii) the degree to which regulatory laws and institutions provided discretionary powers (which enabled governments to intervene arbitrarily); and

(iii) the time it takes to establish regulators and the volume of specialist resources required.

In consequence, by the late 1990s, the optimistic view of regulators was seriously battered by major regulatory failures, in particular after the Asian and Latin American financial crises in 1997-98 when new regulators were effectively discarded and many investments (or at least debt contracts for the investments) became unviable.

A counter view was that regulators - or at least regulatory discretion - was the main problem. For instance, Spiller (2004) argues that concession contracts provide individualized regulation with contracts that are rigid by origin rather than 'relational' as typically found in long-term contracts between private sector entities. This is supposed to resolve the problem of regulatory discretion. The problem with this argument is that, as is now well-known, tight contracts are very brittle in the face of shocks and renegotiation can be difficult.[5] Renegotiation rates are typically very high for developing country concession contracts - particularly for toll road and water concessions which Guasch (2004) reports at (respectively) 55% and 74% for Latin America over the period 1989-2000. However, this probability was reduced by between 20-40% if there was a pre-existing regulator in place. (Guasch, p. 90.)

Stern (2005) sets out the counter-argument to the case for rigid contracts without external regulatory support. This counter-argument is that, where country governance is sufficiently supportive, trust is better achieved for infrastructure investment by establishing a separate external regulatory or quasi-regulatory entity, which has been assigned legal powers to act of its own volition. This agency should have the authority, in consultation with regulated companies and their consumers, to modify existing regulatory obligations (for example, tariffs and quality of service) and to establish new regulatory rights and obligations. In particular, it should have the right to review and revise regulatory obligations according to some defined process. Hence, it operates as a full regulator, including a degree of bounded and accountable discretion. The relevant range of agencies that this encompasses includes classic regulatory agencies, autonomous concession contract monitoring agencies, strong arbitration agencies and external review as well as specialist courts with powers to review and modify contracts (like the French Conseil d'Etat in the case of water concession contracts.)

Such a mechanism provides a way in which contracts can be reappraised and revised in the light of changing circumstances according to a pre-agreed and impartial process. Hence it allows simpler and more transparent initial contracts and better enforcement. In many cases contracts without external regulatory support will at best require major renegotiation and in many cases will fail. However, there are also cases where contracts with little or no regulatory support may well be sufficient. The difference depends firstly on the nature of the contracted service and its associated investment (e.g. whether it is a straight-

[5] Of course, far from all renegotiations lead to project collapse. Nevertheless, according to the World Bank PPI database, over the period 1990-2004, 160 infrastructure projects accounting for 9% of investment flows were cancelled or in distress. For water, 7% of projects accounting for 37% of investment flows in the sector were cancelled or became distressed, i.e. a disproportionate number of high value concession projects.

forward and/or previously successfully delivered investment); and, secondly, on the degree of trust between the purchaser and the seller and/or on whether the parties do or do not have a previous history of successfully managing such contracts. We discuss this further in the next section and again with examples in the appendix (section 6) following the results from our bargaining model.

2.2 Trust Misalignment: Undertrusting and Overtrusting

In this paper we introduce the concepts of 'undertrusting' and 'overtrusting'. These are the key concepts for our model and they can be understood as follows:

Consider the typical case where the government is the buyer of infrastructure services via some type of long duration contract or equivalent[6] and the seller is a private company, typically an infrastructure company. We define "undertrusting" as the case where the selling firm's belief that the buyer will honour the contract in full is less than the buyer himself perceives it to be. Similarly we define as "overtrusting" the case where seller's estimate that it will receive full payment under the contract is greater than the buyer believes it to be.

With undertrusting, the key problem is how to motivate and sustain ongoing and agreed levels of investment in the face of unforeseen developments and incomplete contracts. Undertrusting typically arises when the reputation of the buyer is either not established (as with a major new type of infrastructure contract or a contract in a new and potentially difficult or uncertain area or country); or where the reputation of the buyer is impaired (e.g. from past bad history of government treatment of private and/or foreign investors or political instability).

Conversely with overtrusting, the key problem is whether or not companies, having made particular investments, will receive payments that they think they are owed under the contract when unanticipated changes are needed and/or unforeseen developments occur. Hence, whereas one would expect contracts with undertrusting to break down relatively slowly, contracts with overtrusting are likely to collapse rapidly once the seller has recognised its presence. Overtrusting typically arises when investors have too optimistic a view of the degree to which governments (particularly *future* governments) are both willing and able to commit to commercialized provision of infrastructure.[7]

Trust alignment occurs when the beliefs of the seller and buyer are the same. Of course, this may be at a high level of trust (as in countries in the top 5% of country governance scores) or at a very low level of trust (as in countries with very low country governance scores). In what follows, we show that, the best outcome – particularly for consumers – involves contracts with high levels of mutual trust. However, we also show that infrastructure contracts involving

[6] A fixed period UK-style infrastructure regulatory licence and an infinite US utility authorisation would both be included in this categorisation.

[7] For developing and transition countries, this includes a sustainable commitment to macroeconomic and exchange rate stability that would allow foreign investors to pay debts and repatriate profits in the appropriate currency.

quite large amounts of privately financed investment *may* be sustainable in circumstances of low trust even if they are highly suboptimal.[8]

Similar trust and trust perception issues exist over the commitment of the seller (i.e. the infrastructure company). We do not explicitly discuss such issues in what follows but the analysis should be similar, albeit this time referring to the probability of investment rather than the probability of full payment. We leave this for future research - as well as combining buyer and seller trust and trust perception issues.

3 THE MODEL

The model draws on game-theoretic bargaining models that have been developed in related contexts. In particular, we draw attention to McMillan and Waxman (2007) which explores the importance of trust in terms of the way it influences the bargaining power of governments and multi-national companies. We also draw attention to the paper by Braynov and Sandholm (2002) which has a technical discussion of how trust can be integrated and handled within different types of Nash bargaining solution modelling environments. The general issue of government and company reputation in infrastructure concession contracts is discussed in Guasch and Straub (2006) paper on concession contract renegotiation both with and without the presence of a pre-existing regulatory agency.

Weakness in contract enforcement is one of the main reasons why developing countries generally find it more difficult to attract both international trade as well as infrastructure investment. The dynamic process by which firms engaged in international trade build trustworthiness because contracts are not completely enforceable, is discussed in Araujo and Ornelas (2007), a paper focusing on short term international trade contracts. Braynov and Sandholm discuss contracting with uncertain levels of trust in a static model and the importance of the extent to which the seller's trust equals the buyer's actual trustworthiness. We do combine both of these characteristics in this paper.

In what follows, we discuss uncertain levels of trust in infrastructure contracts but extend the analysis to cover dynamic as well as static aspects of contract sustainability and the role of external regulatory or quasi-regulatory agencies.

The institutional environment

We define an institutional parameter $\lambda \in [0, 1]$ that measures the country's ability to enforce concession contracts. Perhaps the simplest interpretation of λ is that it is a simple indicator of the proportion of contracts enforced by the legal system in any country, as suggested by Anderson and Young (2006). Alternatively it can be considered as an indicator of the probability that contract violations will be detected and punished, as well as whether or not there are

[8]For instance, Paraguay in the 1960s and '70s and some central African states.

effective adjudicating procedures for disputes. Either of these would imply the importance in determining λ using country global governance indicators, like the World Bank Kaufmann *et al.* indices.

For long-term infrastructure contracts with sunk costs, the value of λ is also significantly likely to be affected by whether or not there is some type of external regulatory or quasi regulatory agency in place.[9] The existence and efficiency of any such entity along with general country governance quality will largely determine how close λ is to one.

However, we would also include other parameters in the buyer country's socio-economic environment that are likely to affect its observable ability and willingness to meet long-term contractual commitments. These would include the degree of international indebtedness of the country concerned, the degree of political polarization and stability, etc.

Trustworthiness beliefs held by the firm

The situations that we model incorporate (a) imperfect contract enforcement, (b) potential opportunistic behaviour by the host government and (c) the presence of very large sunk costs (as typically found in the majority of infrastructure contracts). This means that following Williamson (1976), we would expect substantial transaction costs to be present. These factors may prevent such contracts from being concluded, or from being carried out for their full term. Conversely, the more that the government abides by the terms of a contract the more convinced the investing firm can become in the trustworthiness of the purchasing government.

We denote as a' the selling firm's belief that the government will honour the terms of the contract and that it will be paid on delivering the product or service of the contract on the terms stipulated in the contract. There is little theoretical analysis of the dynamic process by which trustworthiness is built as a response to the lack of perfect enforceability of contracts. However there is abundant anecdotal evidence of how trust can be used to compensate for the lack of formal legal agreements or other relevant features of the institutional set up abound. Grief (1993) analyses the formation of coalitions by medieval merchants to compensate for limited contract enforceability, while McMillan and Woodruff (1999) show how relationships based on trust arise and develop in environments where there is virtually no contract enforcement as is the case of Vietnam. Macaulay (1963), argued that a key virtue of relational contracting is that parties can count on each other to abide by the spirit of the contract and therefore do not waste much time and effort in specifying its letter.

We assume that the firm updates is beliefs about the purchaser's type according to Bayes rule:

[9] As discussed above, this includes autonomous concession contract monitoring agencies, external arbitration, expert panels etc., as well as classic infrastructure regulatory commissions/offices.

$$a'(\{paid\}, a') = pr(m \mid \{the\ government\ pays\ the\ seller\} \cap a') = \frac{a'}{a' + \lambda(1 - a')} > a'$$

As a result of the Bayesian process above, the adjustment in a' is upwards unless there is bad news in which case there will be a reversion to the initial value (as we fully explain below). Note that the firm may get paid even if the current government (purchaser) is not trustworthy - in other words it may have an incentive to engage in opportunistic behaviour but is discouraged or prevented from doing so by the institutional environment which successfully enforces the contract. Hence both the parameter for the institutional environment λ, as well as a', the reputation (i.e. the perceived trustworthiness) of the government of the day, play a positive role in forming the subjective probability (as perceived by the seller) of full payment by the purchaser. This is discussed in the next subsection.

Araujo and Ornelas discuss a series of one-period trading contracts. In their model the outcome of each contract feeds into the reputation of the buyer with whom a long term relationship is established via a trust enhancing (or diminishing) effect of successive contracts. We instead wish to apply this approach into a typically long term infrastructure contract where trustworthiness tends to grow incrementally over time. However, there is no doubt that a history of previously successfully concession contracts in a country has a positive externality effect on future concession contracts by increasing the prior estimate by the seller (investor) of the buyer's trustworthiness. The strength of this externality will of course depend on whether this buyer is the same or a different government. We also discuss this in the next subsection.

The firm has an initial prior estimate (belief) $a'_\tau > 0$ and we allow this to increase up to a maximum of 1 during the length of the contract. In other words, we define a history according to which the firm updates its estimate regarding the trustworthiness of the buyer during the life of the contract as and when further information regarding the government becomes available. Then we label as $a'^k_\tau(C, a')$, the value of the estimate made by the seller of the probability that the purchaser is trustworthy after k periods (defined in years, or months, or even days as appropriate) given a starting date τ for the concession contract, during which experience is cumulated applying a cardinality C, where $C = \sum_{j=\tau}^{\tau+k-1} h_j$, $h_j \in \{0, 1\}$. Hence through the life of the contract (which, for an infrastructure contract, will typically tend to run in double digit years) the estimate of the trustworthiness of the trading partner will be updated. Events (news) if non existent or positive are indicated by $h_j = 1$ (i.e. no news is good news[10]), while negative news is indicated by $h_j = 1 - j$. Under this mechanism

[10] Tirole (2008) argues that "parties to a contract tend to specialize in identifying bad news for themselves/good news for the other party". However in our model, the buyer faces no participation constraints as it is the seller who pays for the investment. Hence it is in the seller's interest to unveil both bad as well as good news that may affect his expected profit.

information regarding the trustworthiness of the government by the firm will be cumulated over time. The estimate by the firm at time $\tau+k$ of the government's trustworthiness on a contract that started at time τ is given by the following Bayesian updating process:

$$a_{\tau}^{\prime k}(C, a_{\tau}^{\prime}) = \frac{a_{\tau}^{\prime}}{a_{\tau}^{\prime} + \lambda^{C}(1 - a_{\tau}^{\prime})} \tag{1}$$

Clearly if there is a bad event, $C = 0$, and trustworthiness will revert in the next period back to its prior value of $a_{\tau}^{\prime}$ from where it will start increasing once more. In the absence of bad events C will increase and $a_{\tau}^{\prime k}$ will increase towards its upper maximum value of 1. Hence $a_{\tau}^{\prime k} \in [a_{\tau}^{\prime}, 1]$

The justification for this uneven treatment is that humans perceive trust destroying events as more noticeable than trust building events; hence the former tend to carry more weight than the latter. Once trust is lost it is costly to rebuild and it will take both time and a series of positive events for it to be regained. Note that the institutional environment plays a direct role as well as an indirect one since, if the institutional factors will ensure that payment occurs in any case, contract commitments will be enforced even if the government is untrustworthy. However in our model enforcement is separated from trust as the latter can compensate for the absence of the former (Greif, 1993), although, in general, it is to be expected that trustworthiness should act as a complement to the quality of the institutional environment as discussed in the previous section.

Updating delays and the importance of prior beliefs

The subjective probability held by the firm that it will receive payment is $a = a' + \lambda(1 - a')$. If the institutional setting of the country improves, then the firm will expect to receive its payment with a higher probability and a' will become less important in determining the probability of payment. If a' is updated upwards, then the institutional parameter becomes increasingly less important in determining the belief regarding the probability of payment.

Note that a purchaser's reputation at time τ is not affected by the increase in λ at that time (denoted by λ_{τ}). This is because a is a function of the events that have occurred so far during the contract only up to the start of the current period. However, current period events will affect the purchaser's future reputation at time $\tau + 1$ onwards. This means that an improvement in λ can potentially slow down the updating process regarding the perceived trustworthiness of the trading partner. This is because it makes it more difficult for the firm to determine whether the government is complying with the terms of the contract voluntarily or whether it is doing so because of the institutional restrictions (including the threat of a legal or regulatory challenge, or the commencing of external arbitration, etc.). Hence if a change in λ occurs at time τ, then after k (for $k > 0$) periods:

$$\frac{\partial a_\tau'^k}{\partial \lambda_\tau} = \frac{-C\lambda^{C-1} a_\tau'(1-a_\tau')}{\left(a_\tau' + \lambda^C(1-a_\tau')\right)^2} < 0 \tag{2}$$

And the impact on the overall probability of payment is

$$\frac{da_\tau^k}{d\lambda_\tau} = \frac{\partial(a_\tau^k + \lambda(1-a_\tau'^k))}{\partial \lambda_\tau} = (1-a_\tau'^k) + (1-\lambda)\frac{\partial a_\tau'^k}{\partial \lambda_\tau} \tag{3}$$

$\frac{da_\tau^k}{d\lambda_\tau}$ will be positive provided that:

$$\frac{\lambda}{1-\lambda}\left(1 + \frac{1-a_\tau'}{a_\tau'}\lambda^C\right) > C \tag{4}$$

The left hand side in the above is an increasing function of λ. This implies that in countries with an already strong enforcement environment (UK, France, etc.), (4) will hold. A further increase in λ will lead to a direct increase in the probability of payment as estimated by the seller. However, in a country with a low λ, the firm's beliefs regarding the trustworthiness of its trading partner are very sensitive to changes in the quality of institutional enforcement environment. Hence a small improvement in the enforcement will delay the establishment of a reputation for the buying government by delaying $a_\tau'^k$ climbing upwards away from the prior belief. Hence there are *'increasing returns to the institutional quality'* (Araujo and Ornelas, p. 20) in terms of updating the perception of the probability of payment.

Successful rescues of endangered contracts (like the externally mediated rescue of the Cambodian airport concession described in de Brux, 2008[11]) can result in the substantial increase in the prior belief a_τ', that will be the starting point in a future contract. Hence there is an important *cross contract externality* in that the history of a previously successful contracts will confer significant benefits on subsequent contracts in terms of increasing the starting value of a_τ', thus making further updates desirable, but less crucial than before. If this is combined with a subsequent increase in λ it will lead to a substantial upward revision in the probability of payment a_τ^k.

The discussion above illuminates the discussion in section 2. It is clearly ideal to have a combination of a high λ with a high a_τ' so that each complements the other for any given contract. However, it also helps to explain why within the historical context of each country, the establishment of high personal trustworthiness by a government usually precedes the development of strong

[11] De Brux and others provide evidence that successful renegotiation can be welfare enhancing, rather than welfare reducing as typically perceived in the standard bargaining theory. See de Brux (2008) for a full set of references and a discussion of welfare improving renegotiations - usually achieved via the involvement of an external entity to the contracting parties.

commercial courts and regulatory or quasi-regulatory institutions, rather that the other way round. Initially, for low trust countries, it takes a genuinely reforming and committed government to want to establish trustworthiness and be willing to 'break' with the past to do so. Then this will be followed by the establishment of legal and regulatory institutions by that government or a similarly minded successor. Such actions will strengthen enforcement institutions (i.e. increase λ) and as positive experiences with these institutions accumulates, it will make the success of future contracts less government specific. In particular, it raises the costs for future governments of reneging on contracts or on weakening established supporting institutions. This point is discussed further below.

The buying government's type

The government's own assessment of its trustworthiness is defined as a random variable b. This variable represents the probability of the favourable event $\varepsilon = \{the\ government\ pays\ the\ seller\}$ occurring, which, in turn, depends firstly on the degree of commitment by the government to honour the contract and, secondly, on the level of contract enforcement in that country. Following Myerson (1979), the level of commitment by the government is assumed to be a variable state of nature, which is defined broadly enough to include all subjective unknowns which might influence it.

A country where a government has entered into arrangements with private (particularly foreign) investors either without total commitment or where political and/or economic polarization means that future governments may renege on the commitment[12], is mostly likely to have a b markedly less than 1. Either of these introduces major uncertainties concerning the performance of the contract in the future. Governments may go down this road because of insufficient tax revenue to fund preferred public sector options, because of political and economic pressure from a higher level of government, or as a condition for international lending or aid assistance. Other possibilities are where political opposition to private investment in infrastructure increases over time so that the political costs to the government of maintaining the private investment contracts gradually increase, or where there are federal-state level conflicts and where there are known but under-stated domestic and/or international debt and exchange rate risks. All of these are likely to be associated with a low value of b.

We would normally expect that government commitment to an infrastructure contract would be affected by the level of enforcement at time τ, λ_τ, since a government would be unlikely to enter a contract with a low probability of paying if it knew that it is very likely that it would be forced to pay the contract by the mechanisms in place. Hence we would expect b to be an increasing function of λ.

[12] Examples include Venezuela pre and post the Chavez presidency and the Chad government's actions to suspend the Future Generations Fund to collect earmarked savings from oil sales.

From the arguments above, governments can have a strong incentive to inflate the true actual value of b. But even if the government truthfully reveals this value - and we shall assume initially that this is the case - clearly a and b can differ even when they are both common knowledge.

Disagreement on mutual beliefs can occur among rational agents if the agents have different priors (Aumann 1976) and they follow a different process of updating or forming such beliefs. The main case in the analysis that follows is the undertrusting case where $a < b$ and b is a fair representation of the governments's expectation that it will meet its obligations under the contract, while overtrusting is also mentioned as a case where either from the outset, or more likely as a result of updating during the life of the contract, a is larger than b.

Types of contracts

Much of our attention in subsequent sections is on hybrid contracts. Following Athias and Saussier (2006), we take these to be neither fully flexible nor totally rigid. The latter reflects the inability of the investor in a rigid contract to reliably predict investment outcomes (both investment costs and revenues arising). Major forecasting errors and/or major shocks cause significant maladaptation costs, which can be positive (e.g. where demand is much higher than predicted for a toll road) as well as negative (e.g. substantive investment cost overruns or unexpectedly low demand).

In subsequent sections, we analyse the dynamics of trust perceptions with flexible contracts, rigid contracts and hybrid contracts. We denote the degree of flexibility of the contract by $(1 - \eta)$. We define fully flexible contracts as those where $\eta = 0$. This arises when a post-signing change in contract terms, and/or a renegotiation is certain to occur. Note that we designated pre-specified regulatory reviews as renegotiations for the purpose of defining a flexible contract.[13] For fully rigid contracts, $\eta = 1$. This arises where post-investment changes in contract terms and/or renegotiations are totally excluded. For *hybrid* contracts, (i.e. those where there is some positive expectation of post-investment changes in contract terms and/or renegotiations), $0 < \eta < 1$, with a greater degree of rigidity as $\eta \to 1$.

Any change in investment plans in an originally rigid contract is to be considered as a renegotiation. Pre-set periodic regulatory reviews are also treated as a renegotiation as they examine and typically modify investment requirements as well as unscheduled regulatory tariff reviews. This choice is important as it determines whether infrastructure contracts within an explicit regulatory framework but with periodic reviews at a periodicity as specified in the contract or equivalent are treated as fully flexible contracts or as hybrid contracts. On our definition, they are fully flexible contracts but with k, the updating period, relatively long e.g. each increment in k corresponding to 1-5 years and this is what we have in mind in what follows. Of course, most regulatory systems allow for interim reviews in cases of extreme maladaptation and that increases the flexibility.

[13] This is slightly different from the definition in Guasch (2004).

However, each increment of k can be a short time period, of a fortnightly, monthly or even more frequent form. However, in cases where each period in k is genuinely this short, the notion of a genuinely pre-determined infrastructure contract with periodic renegotiation has collapsed into a pure relational contract comparable to many private sector relational contracts between companies and their suppliers. This seems to be the position in countries where the contracting parties meet regularly on a monthly or similar basis to review progress and revise plans, including investment plans. We have in mind the arrangements observed in the 'behind closed doors' discussions between governments and contractors for infrastructure contracts in some Central American and African countries.

That leaves hybrid contracts. In our modeling, hybrid infrastructure contracts (i.e. those where the probability of renegotiation, $(1-\eta)$, is positive but less than 1) are infrastructure contracts where renegotiation is possible post investment but not pre-scheduled. This would cover concession contracts and PPPs without an external regulatory or quasi-regulatory entity. It would also cover those infrastructure contracts where a regulatory review is possible but not obligatory. If both parties have to agree to a review, the contract is more rigid; if a review follows an application by either party, it is more flexible.

In what follows, we first consider three types of fully flexible contracts. We then look at rigid contracts and finally, at the hybrid contract, where there is a positive probability of ex post renegotiation. The three types of flexible contracts that we consider are:

1. The Athias and Saussier flexible contract model, but including our trustworthiness parameters a and b.

2. The same model with a guaranteed pre-payment mechanism.

3. A benchmark, incentive compatible "F-contract" model with prepayments.

We show that in the third model the optimal solution sets prepayment terms such that the total surplus split between the infrastructure company and the government is identical to the one found in A&S, where trustworthiness terms are absent from the model. Note that this is very different from the solutions obtained with all the other models presented in this paper. We conclude by comparing the efficiency of the hybrid model to the first flexible contract model.

We now turn to the formal analysis where, in each of the subsequent discussions we analyse the bargaining model that corresponds to each of the above models. The time line of the models is as follows:

$<\tau$	τ	$\tau+k, k>0$
Type of contract	Investments and pay are set	Updating of investment and pay
and payment provisions	on the basis of the	decisions in flexible and flexible
are chosen and signed	realised values of	with prepayments contracts
	a, b, and λ at time τ.	Renegotiation may occur $(1-\eta)$
	Prepayments (if any) are also set	in rigid contracts

3.1 Flexible contracts

Let us start with the flexible contracts where we include into the expected payoff functions the parameters a and b as announced respectively by the seller (investing firm) and the buyer (government).

The firm's expected profit function and the expected consumer surplus[14] are given by the following functions respectively:

$$\begin{aligned} \Pi^f &= P_0 - C_0 + at - i \\ CS^f &= B_0 - P_0 + \overline{f}R(i) - bt \end{aligned}$$

where B_0 and C_0 are positive constants representing, firstly, the social benefits and, secondly, the costs of providing the basic service without any investment. t denotes the amount of payment going to the firm following renegotiation between the company and the government on how the surplus $R(i)$ ($R' > 0, R'' < 0, R''' < 0$) created by the investment i undertaken by the firm will be shared between the two parties. $\overline{f}$ and α are inverse measures of the cost of renegotiation and of the degree of asset specificity respectively. If $\alpha = 0$ then the investment is wholly sunk and hence has no opportunity cost. Therefore, $r(i) = \alpha R(i)$ is the proportion of the surplus $R(i)$ which is not sunk and hence has an opportunity cost. For infrastructure industries, $r(i)$ is likely to have a low value. For notational simplicity we shall henceforth refer to expected profits and expected consumer surplus simply as profits and consumer surplus.

The Nash Bargaining solution will be used in the flexible framework to determine the payment going to the firm

$$(\overline{f}R(i) - bt)(at - r(i)) \tag{5}$$

The first parenthesis shows the net gain of the investment to the buyer, while the second parenthesis shows the yield to the seller after subtracting from the expected payment the opportunity cost of its investment.

The participation constraint for the firm to enter in a contract with the government in this country is

$$(a'_\tau + \lambda_\tau(1 - a'_\tau))\, t > i - P_0 + C_0 \tag{6}$$

The equation above clearly shows that the firm's decision to enter a contract with the government is *critically dependent on the prior belief* this company has regarding the government's trustworthiness at the time τ when the contract is to be signed and the state of the institutional environment at that time. As we have already discussed this prior may be the product of a history of previous concession contracts in that country the success of which will lead to the upward

[14] Here we assume that the government fully represents the interests of the consumers. If this full alignment hypothesis is dropped, then this can be easily reflected by the model by assigning appropriate weights to the consumer and producer surplus within the government's objective function.

revision of this prior, i.e. a positive externality of such contracts is internalised in the decision of whether to participate in this new infrastructure contract. As long as $a_\tau > \overline{a}$, where $\overline{a} = \frac{i-P_0+C_0}{t}$ the firm will invest.[15]

On the other hand since it is the firm that makes the investment and pays for it, the gain to the government is always positive. Therefore the contract, once in place, never violates the government's participation constraint.

The payment solution[16] at time $\tau + k$ is:

$$t^{f,k} = \frac{a_\tau^k \overline{f} R(i) + b\alpha R(i)}{2a_\tau^k b} = \frac{\overline{f} R(i)}{2b} + \frac{\alpha R(i)}{2a_\tau^k} \tag{7}$$

The equation above suggests that the lower a and b are, the higher is t, the value of the payment to the firm. However since the contract is flexible, this payment is updated in line with the values of trustworthiness perceptions. We have inserted the time superscript of the elapsed periods since commencement at time τ, in order to denote the stage in the update mechanism of the seller's belief regarding the buyer's trustworthiness. For brevity we have removed the subscript of the starting time in all variables except for a, where it is retained to distinguish a_τ^k from the prior belief of the probability of payment, $a_\tau = a'_\tau + \lambda_\tau(1 - a'_\tau)$. As we have already discussed λ and b may also change from time to time.

Conclusion 1 *Better trustworthiness of the government buyer as estimated by the seller and as perceived by the government for itself will lead to a lower t paid, and hence a better deal for the country in terms of its share of the revenue from the project.*

This result is confirmed econometrically in a recent paper by McMillan and Waxman (2007), where their evidence indicates that higher quality institutions lead to a larger share of the revenues from the investment accruing to the country. In a sense an increase in a and/or b corresponds to a reduction in the political risk premium and the cost of capital for a firm to accept a long duration contract with the government of a particular country. This reduction may

[15] Although not a possibility in our model, it is worth pointing out that if, for any reason, a_τ^k becomes less than $\overline{a}$, the investing firm's participation constraint is violated and the contract will collapse unless it can be successfully renegotiated so that once more $a_\tau^k > \overline{a}$. More relevantly, since a_τ^k is progressively updated each period, it is possible that, after a few successful periods, a_τ^k may come to exceed b if the latter has not increased by as much. This looks to be important in understanding how overtrusting can develop. Such an explanation would fit well with the experience of Argentina pre-2002 as well and the London Underground Tube and Metronet PPP collapse. There is a full discussion in the appendix (section 6) on the absolute and relative values of a and b with some illustrative examples.

[16] Clearly the investment will only take place if $\overline{f}R(i) - bt > 0$ and $at - \alpha R(i) > 0$. If both expressions of the product in (5) are positive we can apply a monotonic transformation of the expression into logarithms and easily check that both the FOC as well as the SOC are satisfied. Moreover in the case of undertrusting since $b > a$:

$$\overline{f}R(i) > bt > at > \alpha R(i)$$

be viewed as an increase in the government's bargaining power (as McMillan and Waxman argue), reflected by the increase in its share of the surplus.

Substituting the above result back into the expected profit and consumer surplus functions gives:

$$\Pi^{f,k} = P_0 - C_0 + \frac{a_\tau^k \overline{f} R(i)}{2b} + \frac{\alpha R(i)}{2} - i$$
$$CS^{f,k} = B_0 - P_0 + \frac{\overline{f} R(i)}{2} - \frac{b}{a_\tau^k}\frac{\alpha R(i)}{2}$$

These expectations are continuously revised over time as the seller updates its beliefs regarding the trustworthiness of the buyer, as well as a result of any changes in b. Also note that the lower are sunk costs (i.e. the higher is α), the higher are expected profits and the lower is the expected consumer surplus. The profit maximising level of investment for the firm is:

$$i^{f,k} \mid R'(i^{f,k}) = \frac{2b}{a_\tau^k \overline{f} + b\alpha} \tag{8}$$

Hence investment decisions taken by the firm are updated in accordance to its beliefs regarding the probability of payment by the buying government. It follows that as $R'' < 0$, $\frac{\partial i^{f,k}}{\partial b} < 0$ while $\frac{\partial i^{f,k}}{\partial \alpha}$, $\frac{\partial i^{f,k}}{\partial a_\tau^k}$, $\frac{\partial i^{f,k}}{\partial \overline{f}} > 0$. Total expected welfare at time $\tau + k$ is:

$$W^{f,k} = \Pi + CS = B_0 - C_0 + \left(\frac{a_\tau^k + b}{2b}\right)\overline{f}R(i^f) + \left(\frac{a_\tau^k - b}{2a_\tau^k}\right)\alpha R(i^{f,k}) - i^{f,k} \tag{9}$$

From (8) if $b > a_\tau^k$, then:

$$i^{f,k} \mid R'(i^{f,k})_{b>a_\tau^k} = \frac{2b}{a_\tau^k \overline{f} + b\alpha} > \frac{2b}{b\overline{f} + b\alpha} = \frac{2}{\overline{f} + \alpha} = i^f \mid R'(i^f)_{b=a_\tau^k<1} = i^f \mid R'(i^f)_{b=a_\tau^k=1} \tag{10}$$

Since $R' = \frac{2b}{a_\tau^k \overline{f} + b\alpha}$, it is easy to conclude that R' is an increasing function of b and a decreasing function of a_τ^k. As R' is an inverse function of investment (since $R'' < 0$), this means that investment and surplus are decreasing functions of b and increasing functions of a_τ^k. The above results indicate that

$$i^{f,k}_{b=a_\tau^k<1} = i^{f,k}_{b=a_\tau^k=1} \text{ and } R(i^{f,k}_{b=a_\tau^k<1}) = R(i^{f,k}_{b=a_\tau^k=1})$$

For high levels of investment and corresponding surplus what matters is that $b = a_\tau^k$ irrespective of whether absolute trustworthiness levels are high or low. Hence high levels of trustworthiness ($b = a_\tau^k = 1$) are not necessarily required to support optimal outcomes in investment and surplus, rather just *matching* values of b and a_τ^k.

Conclusion 2 *Untrustworthy agents can potentially transact as efficiently as trustworthy agents provided that they hold similar estimates of the buyer's commitment to the payment agreement in the contract, provided that these are above the necessary minimum level $\overline{a}$. If the updating mechanism of trustworthiness of the beliefs of the seller results into the buyer being trusted (by the seller) to carry off the payment to the degree that it deserves to be trusted (in terms of its commitment), then investment levels will be as high as when the probability of payment perceived by each side is one. Hence alignment of beliefs, rather than whether the buyer government is per se a trustworthy contracting party, is the most important issue in a fully flexible model.*

Conclusion 2 explains why some countries which are ruled by a tight and corrupt elite where a_τ^k and b are both low but matching, can still sustain private investment in sunk assets through renegotiation with a monopoly supplier (as in the case of some sub-Saharan African countries). Note that this model of matching expectations only works in flexible contracts as it depends on continuous updating and renegotiation, or within a relational contract arrangement.

Undertrusting adds a deadweight loss by making the expected welfare function directly dependent on α as indicated in (9). The higher α is (the lower sunk costs are) then the higher this loss is. Moreover the surplus following renegotiation is now multiplied by a factor $\frac{a_\tau^k+b}{2b}$ less than one, that measures the degree of undertrusting.

Conclusion 3 *Undertrusting is damaging not only because it reduces the investment and corresponding surplus accruing to the society, but also because it reduces the welfare expectations by which a decision authority would rank this contractual choice.*

Note that the opposite conclusion holds for overtrusting. Overtrusting directly increases expected welfare in the two ways mentioned above. This means that flexible contracts where overtrusting is present (normally if a_τ^k overshoots b as a result of uninterrupted updating in the former) will lead to big expected welfare gains in the short run. However they are likely to end in rapid contract collapse as soon as there is a realignment of expectations held by the investing companies to more realistic values (viz. Argentina in the late 1990s).

Theorem 1 *When renegotiation costs are sufficiently low and asset specificity sufficiently high, expected welfare is a decreasing function of the government's (buyer's) perception of its trustworthiness and an increasing function of the selling firm's perception of the government's trustworthiness.*

This holds when $\frac{\overline{f}}{\alpha} > \frac{b}{a_\tau^k} > 1$. *In other words for* $a_\tau^k \overline{f} > b\alpha$ ($b > a_\tau^k$), b (a_τ^k) *has a negative (positive) indirect impact on expected welfare, reinforcing the negative (positive) direct impact of the same parameter on the function.*

Proof. Please refer to the mathematical appendix. ■

As was shown earlier, if $b > a_\tau^k$, expected welfare W^f is smaller than it would be if b was reduced to equal a_τ^k (and vice versa). *Hence undertrusting reduces expected welfare, just as overtrusting increases it (albeit temporarily as mentioned earlier).* Such a result does not require complete trustworthiness, but rather only that $b = a_\tau^k$. We now turn out attention to an attempt to tackle the problem of trust misalignment with the use of prepayment contracts.

3.2 Prepayment contracts

As mentioned in page 5, prepayment contracts can be viewed broadly so as to include arrangements with partial risk guarantees, where the guarantee is against the opportunism that may arise from the side of the government/regulator.

For flexible contracts with prepayments, the Nash bargaining problem is:

$$(\overline{f}R(i) - P_0 - bt)(P_0 + a_\tau^k t - r(i))$$

which gives a payment solution:

$$t^{P_0,k} = \frac{a_\tau^k \overline{f} R(i) + b\alpha R(i) - (a_\tau^k + b)P_0}{2a_\tau^k b} \tag{11}$$

Substituting this back into the expected profit function and consumer surplus functions gives:

$$\begin{aligned} \Pi^{P_0} &= P_0 - C_0 + \tfrac{a_\tau^k \overline{f} R(i) + b\alpha R(i) - (a_\tau + b)P_0}{2b} - i = \\ &\tfrac{(b-a_\tau)P_0}{2b} + \tfrac{a_\tau^k \overline{f}}{2b} R(i) + \tfrac{b\alpha}{2b} R(i) - C_0 - i \\ CS^{P_0} &= B_0 - P_0 - \tfrac{a_\tau^k \overline{f} R(i) + b\alpha R(i) - (a_\tau + b)P_0}{2a_\tau^k} + \overline{f}R(i) = \\ &= B_0 + \tfrac{(b-a_\tau^k)P_0}{2a_\tau^k} + \tfrac{a_\tau^k \overline{f}}{2a_\tau^k} R(i) - \tfrac{b\alpha}{2a_\tau^k} R(i) \end{aligned}$$

A prepayment will be set on the basis of the values at time τ. The existence of a prepayment will clearly affect the participation constraint of the firm as $\overline{a}$ will now become $\overline{a} = \frac{C_0 + i - \frac{(b-a_\tau)P_0}{2b}}{t^{P_0}}$. As both expected profit as well as expected consumer surplus are increasing functions of the prepayment, this can be set at a maximum when there is an issue of undertrusting $(b > a)$:

$$P_0 = \tfrac{a_\tau \overline{f} R(i) + b\alpha R(i)}{a_\tau + b}$$

which if replaced into the above functions they become

$$\begin{aligned} \Pi^{P_0,k} &= \tfrac{(a_\tau + a_\tau^k)\overline{f}R(i) + \left[2b + (a_\tau - a_\tau^k)\right]\alpha R(i)}{2(a_\tau + b)} - C_0 - i \\ CS^{P_0,k} &= B_0 + \tfrac{(a_\tau + a_\tau^k)\left[b\overline{f}R(i) - b\alpha R(i)\right]}{2a_\tau^k (a_\tau + b)} \end{aligned}$$

The profit maximising level of investment at time $\tau + k$ is:

$$i^{P_0,k} \mid R'(i^{P_0,k}) = \frac{2(a_\tau + b)}{(a_\tau + a_\tau^k)\overline{f} + [2b + (a_\tau - a_\tau^k)]\,\alpha} \tag{12}$$

It is easy to check that $R'(i^{P_0,k})$ is decreasing in a_τ^k (for $\overline{f} > \alpha$), which combined with $a_\tau^k \geqq a_\tau$ means that it takes its maximum value for $R'(i^{P_0,k=0}) = \frac{a_\tau + b}{a_\tau \overline{f} + b\alpha}$. Clearly as $R' > 0$, $R'' < 0$ and $R'' < 0$, then since $b > a_\tau^k \geqq a_\tau$:

$$R'(i^{P_0,k>0}) \leqslant R'(i^{P_0,k=0}) = \frac{a_\tau + b}{a_\tau \overline{f} + b\alpha} < R'(i^{f,k=0}) = \frac{2b}{a_\tau \overline{f} + b\alpha}. \tag{13}$$

It follows that at time $\tau + k$ both the investment and the corresponding surplus in a prepayment contract are higher than at time τ, which in turn are higher than the investment and surplus in a flexible contract at time τ. The inequality reads as:

$$i^{P_0,k>0} \geqslant i^{P_0,k=0} > i^{f,k=0} \text{ and } R(i^{P_0,k>0}) \geqslant R(i^{P_0,k=0}) > R(i^{f,k=0}). \tag{14}$$

It is worth noting, that some of the appeal of a flexible contract may be restored over time if the trustworthiness of the government, as updated by the seller during the life of the contract, increases upwards over time (albeit in a snakes and ladders form). At sufficiently high levels of a_τ^k, the level of investment $i^{f,k>0}$ (which $\geqslant i^{f,k=0}$) may come to exceed first $i^{P_0,k=0}$, and then eventually even $i^{P_0,k>0}$ at the same time period. Therefore, at its later stages and if upwards trustworthiness updating has not been frequently interrupted, a lengthy flexible contract with no prepayments may look as a preferable option to the one with prepayments, in terms of the investment incentives the former provides.[17]

The expected welfare function at time τ ($k = 0$) is:

$$W^{P_0,k=0} = B_0 - C_0 + \overline{f} R(i^{P_0,k=0}) - i^{P_0,k=0} \tag{15}$$

We next calculate the impact of b on $W^{P_0,k=0}$, again through the split of the total derivative into a direct and an indirect effect. As the direct effect on expected welfare is clearly equal to zero at time τ, we get:

[17] Pre-payments may in practice involve an insurance premium paid to an agency that offers a regulatory risk or political guarantee. The cost of this insurance is not trivial and clearly rises the longer the period for which it is taken out. Hence, the optimal use of such guarantees is likely to be the minimum period necessary for a_τ^k to reach some desirable level after which the guarantee can be allowed to lapse (assuming it has not previously been called). Hence, the guarantee offers a way in which countries can raise their reputation more quickly but then revert to a standard flexible contract without guarantees. Consequently, we typically observe regulatory risk guarantees for 3-5 years or up to and including the period to the first periodic review by a new regulatory entity.

$$\frac{dW^{P_0}}{db} = \frac{\partial W^{P_0}}{\partial i^{P_0}}\frac{\partial i^{P_0}}{\partial b} = \frac{b(\overline{f}-\alpha)}{(a_\tau\overline{f}+b\alpha)}\frac{a_\tau(\overline{f}-\alpha)}{(a_\tau\overline{f}+b\alpha)^2R''(i^{P_0,k=0})} = \frac{ba_\tau(\overline{f}-\alpha)^2}{(a_\tau\overline{f}+b\alpha)^3R''(i^{P_0,k=0})}$$

which clearly is negative as $R''(i^{P_0}) < 0$. Hence again b has a negative impact on welfare in the case of a prepayment contract.

Similarly,

$$\frac{\partial W^{P_0,k=0}}{\partial a_\tau} = \frac{\partial W^{P_0,k=0}}{\partial i^{P_0,k=0}}\frac{\partial i^{P_0,k=0}}{\partial a_\tau} = \frac{b(\overline{f}-\alpha)}{(a_\tau\overline{f}+b\alpha)}\frac{b(a_\tau-\overline{f})}{(a_\tau\overline{f}+b\alpha)^2R''(i^{P_0,k=0})} = \frac{-b^2(\overline{f}-\alpha)^2}{(a_\tau\overline{f}+b\alpha)^3R''(i^{P_0,k=0})} > 0$$

Conclusion 4 *Under prepayment contracts, expected welfare is a decreasing function of the buying state's probability of payment, and an increasing function of the seller's estimate of receiving payment. The impact of each of these at time τ is limited only to their impact on the level of investment and neither affects the expected welfare function directly. As already noted the preference for a prepayment contract relative to a flexible one is decreasing in $a_\tau^{k=0}$.*

Theorem 2 *The higher the degree of undertrusting, the more efficient are prepayment contracts compared to flexible contracts.*

Proof. Please refer to the mathematical appendix. ■

This gives us a preference relation for the decision maker between the two types of contracts, defined in a similar way to that of Myerson relating prizes (here welfare) to variable states of nature (here the occurrence of full payment), where the latter encompasses all subjective unknowns which might influence the prize to be received.

Issues of incentive compatibility can exist in flexible contracts. In particular, it may be beneficial for the buyer to declare an overestimate of his commitment to pay given that this will reduce the share of the payment that goes to the firm. Note that, even with the context of a prepayment contract the buyer may still have an incentive to overstate b.

Theorem 3 *Both the flexible payment contracts and the flexible prepayment contracts are not always incentive compatible as buyer governments have a significant incentive to exaggerate their stated trustworthiness.*

Proof. Please refer to the mathematical appendix. ■

Therefore the buyer has an incentive to overstate his trustworthiness in both types of contracts (flexible pure and flexible pre-payment) as long as the adverse impact that an inflated b has on investment is not so detrimental for it to more than offset any direct gains accruing to the buyer by overstating his trustworthiness.

3.3 F-contracts

If we drop the assumption that the buyer will always honestly declare its estimate of its own trustworthiness, then in this case it will be more appropriate to use an F-prepayment contract of the form:

$$F = (\overline{f}R(i) - P_0 - bt)^{a_\tau^k}(P_0 + a_\tau^k t - r(i))^b$$

Such a contract allows the trustworthiness declared by each party to affect the payoff of the other party. *This approach with the addition of prepayments makes the payoffs going to both parties independent of the trustworthiness parameters.* As we will show below, the impact of undertrusting on investment and welfare can be eliminated by establishing an F-contract.

The relevance of this model is not as a real world possible contract but in its role as a hypothetical benchmark. However, it is probably not an unreasonable representation of a repeated infrastructure contract in a developed country (e.g. the twentieth toll road or water concession in France or licences for the fourth major UK privatized infrastructure industry.) As we have seen flexible contracts become more difficult to agree and sustain as $\frac{b}{a_\tau^k}$ increases, because such contracts are no longer incentive compatible. The level of efficiency as measured by welfare, achieved by the benchmark F-contract model is only possible in the pure flexible and flexible prepayment contracts when $a_\tau^k = b$.

For F-contracts, the payment solution is determined by maximising F with respect to t:

$$t = \frac{\overline{f}R(i) + \alpha R(i) - 2P_0}{a_\tau^k + b} \tag{16}$$

$$\Pi^{PF} = P_0 - C_0 + a_\tau^k \tfrac{\overline{f}R(i)+\alpha R(i)-2P_0}{a_\tau^k+b} - i = \tfrac{(b-a)P_0+a_\tau^k\overline{f}R(i)+a_\tau^k\alpha R(i)}{a+b} - C_0 - i$$

$$CS^{PF} = B_0 - P_0 - b\tfrac{\overline{f}R(i)+\alpha R(i)-2P_0}{a_\tau^k+b} + \overline{f}R(i) = B_0 + \tfrac{(b-a_\tau^k)P_0+a_\tau^k\overline{f}R(i)-b\alpha R(i)}{a_\tau^k+b}$$

As both of the above functions are increasing functions of the prepayment amount, the latter needs to be increased as the level of undertrusting ($b > a_\tau^k$) increases. This eliminates the incentive for the state to announce a trustworthiness higher than its true one in order to improve its share of consumer surplus as the prepayment is:

$$P_0 = \tfrac{\overline{f}R(i)+\alpha R(i)}{2}$$

which is independent of both a and b. This means that the prepayment is *time independent*. If replaced into the expected profit and consumer surplus functions these also become time independent and respectively equal to:

$$\Pi^{PF} = \tfrac{(a_\tau^k+b)(\overline{f}R(i)+\alpha R(i))}{2(a_\tau^k+b)} - C_0 - i = \tfrac{\overline{f}R(i)}{2} + \tfrac{\alpha R(i)}{2} - C_0 - i$$

$$CS^{PF} = B_0 + \tfrac{(a_\tau^k+b)\overline{f}R(i)-(a_\tau^k+b)\alpha R(i)}{2(a_\tau^k+b)} = B_0 + \tfrac{\overline{f}R(i)}{2} - \tfrac{\alpha R(i)}{2}$$

The prepayment profit maximising level of investment is:

$$i^{PF} \mid R'(i^{PF}) = \frac{2}{\overline{f} + \alpha} \tag{17}$$

$$W^{PF} = B_0 - C_0 + \overline{f}R(i^{PF}) - i^{PF} \tag{18}$$

We see that the investment decision within an F-contract is identical to the one in the A&S model, and similarly the payments to the seller and the buyer are independent of the trustworthiness parameters. *The F-contracts fully avoid the implications of trustworthiness by introducing a system of prepayments such that both the direct as well as the indirect effects of such parameters are eliminated. This also means that the investment decisions taken by the firm are not dependent on the updating mechanism of the seller's beliefs regarding the trustworthiness of the buyer.*

The key point is that the payments in the A&S model have now become prepayments in the F-contracts. Hence, while the A&S model might be a not unreasonable characterization of repeat infrastructure contracts in OECD countries with strong institutions and good prior histories, they omit key features related to trust perceptions that are critical both in uncertain new contracts (e.g. the first prison PPP in any country) and many features that are crucial for mobilizing private investment in developing countries.

Theorem 4 *The higher the degree of undertrusting, the more efficient an F-contract compared to a flexible one and to a flexible prepayment one.*

Proof. Please refer to the mathematical appendix. ■

Using expected welfare as a criterion, if $a_\tau^k < b$, for $k \in [0, 1, 2, ...]$ an F-contract will rank as superior to the other two types of flexible contracts.

3.4 Rigid contracts

We define rigid contracts as those that specify the main contract terms (e.g. prices, payments, etc.) in advance of the investment – and for the duration of the contract. In addition, the contract permanently specifies the level of the investments to be made.

Renegotiation is excluded from the theoretical model. However, in practice, renegotiation cannot be excluded and is common – not least to rescue projects where one or both parties finds emerging outcomes becoming unacceptable. Hence, the pure model is again, to a considerable extent, a hypothetical reference model.

The model incorporates some of the rigidity implications via the introduction of 'maladaptation' costs, which are defined as the difference between expected surplus levels and actual (outcome) surplus levels. The impact of maladaptation costs, $\underline{f}$, falls on investment levels; the way in which this happens is explained directly below. However, higher than expected maladaptation costs will inevitability increase the probability to renegotiate a rigid contract. This latter issue is discussed in subsection 3.5, while here we temporarily assume that such a probability is equal to zero.

In this model, the expected payoffs are:

$$\Pi^r = P_0 - C_0 + a_\tau \underline{f} R(i) - i$$
$$CS^r = B_0 - P_0 + (1 - \underline{f} b) R(i)$$

The value of the maladaptation parameter, $\underline{f} < 1$, is an inverse measure of the potential size of the investor's loss over the distribution of outcomes; e.g. actual versus expected traffic flows for toll roads. This parameter in our model is multiplied by the investor's expectation a_τ that the buyer will pay him the surplus agreed in the contract. Correspondingly, the surplus received by the purchasing government is increased by this investor's loss.

The firm will choose an investment level i^r such that:

$$i^r \mid R'(i^r) = \frac{1}{a_\tau \underline{f}} \tag{19}$$

So in this case the level of investment *only depends on the prior belief held by the seller regarding the trustworthiness of the buyer,* a_τ, and is not affected by any updating process regarding the trustworthiness of the buyer government.

In this model, expected welfare is:

$$W^r = \Pi^r + CS^r = B_0 - C_0 + \left[1 + (a_\tau - b)\underline{f}\right] R(i^r) - i^r \tag{20}$$

As in the case of flexible uncertain contracts, W^r is a decreasing function of b. It is also an increasing function of a_τ. For the case of $a_\tau = b$, the maladaptation costs only influence welfare indirectly (through their impact on investment). If $b > a_\tau$ (undertrusting) then the direct impact of $\underline{f}$ is negative and constitutes a deadweight loss, while in the reverse case of overtrusting its direct impact on welfare is positive.

The government's own perception of its trustworthiness only has a direct effect on welfare, as investment is not affected by b. Hence:

$$\tfrac{dW^r}{db} = -\underline{f} R(i^r) < 0$$

The impact of a_τ on expected welfare still retains both a direct and an indirect effect:

$$\tfrac{dW^r}{da_\tau} = \tfrac{\partial W^f}{\partial a_\tau} + \tfrac{\partial W^r}{\partial i^r}\tfrac{\partial i^r}{\partial a_\tau} = \underline{f} R(i^f) + \left[\tfrac{1+(a_\tau - b)\underline{\underline{f}}}{a_\tau \underline{f}} - 1\right] \tfrac{\partial i^r}{\partial a} \Leftrightarrow$$
$$\tfrac{dW^r}{da_\tau} = \underline{f} R(i^f) + \tfrac{1 - b\underline{\underline{f}}}{a_\tau \underline{f}} \tfrac{\partial i^r}{\partial a_\tau} > 0$$

In other words, with undertrusting W^r is an increasing function of a_τ, i.e. an increasing function of the seller's prior belief regarding the trustworthiness of the buying state. Unlike the flexible uncertain payment contracts, here the *actual* size of the parameter a_τ does matter on investment since if $a_\tau = b < 1$:

$$i^r \mid R'(i^r)_{b=a_\tau<1} = \frac{1}{a_\tau \underline{f}} > i^r \mid R'(i^r)_{b=a_\tau=1} = \frac{1}{\underline{f}} \Leftrightarrow i^r_{a_\tau=b<1} < i^r_{a_\tau=b=1} \quad (21)$$

This implies that $R(i^r)_{b=a_\tau<1} < R(i^r)_{b=a_\tau=1}$.

In summary, for rigid contracts matching estimates of trustworthiness are still important, but in this case, unlike the flexible contract case, the *absolute level* of the prior belief a_τ is important and needs to be high. Good outcomes on efficiency and investment require both a_τ to be close to one, as well as aligned values between b and this prior belief. Hence, the sustainability of rigid contracts and the investment and expected welfare outcomes of such contracts depend considerably more on prior trustworthiness and institutional quality than do flexible contracts; they also require an alignment of perceptions from the outset of the contract since there can be no updating of perceptions as it happens in flexible contracts.

3.5 Hybrid contracts

We finally analyse the hybrid model, where there is always some positive probability that subsequent to investment taking place, rigid contracts will be renegotiated, and/or key terms reset. The key issues that we explore in this section are the relative efficiency (in terms of welfare) between flexible and hybrid models in terms of the values of key parameters namely: i) maladaptation costs, ii) the probability of renegotiation of an *ex ante* rigid contract, iii) sunk costs and iv) renegotiation costs.

We follow the terminology of A&S and denote by $(1-\eta)$ the probability that an *ex ante* rigid contract will be renegotiated[18]. We calculate the profit function of the firm as:

$$\Pi^H = \eta \Pi^r + (1-\eta)\Pi^f =$$

$$= \eta\left(P_0 - C_0 + a_\tau \underline{f} R(i) - i\right) + (1-\eta)\left(P_0 - C_0 + \tfrac{a_\tau^k \overline{f} R(i)}{2b} + \tfrac{\alpha R(i)}{2} - i\right) \Leftrightarrow$$

$$\Pi^H = P_0 - C_0 + a_\tau R(i)\left(\eta \underline{f} + \frac{(1-\eta)a_\tau^k \overline{f}}{2ba_\tau} + \frac{(1-\eta)\alpha}{2a_\tau}\right) - i \quad (22)$$

The profit maximising level of investment at time $\tau + k$ will be:

$$i^{H,k} \mid R'(i^{H,k}) = \frac{2}{\eta(2a_\tau \underline{f} - \frac{a_\tau^k}{b}\overline{f} - \alpha) + \frac{a_\tau^k}{b}\overline{f} + \alpha} = \frac{2b}{2\eta a_\tau b \underline{f} + (1-\eta)(a_\tau^k \overline{f} + b\alpha)} \quad (23)$$

[18] One-off renegotiation or renegotiation by review other than pre-scheduled regulatory review.

So when $\eta = 1$, the results are identical to those of a rigid contract as the government can credibly commit not to renegotiate the contract, while for $\eta = 0$ they coincide with those in the flexible model discussed in the beginning of this paper. We focus on the hybrid case where $0 < \eta < 1$.

Calculating the difference between the hybrid and the flexible contracts,

$$CS^{H,k} = \eta CS^r + (1-\eta)CS^f = \eta\left(B_0 - P_0 + (1-\underline{f}b)R(i)\right) + \\ +(1-\eta)\left(B_0 - P_0 + \frac{\overline{f}R(i)}{2} - \frac{b}{a_\tau^k}\frac{\alpha R(i)}{2}\right) = \\ B_0 - P_0 + \left(\eta(1-\underline{f}b) + (1-\eta)\frac{\overline{f}}{2} - (1-\eta)\frac{b}{a_\tau^k}\frac{\alpha}{2}\right)R(i)$$

Hence the expected welfare outcome in the hybrid contract at time $\tau + k$, $W^{H,k}$, is:

$$W^{H,k} = B_0 - C_0 + \left[\eta + \eta\underline{f}(a_\tau - b)\right]R(i^{H,k}) + (1-\eta)\alpha\frac{a_\tau^k - b}{2a_\tau^k}R(i^{H,k}) + \\ +(1-\eta)\overline{f}\frac{a_\tau^k + b}{2b}R(i^{H.k}) - i^{H,k}$$

If we calculate the difference between the expected welfare in a hybrid contract and the expected welfare in a flexible contract we get:

$$W^{H,k} - W^{f,k} = \eta + \eta\underline{f}(a_\tau - b)R(i^{H,k}) + \left[\overline{f}\frac{a_\tau^k + b}{2b} + \alpha\frac{a_\tau^k - b}{2a_\tau^k}\right]\left[(1-\eta)R(i^{H,k}) - R(i^{f.k})\right] + \\ + i^{H,k} - i^{f,k} \tag{24}$$

We next calculate the impact on this difference of all the parameters, namely $\overline{f}, \underline{f}, \alpha$ and η. We present the direct and indirect effects (through investment) of all these parameters in the appendix. The results lead us to the following conclusions:

Proposition 1 *Using expected welfare as a criterion, for $a_\tau^k\overline{f} > b\alpha$ and $\eta > 0$, the lower are maladaptation costs (the higher is $\underline{f}$), the more efficient is the hybrid model relative to the flexible one. But if the negative direct effect on welfare comes to dominate the positive indirect one on investment, then the flexible model is more efficient relative to the hybrid one.*

Proof. Please refer to the mathematical appendix. ■

The proposition above may well help explain why contracts without external regulatory or quasi-regulatory review are more difficult to sustain the higher is uncertainty regarding costs and revenues, as it is the degree of uncertainty that largely determines the scale of maladaptation costs. Moreover note how the existence of undertrusting gives rise to the requirement that sunk costs are sufficiently high and renegotiation costs sufficiently low for $a_\tau^k\overline{f} > b\alpha$ to hold;

a condition more demanding than in the corresponding proposition in the A&S paper, where the necessary condition was that $\overline{f} > \alpha$. Our analysis in the appendix shows that the assumption $a_\tau^k \overline{f} > b\alpha$ implies that the impact of investment on expected welfare is positive for both types of contracts $\left(\frac{\partial W^H}{\partial i^H}, \frac{\partial W^f}{\partial i^f} > 0\right)$.

Specifically, the gap between $\overline{f}$ and α needs to be sufficiently high so that when the former is multiplied by the updated belief of the firm regarding the probability of pay by the government, $a_\tau^k < 1$, and the latter by b ($> a_\tau^k$), the inequality does not change its direction. The more pronounced undertrusting becomes (the higher the gap between b and a_τ^k is), the higher the difference between $\overline{f}$ and α needs to be for the proposition to hold.

In other words, the higher the level of undertrusting, the less likely is the hybrid contract to be more efficient. This is because an increase in the gap between b and a will make the inequality $a_\tau^k \overline{f} > b\alpha$ increasingly more difficult to sustain. If it becomes unsustainable and $a_\tau^k \overline{f} < b\alpha$, then the positive impact of $\underline{f}$ on expected welfare will be far smaller and, possibly, even negative. Hence substantial undertrusting may turn the tables in favour of the flexible contract.

The next three propositions, which are all formally set out, proved and analysed in the mathematical appendix, set the preference relations for a decision maker between the hybrid and the flexible contract based on expected welfare.

Proposition 2 argues that the lower the probability to renegotiate is, the more efficient is a hybrid contract compared to a flexible one. Undertrusting lessens the positive impact of η on the expected welfare superiority of the hybrid contract. The direct effect of η may be negative; if this is the case it will reduce or even dominate the positive indirect effect of η on welfare. So extensive undertrusting reduces the strength of this proposition and may even come to reverse it.

Proposition 3 argues that the lower the asset specificity the more efficient a flexible contract compared to a hybrid one. As long as we restrict the direct negative impact of a higher α on the expected welfare of a hybrid contract to be larger (in absolute terms) than the same impact on a flexible contract (this can be done by assuming a sufficiently low η), the direct effect further reinforces the welfare superiority of the flexible contract as established in terms of the indirect effect.

Finally, according to proposition (4), provided that η is sufficiently large for the positive direct effect of $\overline{f}$ on expected welfare to be larger in a flexible rather than a hybrid contract, this direct effect will reinforce the indirect effect in supporting the argument that the expected welfare superiority of the flexible model will increase as $\overline{f}$ increases.

4 CONCLUSIONS

We believe that our approach to the sustainability of long-run infrastructure contracts (defined in the widest sense i.e. to include licences, franchises, etc.)

based on trust levels and the relative alignment of trust perceptions between seller companies and buyer governments sheds considerable light on some much debated issues in infrastructure provision involving private investment. In particular, it provides a new perspective on the relative merits of Demsetz franchise contracts relative to external regulation as discussed in Littlechild (2002). It also provides a new perspective on the supposed benefits of rigidity in infrastructure contracts, especially rigid contracts in difficult environments, as advocated by Spiller and others.

Our modeling shows that infrastructure contracts are subject to serious time inconsistency problems unless model assumptions are chosen so that these are prevented, as is the case in the Athias and Saussier (2006) model. In general, the expectations of sellers that contracts will be fully honoured by buyers need not be the same as those of buyer governments. Sellers' expectations of buyer government's performance will typically be lower, hence giving rise to undertrusting, particularly for new types of contract, new regulatory or similar institutions as well as for infrastructure contracts in countries with little previous experience, etc.

The greater the misalignment of trust perceptions (i.e. the greater the gap between initial seller and buyer perceptions of buyer government trustworthiness), the higher the problem of suboptimal outcomes in investment and reduction in welfare expectations regarding infrastructure contracts. However, as we show in our model, expectations can be updated over time with experience, both directly and via the development of institutions that operate to support contracts. A wide range of institutions is relevant to this including country governance institutions such as law courts and others. However, an important relevant one is whether or not there are effective external and autonomous regulatory or quasi regulatory entities that can review and, where necessary, modify infrastructure contracts under due process.

If such institutions exist and operate (including being allowed to operate) effectively, then they can do much to help improve the payment reputations of governments. Of course, they may not be able (or allowed) to operate in this way – and this is the case in many countries – but, where they can and do, they provide an important additional component in sustaining trust between infrastructure suppliers and country governments, in developed as well as in developing countries.

Our approach here builds on the transactions cost model of Williamson and provides additional reasons to favour regulation rather than Demsetz franchise contracts for infrastructure – at least where there are any significant long-run uncertainties on revenues and costs. There are clear benefits to external regulation as it helps to reduce or eliminate initial moderate trust misalignments by raising absolute trust levels by establishing country payment reputation both directly, by increasing a_τ^k and, indirectly by increasing the degree of institutional quality λ. Both of these lead to a substantial upward revision in the probability of payment and hence reputation.

Regarding rigid contracts (defined as those with no procedure for revising investment requirements or for revising other conditions post-investment), we show that these are more difficult to sustain than flexible contracts. They require high absolute levels of trust as well as trust alignment between the parties. Precisely because they are fixed from the start, the contracts cannot benefit from update improvements in perceptions from successful operation in early contract periods. Hence, as is now well-known, tight contracts are very brittle in the face of shocks and renegotiation can be difficult.

Our model provides a theoretical underpinning to the skepticism about rigid contracts given high failure rates for such contracts in developing countries. Again, reputation – and the benefits of an effective regulatory regime and process involving bounded and accountable discretion - look to be superior to rigid contracts. The problem, though, is that the latter may not be achievable in difficult environments. Nevertheless, our model produces additional arguments against 'rigid-by-origin' infrastructure contracts in institutionally difficult environments.

The starting point for our modeling was the Athias and Saussier model. As noted above, this is constructed so that time inconsistent solutions do not arise. This is probably adequate for their purposes which were to explain renegotiation probabilities for toll roads contrasts in France and, with few exceptions some other OECD countries. Particularly on repeat contracts, one would expect few major trust misalignment issues. But, that does not apply either to infrastructure contracts for new topics (including PPPs) nor does it apply to most infrastructure contracts in middle and low income countries.

We have extended the A&S model so that it can not only handle variations in the absolute level of trust perceptions but can also address trust misalignments via a dynamic updating process. Hence, we have extended the model so that it covers the necessary institutional environment to sustain private (or privately funded) investment for new types of investment, new types of contractual arrangements and in countries where there is little previous history – or a record of previously problematic history. In addition, we have demonstrated how this is likely to be linked to the existence of an external regulatory entity.

The basic A&S model generally suits well infrastructure contracts with private investment where trust levels between buyers and sellers are high and there are no trust misalignments. However, our modeling suggests that for moderate undertrusting, flexible contracts, maybe with prepayment, particularly in first few years of contract are likely to be superior provided that the updating period - via pre-fixed regulatory or similar reviews - is relatively long (i.e. at least 1 year, preferably 3-5 years). For more serious undertrusting, the solution above may perhaps be successful but, particularly if accompanied by low absolute levels of trust, we suspect that the best chance to proceed is via fully flexible, quasi-relational contracts. Rigid contracts only seem worthwhile if there is little inherent uncertainty, particularly on post-investment revenues.

5 REFERENCES

Anderson, J. and Young, L. (2006), 'Trade and Contract Enforcement', The B.E. Journal of Economic Analysis & Policy, 5:1 (Contributions), article 30.

Araujo, L. and Ornelas, E. (2007), 'Trust-Based Trade', http://ssrn.com/abstract=642803

Athias, L. and Saussier, S. (2006), 'Contractual Design of Toll Adjustment Provisions in Infrastructure Contracts', Atom-U, Paris-Sorbonne, http://ssrn.com/abstract=828944

Aumann, R. (1976), 'Agreeing to Disagree', The Annals of Statistics, Vol. 4, pp 1236-1239.

Bolt, C. (2003), 'Regulating the London Underground, Beesley Lecture, www.ppparbiter.org.uk

Bolt, C. (2007), 'Regulating by Contract and by Licence – The Relationship between Regulatory Form and its Effectiveness', CRI Bath and www.ppparbiter.org.uk

Braynov, S. and Sandholm, T. (2002), 'Contracting with Uncertain Level of Trust', Computational Intelligence, Vol.18, No. 4, pp 501-514.

De Brux, J. (2008), 'The Dark and Blue Sides of Renegotiation: An Application to Transport Concession Contracts', Centre d' Economie de la Sorbonne, Universitė Paris 1 Panthėon Sorbonne.

Greif, A. (2006), Institutions and the Path to the Modern Economy: Lessons from Medieval Trade, Cambridge University Press.

Greif, A. (1993), 'Contract Enforceability and Economic Institutions in Early Trade: The Maghribi Traders' Coalition', American Economic Review, Vol. 83 (3) , pp 525-548.

Guasch, J.L. (2004), 'Granting and Renegotiating Concession Contracts: Doing It Right', World Bank Institute.

Guasch, J.L. and Straub, S. (2006), 'Renegotiation of Infrastructure Concessions: An Overview', Annals of Public and Cooperative Economics, Vol. 77, No 4.

Laffont, J.J. (2005), Regulation and Development, Cambridge University Press.

Levine, P., Stern, J. and Trillas, F. (2005), 'Utility Price Regulation and Time Inconsistency: Comparisons with Monetary Policy', Oxford Economic Papers, Vol. 57, pp 447-478.

Littlechild, S.L. (2002), 'Competitive Bidding for a Long-Term Electricity Distribution Contract', Review of Network Economics, Vol. 1, Issue 1, pp 1-38.

McMillan, M.S. and Waxman, A. (2007), 'Profit Sharing Between Host Countries and Multinationals in Natural Resource Extraction: An Empirical Investigation', Brookings Trade Forum.

McMillan, J. and Woodruff, C. (1999), 'Interfirm Relationships and Informal Credit in Vietnam', Quarterly Journal of Economics, Vol. 114, pp 1285-1320.

Macaulay, S. (1963), 'Non Contractual Relations in Business', American Sociological Review, Vol. 28 (1), pp. 55-70.

Menard, C. and Saussier, S. (2002), 'Contractual Choice and Performance: Water Supply in France', in E. Brousseau and J.M. Glachant (eds.) The Economics of Contracts: Theories and Applications, Cambridge University Press.

Myerson, R.B. (1979), 'An Axiomatic Derivation of Subjective Probability, Utility, and Evaluation Functions', Theory and Decision, Vol. 11, pp 339-352.

Spiller, P.T. (2008), 'An Institutional Theory of Public Contracts: Regulatory Implications, National Bureau of Economic Research, working paper 14152, http://www.nber.org/papers/w14152

Spiller, P. (2004), 'An Institutional Theory of Public Contracts', ISNIE Conference 2004.

Stern, J. (2005), 'Regulation and Contracts: The Inevitability of Discretion', CCRP Workshop, Barcelona, Spain.

Stern, J. (2003), 'Regulation and Contracts: Substitutes or Complements? Lessons from UK Historical Experience', Journal of Policy Reform, Vol. 6, No 4, December 2003.

Tirole, J. (2008) 'Cognition and Incomplete Contracts', American Economic Review, forthcoming.

Williamson, O.E. (1976) 'The Economics of Internal Organization: Exit and Voice in Relation to Markets and Hierarchies' American Economic Review, Vol. 66, No 2, pp 369-377.

6 APPENDIX - TRUST PERCEPTION VALUES AND ILLUSTRATIVE EXAMPLES

In the literature to date, there is no distinction between trust levels between investors and (buyer) governments. Indeed, the implicit assumption is that there is no misalignment between these two. However, this may be an unfortunate simplification.

The reality is not only that contracts are most likely to break down when there is such misalignment, but also that as we have theoretically shown it is unlikely to achieve incentive compatible contracts unless perceptions can be aligned either initially or during the course of the contract. That, in turn, may help explain whether infrastructure contracts that run into difficulties can be renegotiated between the parties and whether a regulatory or quasi-regulatory entity is likely to be necessary to sustain the viability of the contract.

Our conjecture is that in circumstances where the seller's perception of the reliability of the buyer is much lower than the buyer's, the contract is most likely to break down irrevocably. For contracts where the seller's updated perception of the buyer's reliability overshoots (is higher than justified given the buyer's type, e.g. there is overtrusting), contracts may continue satisfactorily until the misalignment is revealed at which point they are likely to fall apart rapidly. Conversely, contracts can survive where the levels of trust are low but perceptions are correctly aligned.

Some illustrative examples

The role of an external regulatory or similar entity may be crucial for continued operation of the contract. For undertrusting, de Brux (2008) provides a particularly striking example. She discusses the first worldwide airport concession which happened in the Kingdom of Cambodia, a country with a very weak judicial system, widespread corruption and no previous history of concession contracts . A French infrastructure company had a signed a concession contract in 1995 not just to run and extensively modernise the existing airport but also to build a new one. However, during the summer of 1997 the Asian economic crisis started to spread over Cambodia while, at the same time, a military insurrection took place in the capital of the country. Given the poor revenue outlook – and export protection of the original contract - the French infrastructure company was willing to walk away and the Cambodian government was also willing for the original contract to be terminated. However both parties, after months of renegotiation, successfully amended the contract – but only with the external mediating assistance of a French government representative. The success of the renewed contract (which is still in operation) came from the fact that both parties were persuaded by this external party to allow the spirit rather than the letter of the contract (which allowed termination of the agreement by either side under such extreme circumstances) to prevail. Cooperation through renegotiation prevailed over opportunism in this case, but only thanks to a quasi-regulatory review by an external party.

Another important similar – but bad outcome - example is given in Spiller (2008) regarding the water operation and management concession contract in the City of Atlanta. In this case, the operator claimed within a year or so of the start of the contract that the target and annual fees agreed were far too low and requested a renegotiation. Such a renegotiation would have had to have been directly between the parties - external regulatory review was not an option. However, because of the political costs of the renegotiation, the City of Atlanta preferred to take back the contract at a cost of $40 million/year on a $22 million/year contract. In this case, the problem was third-party opportunism rather than government opportunism leading to " a highly rigid contract forcing [the parties] to renegotiate or terminate" and, in this case, ending up in termination.

In the case of overtrusting, the issue is often that investing firms have exaggerate perceptions of the degree of the independence and power of a supposedly independent regulator. That can be argued for both Argentina and Hungary energy privatizations in the 1990s - and also, perhaps, for the failure of the London Underground Tube Metronet PPP in spite of the best efforts of the PPP Arbiter. Note that, in both cases, the contract had operated for some years in a new environment but with no serious need to test the credibility of the new regulatory entity (no news). In consequence, the seller's perceived trust that they would get paid in full in all circumstances appears to have overshot the true level and generated the overtrusting apparent at the point of crisis.

Trust perception cases; a typology

Most of the discussion on trust and most of the theoretical models in this field accept that a and b can be high or low depending on the country or project but, implicitly or explicitly assume that $a = b$. However, there are circumstances where a and b are both low (e.g. under 0.5) but both parties have the same perspective and hence private investment in infrastructure may be sustainable. Conversely, there may be circumstances where a and b are both relatively high (e.g. above 0.5) but a is sufficiently less than b so as to create a significant degree of mistrust.

Table 1
Perceptions of Trustworthiness

Case (A)	Case (C)
Repeat project and/or contract	New type of project or contract
Country with strong institutions	Country with strong institutions
and high trustworthiness reputation	and high trustworthiness reputation
$a = b, \;\; a, b \longrightarrow 1$ (*large*)	$a < b, \;\; a, b \gtrsim 0.5$ (*moderate*)
Case (B)	Case (D)
Repeat project and/or contract	New type of project or contract
Country with weak and/or	Country with past history of weak
corrupt institutions	and/or corrupt institutions but trying to
	establish reputation for trustworthiness
$a = b, \;\; a, b \longrightarrow 0$	$a < b, \;\; a, b < 0.5$ (*small*)

We can illustrate the arguments in our theoretical model - at least for undertrusting - by setting out a simple typology, based on a 4 quadrant table as in Table 1 above. We can then discuss some illustrative examples on each case as set in this table.[19]. Let us briefly consider each quadrant in turn.

Case (A) represents well-established types of project in high reputation countries. For many types of infrastructure concession contracts, trust is likely to be high and the contracting parties may well be able to monitor, enforce and revise their contracts straightforwardly, without a need for external assistance (other than occasionally for arbitration/dispute resolution or similar) or for 'prepayment' arrangements. Hence, private investment is readily forthcoming and at a reasonable cost of capital as perceived risk is low. Examples include repeat water supply management contracts in easy to access and process water (as in Menard and Saussier), repeat UK PPP contracts in politically uncontentious sectors, electricity distribution in Chile. This is a sustainable and efficient process that is potentially welfare maximising and which also corresponds to the A&S model.

Case (B) represents infrastructure contracts in countries with low quality institutions. Supplying companies can and do have supply contracts with governments in Latin America, Sub-Saharan Africa and elsewhere where government is arbitrary and/or corrupt – and liable to change on the replacement of the current autocrat.

The key point is that as previously discussed, these are essentially *relational* contracts where the monitoring, enforcement and revision is done between the two parties who know one another well. The contracts will only be sustainable if the supplier can expect to receive a return adjusted for higher risks and for any (potentially large) corruption payments – both buyer and seller may receive returns from corrupt practices. This process is sustainable (at least while the

[19] We discuss overtrusting below but it cannot be captured as in Table 1.

current parties continue in place) but it is highly inefficient and far from welfare maximizing.

Case (C) represents early and potentially difficult contracts in high reputation countries. In the UK, the London Underground PPPs were in this category as were the NATS air traffic control contract and early PPPs in hospitals and prisons. In these cases, to sustain the contract, it clearly helps to have an external regulatory entity – the PPP Arbiter for the London Underground, the Civil Aviation Authority for NATS.

Note that in most of these cases, there has been an explicit or implicit government guarantee providing a 'pre-payment' facility. There clearly are potential incentive compatibility problems so that breakdown is likely in the case of major disputes. But, provided the first contract (or first few years of the contract) go well and any major problems are addressed by successful renegotiation (as with NATS), subsequent contracts or periods should go well. This is because updating means that a_{τ}^{k} becomes equal to or close to b.

Most of these contracts faced not only significant political risk, but most also had serious construction, technology, and/or demand risks. The London Underground contracts also had major issues of ongoing rather than front-loaded investment. Interestingly, an early major success for UK PPPs was the Dartford bridge crossing of the River Thames. For that project, an effective and robust 'pre-payment' mechanism was put in place through allowing the duration of the concession to correspond to that necessary for the contractor to recover his principal and earn an agreed rate of return (i.e. an NPV contract).

Finally, Case (D) represents countries that start with poor reputations but are trying hard to obtain private investment into infrastructure e.g. into roads, power generation, sometimes water. To attract that investment, governments may pass concession laws, introduce independent regulators or allow external arbitration or similar. Examples of such countries include Uganda, Nigeria, Mozambique and Romania. Several of these also adopted pre-payment arrangements via regulatory risk guarantees.

However, supplying companies are likely to want a demonstrable record of achievement for those institutions before reducing their cost of capital risk premia. Hence, the private investment may not be possible – at least not at a cost that would be acceptable in terms of the final tariff. In these circumstances, private investment will only be forthcoming and sustainable if there is external support in place e.g. from an effective 'pre-payment' agreement as well as the eventual establishment of external regulatory or similar institutions. That is where transitional regulatory risk guarantees and other forms of external underpinning (e.g. on-demand guarantees, bilateral investment treaties, comprehensive credit insurance, etc.) can help align perceptions or relative trustworthiness.

If this process is successful and the country floats away from the (hopefully unused) pre-payment support, the result is an efficient equilibrium with realigned trust perceptions.

7 MATHEMATICAL APPENDIX

Proof of Theorem 1

We first show that $W^{f,k}$ is a decreasing function of b. To calculate the impact of b on $W^{f,k}$ we split this into a direct and an indirect effect; the latter evaluates the impact of b on $W^{f,k}$ via the impact of b on the level of investment. Hence:

$$\frac{dW^{f,k}}{db} = \frac{\partial W^{f,k}}{\partial b} + \frac{\partial W^{f,k}}{\partial i^f}\frac{\partial i^{f,k}}{\partial b} = -\frac{2a_\tau^k}{(2b)^2}\overline{f}R(i^{f,k}) - \frac{1}{2a_\tau^k}\alpha R(i^{f,k}) + \left[\frac{a_\tau^k+b}{2b}\overline{f}\frac{2b}{a_\tau^k\overline{f}+b\alpha} + \frac{a_\tau^k-b}{2a_\tau^k}\alpha\frac{2b}{a_\tau^k\overline{f}+b\alpha} - 1\right]\frac{\partial i^{f,k}}{\partial b} =$$
$$-\frac{2a_\tau^k}{(2b)^2}\overline{f}R(i^{f,k}) - \frac{1}{2a_\tau^k}\alpha R(i^{f,k}) + \frac{b(a_\tau^k\overline{f}-b\alpha)}{a_\tau^k(a_\tau^k\overline{f}+b\alpha)}\frac{\partial i^{f,k}}{\partial b} =$$
$$= -\frac{2a_\tau^k}{(2b)^2}\overline{f}R(i^{f,k}) - \frac{1}{2a_\tau^k}\alpha R(i^{f,k}) + \frac{b(a_\tau^k\overline{f}-b\alpha)}{a_\tau^k(a_\tau^k\overline{f}+b\alpha)}\frac{\frac{2a_\tau^k\overline{f}}{(a_\tau^k\overline{f}+b\alpha)^2}}{R''(i^{f,k})} \Leftrightarrow$$

$$\frac{dW^{f,k}}{db} = -\frac{2a_\tau^k}{(2b)^2}\overline{f}R(i^{f,k}) - \frac{1}{2a_\tau^k}\alpha R(i^{f,k}) + \frac{2\overline{f}b(a_\tau^k\overline{f}-b\alpha)}{(a_\tau^k\overline{f}+b\alpha)^3R''(i^{f,k})} \tag{25}$$

If $b > a_\tau^k$ (undertrusting) and $\frac{\overline{f}}{\alpha} > \frac{b}{a_\tau^k} > 1$, $\frac{\partial W^{f,k}}{\partial i^{f,k}} = \frac{b(a_\tau^k\overline{f}-b\alpha)}{a_\tau^k(a_\tau^k\overline{f}+b\alpha)} > 0$, and $\frac{\partial R'(i^{f,k})}{\partial b} = \frac{2a_\tau^k\overline{f}}{\left(a_\tau^k\overline{f}+b\alpha\right)^2} > 0$. The latter implies a negative impact of b on the level of investment $i^{f,k}$ since $\frac{\partial i^{f,k}}{\partial b} = \frac{\partial i^{f,k}}{\partial R'(i^{f,k})}\frac{\partial R'(i^{f,k})}{\partial b} = \frac{\frac{\partial R'(i^{f,k})}{\partial b}}{R''(i^{f,k})} < 0$. Therefore, b has a negative indirect impact on expected welfare, reinforcing the negative direct impact.

Similarly, we calculate the impact of a_τ^k on W^f:

$$\frac{dW^{f,k}}{da_\tau^k} = \frac{\partial W^{f,k}}{\partial a_\tau^k} + \frac{\partial W^{f,k}}{\partial i^{f,k}}\frac{\partial i^{f,k}}{\partial a_\tau^k} = \frac{1}{2b}\overline{f}R(i^{f,k}) + \frac{2b}{(2a_\tau^k)^2}\alpha R(i^{f,k}) + \left[\frac{a_\tau^k+b}{2b}\overline{f}\frac{2b}{a_\tau^k\overline{f}+b\alpha} + \frac{a_\tau^k-b}{2a_\tau^k}\alpha\frac{2b}{a_\tau^k\overline{f}+b\alpha} - 1\right]\frac{\partial i^{f,k}}{\partial a_\tau^k} =$$
$$\frac{1}{2b}\overline{f}R(i^{f,k}) + \frac{2b}{(2a_\tau^k)^2}\alpha R(i^{f,k}) + \frac{b(a_\tau^k\overline{f}-b\alpha)}{a_\tau^k(a_\tau^k\overline{f}+b\alpha)}\frac{\partial i^{f,k}}{\partial a_\tau^k}$$

As $\frac{\partial R'(i^{f,k})}{\partial a_\tau^k} = \frac{-2b\overline{f}}{\left(a_\tau^k\overline{f}+b\alpha\right)^2} < 0$, this implies a positive impact of a_τ^k on the level of investment $i^{f,k}$ since $\frac{\partial i^{f,k}}{\partial a_\tau^k} = \frac{\partial i^{f,k}}{\partial R'(i^{f,k})}\frac{\partial R'(i^{f,k})}{\partial a_\tau^k} = \frac{\frac{\partial R'(i^{f,k})}{\partial a_\tau^k}}{R''(i^{f,k})} > 0$.

Proof of Theorem 2

Taking the difference between $W^{P_0} - W^f$ at time τ ($k = 0$) and differentiating with respect to b gives:

$$\frac{\partial(W^{P_0}-W^f)}{\partial b} = \frac{2a_\tau}{(2b)^2}\overline{f}R(i^f) + \frac{1}{2a_\tau}\alpha R(i^f) - \frac{b(a_\tau\overline{f}-b\alpha)}{a_\tau(a_\tau\overline{f}+b\alpha)}\frac{\partial i^f}{\partial b} + \frac{b(\overline{f}-\alpha)}{(a_\tau\overline{f}+b\alpha)}\frac{\partial i^{P_0}}{\partial b} =$$
$$\frac{2a_\tau}{(2b)^2}\overline{f}R(i^f) + \frac{1}{2a_\tau}\alpha R(i^f) - \frac{2\overline{f}b(a_\tau\overline{f}-b\alpha)}{(a_\tau\overline{f}+b\alpha)^3R''(i^f)} + \frac{ba_\tau(\overline{f}-\alpha)^2}{(a_\tau\overline{f}+b\alpha)^3R''(i^{P_0})} =$$
$$= \frac{2a_\tau}{(2b)^2}\overline{f}R(i^f) + \frac{1}{2a_\tau}\alpha R(i^f) + \frac{b}{(a_\tau\overline{f}+b\alpha)^3}\frac{a_\tau(\overline{f}-\alpha)^2R''(i^f) - 2\overline{f}(a_\tau\overline{f}-b\alpha)R''(i^{P_0})}{R''(i^f)R''(i^{P_0})}$$

where since $R'', R''' < 0$ and $i^{P_0} > i^f$ we have that $R''(i^{P_0}) < R''(i^f) < 0$. Analogously,

$$\frac{\partial(W^{P_0}-W^f)}{\partial a_\tau} = \frac{-b^2(\overline{f}-\alpha)^2}{(a_\tau\overline{f}+b\alpha)^3 R''(i^{P_0})} - \frac{1}{2b}\overline{f}R(i^f) - \frac{2b}{(2a_\tau)^2}\alpha R(i^f) + \frac{2\overline{f}b^2(a_\tau\overline{f}-b\alpha)}{a_\tau(a_\tau\overline{f}+b\alpha)^3 R''(i^f)} =$$
$$= -\frac{1}{2b}\overline{f}R(i^f) - \frac{2b}{(2a_\tau)^2}\alpha R(i^f) - \frac{b^2}{a_\tau(a_\tau\overline{f}+b\alpha)^3}\frac{a_\tau(\overline{f}-\alpha)^2 R''(i^f) - 2\overline{f}(a_\tau\overline{f}-b\alpha)R''(i^{P_0})}{R''(i^f)R''(i^{P_0})}$$

Hence unless $\frac{\overline{f}^2-\alpha^2}{2\overline{f}\alpha} < \frac{b}{a_\tau} - 1$[20] and $-\frac{b^2}{a_\tau(a_\tau\overline{f}+b\alpha)^3}\frac{a_\tau(\overline{f}-\alpha)^2 R''(i^f) - 2\overline{f}(a_\tau\overline{f}-b\alpha)R''(i^{P_0})}{R''(i^f)R''(i^{P_0})} > \frac{1}{2b}\overline{f}R(i^f) + \frac{2b}{(2a_\tau)^2}\alpha R(i^f)$, we will have that $\frac{\partial(W^{P_0}-W^f)}{\partial b}$ is positive and $\frac{\partial(W^{P_0}-W^f)}{\partial a_\tau}$ negative. Hence as undertrusting increases because a_τ decreases and/or b decreases, a prepayment contract becomes more efficient in relation to a flexible contract.

Proof of Theorem 3

Let us assume a falsely declared beta (say b^{dl}) higher that the true beta (say b^{tr}). By totally differentiating the payment solution in (8) we get that:

$$\frac{dt^{f,k}}{db^{dl}} = \frac{\partial t^{f,k}}{\partial b^{dl}} + \frac{\partial t^{f,k}}{\partial i^{f,k}}\frac{\partial i^{f,k}}{\partial b^{dl}} = \frac{-\overline{f}R(i^{f,k})}{2(b^{dl})^2} + \left(\frac{1}{a_\tau^k}\right)\frac{\partial i^{f,k}}{\partial b^{dl}} < 0$$

Hence as

$$CS^{f,k} = B_0 - P_0 + \overline{f}R(i^{f,k}) - b^{tr}t^{f,k} \Leftrightarrow$$
$$\frac{dCS^{f,k}}{db^{dl}} = \overline{f}\frac{2b^{dl}}{a_\tau^k\overline{f}+b^{dl}\alpha}\frac{\partial i^{f,k}}{\partial b^{dl}} - b^{tr}\frac{dt^{f,k}}{db^{dl}} \Leftrightarrow$$

$$\frac{dCS^{f,k}}{db^{dl}} = b^{tr}\frac{\overline{f}R(i^{f,k})}{2(b^{dl})^2} + \frac{1}{a_\tau^k\overline{f}+b^{dl}\alpha}\frac{(2\overline{f}a_\tau^k b^{dl} - \overline{f}a_\tau^k b^{tr} - b^{tr}b^{dl}\alpha)}{a_\tau^k}\frac{\partial i^{f,k}}{\partial b^{dl}} \tag{26}$$

As $\overline{f} > \alpha$ and $1 \geqslant b^{dl} > b^{tr}$, the term in the brackets is positive and hence the overall indirect effect is negative. Hence the buyer has an incentive to overstate his trustworthiness as long as the impact of an inflated b on investment is not so detrimental as to substantially reduce both i and hence R (which are determined by the firm given its profit maximising investment decision) to such an extent that more than offsets any direct gains for the buyer.

Similarly, for the case of prepayments, by totally differentiating $P_0 = \frac{a_\tau\overline{f}R(i)+b^{dl}\alpha R(i)}{a_\tau+b^{dl}}$, we get that:

$$\frac{dP_0}{db^{dl}} = \frac{\partial P_0}{\partial b^{dl}} + \frac{\partial P_0}{\partial i^{P_0}}\frac{\partial i^{P_0}}{\partial b^{dl}} =$$
$$\frac{-a_\tau\overline{f}R(i)}{(a_\tau+b^{dl})^2} + \frac{\alpha R(i)(a+b^{dl})-b^{dl}\alpha R(i)}{(a_\tau+b^{dl})^2} + \left(\frac{a_\tau+b^{dl}}{a_\tau\overline{f}+b^{dl}\alpha}\right)\frac{a_\tau\overline{f}+b^{dl}\alpha}{a_\tau+b^{dl}}\frac{\partial i^{P_0}}{\partial b^{dl}} \Leftrightarrow$$
$$\frac{dP_0}{db^{dl}} = \frac{a_\tau(\alpha-\overline{f})R(i)}{(a_\tau+b^{dl})^2} + \frac{\partial i^{P_0}}{\partial b^{dl}} < 0$$

[20] This is rather unlikely: clearly $\frac{\overline{f}^2-\alpha^2}{2\overline{f}\alpha}$ is an increasing function of $\overline{f}$ and a decreasing function of α, hence unless the former is small and the latter large this inequality is unlikely to hold. If $\frac{\overline{f}}{\alpha} > \frac{b}{a_\tau} > 1$, it is more likely than not that $\frac{\overline{f}^2-\alpha^2}{2\overline{f}\alpha} > \frac{b-a_\tau}{a_\tau}$ rather than the other way round.

Hence as

$$CS^{P_0} = B_0 - P_0 + \overline{f}R(i) - 0b^{tr} \Leftrightarrow$$
$$\frac{dCS^{P_0}}{db^{dl}} = \overline{f}\frac{a_\tau + b^{dl}}{a_\tau \overline{f} + b^{dl}\alpha}\frac{\partial i^{P_0}}{\partial b^{dl}} - \frac{dP_0}{db^{dl}} \Leftrightarrow$$

$$\frac{dCS^{P_0}}{db^{dl}} = \frac{a_\tau(\overline{f} - \alpha)R(i)}{(a_\tau + b^{dl})^2} + \frac{b^{dl}(\overline{f} - \alpha)}{a_\tau \overline{f} + b^{dl}\alpha}\frac{\partial i^{P_0}}{\partial b^{dl}} \tag{27}$$

Hence again the buyer has an incentive to overstate his trustworthiness provided that the impact of an inflated b on investment is not so detrimental that the reduction in investment as denoted by the second term in the relation above more than offsets any direct gains to the buyer (as denoted by the first term). However, unlike $\frac{dCS^f}{db^{dl}}$, $\frac{dCS^{P_0}}{db^{dl}}$ does not depend on the magnitude of the true value of b, b^{tr}.

Proof of Theorem 4

Comparing the PF solution (prepayment F-contracts) to those of pure flexibility contracts f or prepayment ones, it is easy to show that for $b > a_\tau > a_\tau^k$:

$$R'(i^{PF}) = \frac{2}{\overline{f} + \alpha} \leqslant R'(i^{P_0,k}) = \frac{2(a_\tau + b)}{(a_\tau + a_\tau^k)\overline{f} + [2b + (a_\tau - a_\tau^k)]\alpha}$$
$$R'(i^{PF}) = \frac{2}{\overline{f} + \alpha} \leqslant R'(i^{f,k}) = \frac{2b}{a_\tau \overline{f} + b\alpha}$$

it follows that $i^{PF} > i^{P_0,k}$, $i^{PF} > i^{f,k}$ and $R(i^{PF}) > R(i^{P_0,k})$, $R(i^{PF}) > R(i^{f,k})$.

As $\frac{\partial W^{PF}}{\partial i^{PF}} = \overline{f}R'(i^{PF}) - 1 = \frac{2\overline{f} - \overline{f} - \alpha}{\overline{f} + \alpha} = \frac{\overline{f} - \alpha}{\overline{f} + \alpha}$, $\frac{\partial i^{PF}}{\partial b} = \frac{\partial i^{PF}}{\partial R'(i^{PF})}\frac{\partial R'(i^{PF})}{\partial b} = \frac{\frac{\partial R'(i^{PF})}{\partial b}}{R''(i^{PF})} = 0$ and $\frac{\partial R'(i^{PF})}{\partial b} = 0$, both the direct as well as the indirect effects of b on welfare are zero. Hence taking the difference between $W^{PF} - W^f$ and differentiating with respect to b gives:

$$\frac{\partial\left(W^{PF} - W^{f,k}\right)}{\partial b} = \frac{2a_\tau^k}{(2b)^2}\overline{f}R(i^{f,k}) + \frac{1}{2a_\tau^k}\alpha R(i^{f,k}) - \frac{b(a_\tau^k \overline{f} - b\alpha)}{a_\tau^k(a_\tau^k \overline{f} + b\alpha)}\frac{\partial i^{f,k}}{\partial b} > 0$$

Hence the higher b is, the more efficient is the F- prepayment contract as compared to the pure flexible contract of A&S.

Similarly both the direct as well as the indirect effect of a on W^{PF} is zero, and hence the lower a_τ^k is, the more efficient an F- prepayment contract as compared to a flexible contract.

In an analogous manner, we compare the expected welfare implications of an F-contract to that of a prepayment contract. Calculating:

$$W^{PF} - W^{P_0,k} = \overline{f}R(i^{PF}) - i^{PF} - \overline{f}R(i^{P_0,k}) + i^{P_0,k}$$

and differentiating $W^{P_0,k}$ with respect to b gives:

$$\frac{dW^{P_0,k}}{db} = \frac{\partial W^{P_0,k}}{\partial b} + \frac{\partial W^{P_0}}{\partial i^{P_0,k}} \frac{\partial i^{P_0,k}}{\partial b} = \frac{\partial W^{P_0,k}}{\partial b} + \frac{\partial W^{P_0}}{\partial i^{P_0,k}} \frac{\partial R'(i^{P_0,k})}{\partial b} \frac{\partial i^{P_0,k}}{\partial R'(i^{P_0,k})}$$

The direct effect of b on the expected welfare in a prepayment contract is:

$$\frac{\partial W^{P_0,k}}{\partial b} = \frac{(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})}{2(a_\tau+b)^2} +$$
$$\frac{2\left(a_\tau^k\right)(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})(a_\tau+b)-2\left(a_\tau^k\right)(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})b}{4(a_\tau^k)^2(a_\tau+b)^2} =$$
$$= \frac{\left(a_\tau^k\right)(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})}{2(a_\tau^k)(a_\tau+b)^2} + \frac{(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})(a_\tau+b)-(a_\tau+a_\tau^k)\left(\overline{f}-\alpha\right)R(i^{P_0,k})b}{2(a_\tau^k)(a_\tau+b)^2} \Leftrightarrow$$
$$\frac{\partial W^{P_0,k}}{\partial b} = \frac{(a_\tau+a_\tau^k)^2\left(\overline{f}-\alpha\right)R(i^{P_0,k})}{2(a_\tau^k)(a_\tau+b)^2} > 0$$

The indirect effect of b on the expected welfare in a prepayment contract will the product of the following three terms:

$\frac{\partial W^{P_0,k}}{\partial i^{P_0,k}} = \frac{\left(\overline{f}-\alpha\right)(a_\tau+2b-a_\tau^k)}{(a_\tau+a_\tau^k)\overline{f}+(2b+a_\tau-a_\tau^k)\alpha}$, $\frac{\partial R'(i^{P_0,k})}{\partial b} = \frac{\left(\overline{f}-\alpha\right)(a_\tau+a_\tau^k)}{\left[(a_\tau+a_\tau^k)\overline{f}+(2b+a_\tau-a_\tau^k)\alpha\right]^2}$ and $\frac{\partial i^{P_0,k}}{\partial R'(i^{P_0,k})} = \frac{1}{R''(i^{P_0,k})}$

So,

$$\frac{\partial W^{P_0,k}}{\partial i^{P_0,k}} \frac{\partial R'(i^{P_0,k})}{\partial b} \frac{\partial i^{P_0,k}}{\partial R'(i^{P_0,k})} = \frac{\left(\overline{f}-\alpha\right)^2(a_\tau+2b-a_\tau^k)(a_\tau+a_\tau^k)}{\left[(a_\tau+a_\tau^k)\overline{f}+(2b+a_\tau-a_\tau^k)\alpha\right]^3 R''(i^{P_0,k})} < 0$$

At time τ the direct effect is equal to zero and we have that:

$$\frac{\partial\left(W^{PF}-W^{P_0,k}\right)}{\partial b} =- \frac{\left(\overline{f}-\alpha\right)^2 b a_\tau}{\left[(a_\tau\overline{f}+b\alpha\right]^3 R''(i^{P_0,k})} > 0$$

Hence the higher b is, the more efficient the F-prepayment contract is as compared to the prepayment contract, and this effect tends to be intensified towards the beginning of the contract where a is lower. If later on during the life of the contract there is upwards updating in the trust beliefs held by the firm, then this will reduce the superiority of such F contracts.

The opposite result will hold for a_τ as:

$$\frac{\partial(W^{PF}-W^{P_0,k})}{\partial a_\tau} = 0 + \frac{b^2(\overline{f}-\alpha)^2}{(a_\tau\overline{f}+b\alpha)^3 R''(i^{P_0,k})} < 0.$$

■

Next, we set out in detail the proofs for the four propositions referred to in section 3.5. For $\eta > 0$, $i^{H,k} > i^{f,k}$, $R(i^{H,k}) > R(i^{f,k})$ we require that $R'(i^{H,k}) < R'(i^{f,k})$, which holds if:

$$2a_\tau b\underline{f} - a_\tau^k\overline{f} > b\alpha \tag{28}$$

It then follows that $R^{''}(i^{H,k}) < R^{''}(i^{f,k}) < 0$.

We now look at the impact of parameters on investment. First we look at **the impact of** α **:**

$$\frac{\partial i^{f,k}}{\partial \alpha} = \frac{\frac{\partial R'(i^{f,k})}{\partial \alpha}}{R''(i^{f,k})} = \frac{\frac{-2b^2}{(a_\tau^k \overline{f}+b\alpha)^2}}{R''(i^{f,k})} > 0$$

$$\frac{\partial i^{H,k}}{\partial \alpha} = \frac{\frac{\partial R'(i^{H,k})}{\partial \alpha}}{R''(i^{H,k})} = \frac{\frac{-2b^2(1-\eta)}{\left(2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k \overline{f}+b\alpha)\right)^2}}{R''(i^{H,k})} > 0$$

$$2b^2 > 2b^2(1-\eta), \frac{1}{(a_\tau^k \overline{f}+b\alpha)^2} > \frac{1}{\left(2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k \overline{f}+b\alpha)\right)^2}$$

and

$$0 > R''(i^{f,k}) > R''(i^{H,k}) \Leftrightarrow -\frac{1}{R''(i^{f,k})} > -\frac{1}{R''(i^{H,k})} > 0,$$

it follows that

$$\frac{\partial i^{H,k}}{\partial \alpha} < \frac{\partial i^{f,k}}{\partial \alpha} \tag{29}$$

Also, for the **impact on investment of renegotiation costs,** $\overline{f}$:

$$\frac{\partial i^{f,k}}{\partial \overline{f}} = \frac{\frac{\partial R'(i^{f,k})}{\partial \overline{f}}}{R''(i^{f,k})} = \frac{\frac{-2ba}{(a_\tau^k \overline{f}+b\alpha)^2}}{R''(i^{f,k})} > 0$$

$$\frac{\partial i^{H,k}}{\partial \overline{f}} = \frac{\frac{\partial R'(i^{H,k})}{\partial \overline{f}}}{R''(i^{H,k})} = \frac{\frac{-2ba_\tau^k(1-\eta)}{\left(2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k \overline{f}+b\alpha)\right)^2}}{R''(i^{H,k})} > 0$$

Hence as above,

$$\frac{\partial i^{H,k}}{\partial \overline{f}} < \frac{\partial i^{f,k}}{\partial \overline{f}} \tag{30}$$

The **impact of the maladaptation parameter,** $\underline{f}$ is:

$$\frac{\partial i^{f,k}}{\partial \underline{f}} = 0$$

$$\frac{\partial i^{H,k}}{\partial \underline{f}} = \frac{\frac{\partial R'(i^{H,k})}{\partial \underline{f}}}{R''(i^{H,k})} = \frac{\frac{-4\eta a_\tau b^2}{\left(2\eta a_\tau b\underline{f}+(1-\eta)(a\overline{f}+b\alpha)\right)^2}}{R''(i^{H,k})} > 0$$

Therefore:

$$\frac{\partial i^{H,k}}{\partial \underline{f}} > \frac{\partial i^{f,k}}{\partial \underline{f}} = 0 \tag{31}$$

The impact of b :

$$\frac{\partial i^{f,k}}{\partial b} = \frac{\frac{\partial R'(i^{f,k})}{\partial b}}{R''(i^{f,k})} = \frac{\frac{2a_\tau^k \overline{f}}{(a_\tau^k \overline{f}+b\alpha)^2}}{R''(i^{H,k})} < 0$$

$$\frac{\partial i^{H,k}}{\partial b} = \frac{\frac{\partial R'(i^{H,k})}{\partial b}}{R''(i^{H,k})} = \frac{\frac{2(1-\eta)a_\tau^k \overline{f}}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k \overline{f}+b\alpha)\right]^2}}{R''(i^{H,k})} < 0$$

$$\frac{2a\overline{f}}{(a\overline{f}+b\alpha)^2} > \frac{2(1-\eta)a_\tau^k \overline{f}}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k \overline{f}+b\alpha)\right]^2}$$

$$0 > R''(i^{f,k}) > R''(i^{H,k}) \Leftrightarrow -\frac{1}{R''(i^{f,k})} > -\frac{1}{R''(i^{H,k})} > 0$$

$$-\frac{\frac{2a_\tau^k \overline{f}}{(a\overline{f}+b\alpha)^2}}{R''(i^{f,k})} > -\frac{\frac{2(1-\eta)a_\tau^k \overline{f}}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a\overline{f}+b\alpha)\right]^2}}{R''(i^{H,k})} \Leftrightarrow$$

$$0 > \frac{\partial i^{H,k}}{\partial b} > \frac{\partial i^{f,k}}{\partial b} \tag{32}$$

Also the impact of a_τ^k:

$$\frac{\partial i^{f,k}}{\partial a_\tau^k} = \frac{\frac{\partial R'(i^{f,k})}{\partial a_\tau^k}}{R''(i^{f,k})} = \frac{\frac{-2b\overline{f}}{(a_\tau^k\overline{f}+b\alpha)^2}}{R''(i^{H,k})} > 0$$

$$\frac{\partial i^{H,k}}{\partial a_\tau^k} = \frac{\frac{\partial R'(i^{H})}{\partial a_\tau^k}}{R''(i^{H,k})} = \frac{\frac{-2b(1-\eta)\overline{f}}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right]^2}}{R''(i^{H,k})} > 0$$

We have that,

$$2b\overline{f} > 2b(1-\eta)\overline{f}$$

and,

$$\frac{1}{(a_\tau^k\overline{f}+b\alpha)^2} > \frac{1}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right]^2}$$

Moreover,

$$0 > R''(i^{f,k}) > R''(i^{H,k}) \Leftrightarrow -\frac{1}{R''(i^{f,k})} > -\frac{1}{R''(i^{H,k})} > 0$$

Therefore,

$$-\frac{\frac{-2b\overline{f}}{(a_\tau^k\overline{f}+b\alpha)^2}}{R''(i^{f,k})} > -\frac{\frac{-2b(1-\eta)\overline{f}-4b^2\eta\underline{f}}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right]^2}}{R''(i^{H,k})} \Leftrightarrow$$

$$\frac{\partial i^{H,k}}{\partial a_\tau^k} < \frac{\partial i^{f,k}}{\partial a_\tau^k} \tag{33}$$

Finally, we examine the impact on investment on the probability or renegotiation, η:

$$\frac{\partial i^{f,k}}{\partial \eta} = 0$$

and

$$\frac{\partial i^{H,k}}{\partial \eta} = \frac{\frac{\partial R'(i^{H,k})}{\partial \eta}}{R''(i^{H,k})} = \frac{\frac{-2b\left[2a_\tau b\underline{f}-a_\tau^k\overline{f}-b\alpha\right]}{\left[2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right]^2}}{R''(i^{H,k})} > 0$$

Hence,

$$\frac{\partial i^{H,k}}{\partial \eta} > \frac{\partial i^{f,k}}{\partial \eta} = 0 \tag{34}$$

To derive the indirect impact of the above parameters on expected welfare, we first need to calculate the investment derivatives $\frac{\partial W^{H,k}}{\partial i^{H,k}}$ and $\frac{\partial W^{f,k}}{\partial i^{f,k}}$ respectively.

When calculating the indirect effect on expected welfare in the flexible and hybrid rigid models we impose the condition:

$$0 < \frac{\partial W^{H,k}}{\partial i^{H,k}} = \frac{b}{a_\tau^k}\frac{2\eta a_\tau(1-\underline{f}b)+(1-\eta)(a_\tau^k\overline{f}-b\alpha)}{\left(2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right)} < \frac{\partial W^{f,k}}{\partial i^{f,k}} = \frac{b}{a_\tau^k}\frac{(a_\tau^k\overline{f}-b\alpha)}{(a_\tau^k\overline{f}+b\alpha)} \quad (35)$$

For the above to hold, it suffices to show that:

$$\begin{gathered}\left[2\eta a_\tau(1-\underline{f}b)+(1-\eta)(a_\tau^k\overline{f}-b\alpha)\right](a_\tau^k\overline{f}+b\alpha) < \\ \left[\left(2\eta a_\tau b\underline{f}+(1-\eta)(a_\tau^k\overline{f}+b\alpha)\right)\right](a_\tau^k\overline{f}-b\alpha) \Leftrightarrow \\ 2\eta a_\tau(1-\underline{f}b)(a_\tau^k\overline{f}+b\alpha) < 2\eta a_\tau b\underline{f}(a_\tau^k\overline{f}-b\alpha) \Leftrightarrow \\ (a_\tau^k\overline{f}+b\alpha) < b\underline{f}(a_\tau^k\overline{f}-b\alpha)+\underline{f}b(a_\tau^k\overline{f}+b\alpha) \Leftrightarrow \\ (1-b\underline{f})(a_\tau^k\overline{f}+b\alpha)-b\underline{f}(a_\tau^k\overline{f}-b\alpha) < 0 \Leftrightarrow\end{gathered}$$

$$b\alpha < a_\tau^k\overline{f}(2b\underline{f}-1) \quad (36)$$

If $\frac{a_\tau}{a_\tau^k} > \overline{f}$, then

$$a_\tau^k\overline{f}(2b\underline{f}-1) < 2a_\tau b\underline{f} - a_\tau^k\overline{f}.$$

This means that inequality (36) implies inequality (28), while if $\frac{a_\tau}{a_\tau^k} < \overline{f}$, (28) implies (36). Remember that what has also been assumed so far is that $a_\tau^k\overline{f} > b\alpha$. Therefore, (36) can be true provided that $2b\underline{f}-1$ is positive and sufficiently close to one for the direction of the inequality to be retained.

Proof of Proposition 1

Obviously both the direct as well as the indirect effect of $\underline{f}$ on expected welfare under a flexible contract is zero. Hence $\frac{\partial i^{H,k}}{\partial \underline{f}} > \frac{\partial i^{f,k}}{\partial \underline{f}} = 0 \Leftrightarrow \frac{\partial W^{H,k}}{\partial i^{H}}\frac{\partial i^{H,k}}{\partial \underline{f}} > \frac{\partial W^{f}}{\partial i^{f}}\frac{\partial i^{f}}{\partial \underline{f}} = 0$. Moreover as the direct effect of $\underline{f}$ on $W^{H,k}$ is equal to $\eta(a-b)R(i^{H,k}) < 0$ this means that the efficiency of the hybrid model relative to the flexible one is eroded by the existence of a deadweight loss in the case of undertrusting. If the negative direct effect on $W^{H,k}$ is dominated by the positive indirect effect on $W^{H,k}$, then the higher $\underline{f}$ (i.e. the lower the misalignment cost is), the more efficient the hybrid contract is compared to a flexible one. On the other hand, if the direct effect dominates the indirect effect the reverse will be the case. However the latter is unlikely to happen for as long as $\frac{\overline{f}}{\alpha} > \frac{b}{a_\tau^k} > 1$ as the gap in the value of b and a_τ^k will be exceeded by the gap in the values of $\overline{f}$ and α. ■

For the next proposition, we shall add to the assumption $a_\tau^k\overline{f} > b\alpha$, assumption (28) that $2a_\tau b\underline{f} - \overline{f}a_\tau^k > b\alpha$. As already mentioned, this latter inequality assumption implies that:

$$\begin{aligned} i^{H,k} &> i^{f,k}, \\ R(i^{H,k}) &> R(i^{f,k}), \\ R'(i^{H,k}) &< R'(i^{f,k}), \\ R''(i^{H,k}) &< R''(i^{f,k}). \end{aligned}$$

Proposition 2 *For $a_\tau^k \overline{f} > b\alpha$, $2ba_\tau \underline{f} - \overline{f} a_\tau^k > b\alpha$ and $\eta > 0$, the lower the probability to renegotiate a rigid contract (the higher η), the more efficient a hybrid contract compared to a flexible one.*

Proof. If $b\alpha < 2ba_\tau \underline{f} - a_\tau^k \overline{f}$, then $\frac{\partial i^{H,k}}{\partial \eta} > \frac{\partial i^{f,k}}{\partial \eta} = 0$. This means that given (28):

$$\frac{\partial W^H}{\partial i^{H,k}} \frac{\partial i^{H,k}}{\partial \eta} > \frac{\partial W^{f,k}}{\partial i^{f,k}} \frac{\partial i^{f,k}}{\partial \eta} = 0$$

Moreover in the hybrid contract there is a direct effect of the same parameter equal to:

$$[1 + \underline{f}(a_\tau - b)]R(i^{H,k}) - \alpha \frac{a_\tau^k - b}{2a_\tau^k} R(i^{H,k}) - \overline{f} \frac{a_\tau^k + b}{2b} R(i^{H,k}) \Leftrightarrow$$
$$\frac{2R(i^{H,k})}{4a_\tau^k b} [2a_\tau^k b + 2a_\tau^k b \underline{f}(a_\tau - b) - b(a_\tau^k - b)\alpha - a_\tau^k (a_\tau^k + b)\overline{f}]$$

For the direct effect to reinforce the indirect one, the former should be positive, which is the case as:

$$\begin{aligned} &2ba_\tau^k > a_\tau^k(a_\tau^k + b)\overline{f} + b(a_\tau^k - b)\alpha - 2a_\tau^k b \underline{f}(a_\tau - b) \Leftrightarrow \\ &2ba_\tau^k > a_\tau^k(a_\tau^k \overline{f} + b\alpha - 2b\underline{f} a_\tau) + b(a_\tau^k \overline{f} - b\alpha + ba_\tau^k \underline{f}) \\ &ba_\tau^k(1 - \overline{f}) + ba_\tau^k(1 - \underline{f}) + b\alpha > a_\tau^k(a_\tau^k \overline{f} + b\alpha - 2b\underline{f} a_\tau) \end{aligned}$$

Given (28) $a_\tau^k \overline{f} + b\alpha - 2b\underline{f} a_\tau < 0$, and hence the above inequality always holds. ■

For the remaining two propositions, we shall start from the requirement that the impact of investment on expected welfare in a hybrid contract is smaller that the impact of investment on expected welfare in a flexible model ($0 < \frac{\partial W^{H,k}}{\partial i^{H,k}} < \frac{\partial W^{f,k}}{\partial i^{f,k}}$). As already shown, this requires inequality (36), which is re-written below, to hold:

$$a_\tau^k \overline{f}(2b\underline{f} - 1) > b\alpha \Longleftrightarrow$$

$$\underline{f} > \frac{a_\tau^k \overline{f} + b\alpha}{2a_\tau^k b \overline{f}} \left(> \frac{a_\tau^k \overline{f} + b\alpha}{2a_\tau^k b} = \frac{\overline{f}}{2b} + \frac{\alpha}{2a_\tau^k} > \frac{\overline{f} + \alpha}{2} \right)$$

Hence inequality (36) imposes further size boundaries for $\overline{f}$, $\underline{f}$ and α. In particular, the lower boundary for the value of $\underline{f}$, which is an inverse measure of the misalignment costs, becomes even more restrictive than in Proposition 2. More simply, the maladaptation costs are smaller (i.e. $\underline{f}$ is higher) than the level needed to ensure that as the probability of renegotiation decreases, the hybrid contract becomes more efficient relative to the flexible one. Assuming that $a\overline{f} > b\alpha$, (28) and (36) all hold we have the following two propositions:

Proposition 3 *For* $0 < \frac{\partial W^{H,k}}{\partial i^{H,k}} < \frac{\partial W^{f,k}}{\partial i^{f,k}}$ *and* $0 < \eta < \frac{R(i^{H,k})-R(i^{f,k})}{R(i^{H,k})}$*, the lower the level of asset specificity (i.e. the higher* α*), the more efficient the flexible contract compared to the hybrid contract.*

Proof. Concerning the indirect effects, given that $0 < \frac{\partial i^{H,k}}{\partial \alpha} < \frac{\partial i^{f,k}}{\partial \alpha} \Leftrightarrow$

$$\frac{\partial W^{H,k}}{\partial i^{H,k}}\frac{\partial i^{H,k}}{\partial \alpha} < \frac{\partial W^{f,k}}{\partial i^{f,k}}\frac{\partial i^{f,k}}{\partial \alpha},$$

if (36) and (28) both hold. As already discussed the direct effect of α on expected welfare is negative in both contracts given the introduction of a deadweight loss if $a_{\tau}^{k} < b$. Hence for this negative impact to be of a smaller absolute size for the flexible compared to the hybrid contract, so that the above inequality is preserved, the condition is that

$$(1-\eta)R(i^{H,k}) > R(i^{f,k}) \Leftrightarrow \eta < \frac{R(i^{H,k})-R(i^{f,k})}{R(i^{H,k})}$$

The upper boundary set for η reflects the requirement that the direct effect (deadweight loss) of α on welfare is (in absolute terms) smaller in the flexible contract than in hybrid one. This combined with the indirect effect of α will imply that $\frac{d(W^{H,k}-W^{f,k})}{d\alpha} < 0$, and therefore proposition 3 applies. ■

Proposition 4 *For* $0 < \frac{\partial W^{H,k}}{\partial i^{H,k}} < \frac{\partial W^{f,k}}{\partial i^{f,k}}$ *and* $\eta > \frac{R(i^{H,k})-R(i^{f,k})}{R(i^{H,k})}$*, the lower the renegotiation costs (i.e. the higher* $\overline{f}$*), the more efficient a flexible contract compared to a hybrid contract.*

Proof. Given that $0 < \frac{\partial i^{H,k}}{\partial \overline{f}} < \frac{\partial i^{f,k}}{\partial \overline{f}} \Leftrightarrow$

$$\frac{\partial W^{H,k}}{\partial i^{H,k}}\frac{\partial i^{H,k}}{\partial \overline{f}} < \frac{\partial W^{f,k}}{\partial i^{f,k}}\frac{\partial i^{f,k}}{\partial \overline{f}},$$

if (36) is satisfied which means that (35) holds. Therefore there is a larger indirect effect for the flexible as compared to the hybrid model. This will be strengthened by the direct effect if $(1-\eta)R(i^{H,k}) < R(i^{f,k}) \Leftrightarrow \eta > \frac{R(i^{H,k})-R(i^{f,k})}{R(i^{H,k})}$ as then $\frac{\partial W^{H,k}}{\partial \overline{f}} < \frac{\partial W^{f,k}}{\partial \overline{f}}$. In other words, the lower boundary for η reflects the requirement that the direct positive effect of $\overline{f}$ on welfare is greater in the flexible contract than in hybrid rigid contract. Given this boundary, proposition 4 of the A&S paper, that the lower the renegotiation costs (the higher $\overline{f}$), the more efficient the flexible contract relative to the hybrid model (i.e. $\frac{d(W^{H}-W^{f})}{d\overline{f}} < 0$), is reinforced under conditions of undertrusting. ■

The actual size of the commitment not to renegotiate matters in both propositions (3) and (4). This is once more the result of the existence of the direct effect that both parameters α and $\overline{f}$ have on welfare, but in an opposite manner. As far as proposition (4) is concerned, the higher η is (the higher the commitment not to renegotiate) the more similar the hybrid model becomes to the pure rigid one. All other things being equal, the higher $\overline{f}$ is (the lower renegotiation costs are), the more advantageous the flexible contract is. This result is the same as the A&S proposition (4). On the other hand, the lower η is (the higher the probability to renegotiate), then the hybrid model becomes increasingly similar to the flexible one. Hence the flexible contract loses some of its advantage in terms of low renegotiation costs, but gains an advantage in terms of low asset specificity terms, as it further strengthens the argument that a flexible contract is to be preferred if sunk costs are low, as proposition (3) indicates.