

The Joy of Flying: Efficient Airport PPP contracts

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January 19, 2016

Abstract

We examine the optimal concession contract for an infrastructure that generates both user fee revenue and ancillary commercial revenue. For example, airports charge user fees to passengers and airlines (aviation revenue) and collect revenue from shops, restaurants, parking lots and hotels (non-aviation revenue). While passenger flow and the demand for the infrastructure are exogenous, the demand for ancillary services depends both on exogenous passenger flow and on the concessionaire's effort and diligence. We show that the optimal principal-agent contract separates exogenous and endogenous risks. On the one hand, the term of the concession is longer when passenger flow is low, so that the concessionaire bears no exogenous demand risk. On the other hand, the concessionaire bears part or all of ancillary risk, which fosters effort. The optimal contract can be implemented with a standard Present-Value-of-Revenue (PVR) auction in which bidders bid on the present value of aviation revenue only. The concession ends when the bid is collected.

JEL: H440, R420, L51

*Fischer gratefully acknowledges the financial support of Instituto Milenio "Sistemas Complejos de Ingeniería".

1 Introduction

In recent years PPPs have become the main mechanism for airport procurement.¹ Indeed, according to the PPIAF database, in 2014 there were 141 airport PPPs around the world (Farrell and Vanelslander, 2015). One of the main features of an airport PPP is that it has two sources of income, aviation revenues (e.g. landing or airport fees) and ancillary services such as sales in duty-free shops, restaurants, airport hotels, parking and rental cars. According to *The Economist*, this makes airport PPPs particularly attractive business propositions:

“What sets airports apart from most investments in infrastructure is their dual income stream: they bring in money both on the aeronautical side (landing fees, contracts with carriers) and from passengers (parking, shopping, hotels). If you own a toll road and traffic dwindles, there’s not much you can do. But with an airport there are lots of levers to pull, such as cutting capital costs, firing staff and upping the price of parking.”²

It is also worth noting that revenues from ancillary (non-aviation) services are almost as important as aviation revenues and are responsible for a substantial fraction of the profits made by an airport (Graham, 2009). Moreover, if we assume that the quality of aviation related services is contractible and that airports are sufficiently distant that they do not compete, demand at the airport can be considered exogenous and driven by factors beyond the control of a concessionaire. However, we assume that demand for non-aeronautical services is responsive to non-observable effort exerted by the concessionaire. Under this conditions, we analyze the structure of the optimal PPP contract; i.e., the distribution of revenues and risks that provide efficient incentives to the concessionaire.

We find that the optimal contract has three characteristics. One is that the concessionaire does not bear any of the exogenous aviation demand risk caused by variations in the demand for the airport, i.e., in passenger volume.³ At the same time, the concessionaire bears ancillary profit risk, which provides incentives to invest in ancillary services and exert costly effort. Finally, the contract can be implemented with a least-present-value-of-revenue auction (PVR) in which bidders compete on the amount of present value aviation revenue they desire, and there is a sharing rule for non-aviation revenues. Note that the bidding variable does not include the level of ancillary revenue. As in any PVR contract, the duration is variable and the concession ends as soon as the concessionaire collects aviation fees equal to the winning bid.

In our model, a risk neutral planner hires a risk-averse concessionaire to build and operate an airport. Each passenger pays a user fee and aviation revenue is random and exogenous. In addition, the concessionaire can exert costly effort which increases ancillary revenue per passenger with positive probability.

¹On airport reform and privatization see, for example, Gillen (2011) and Winston and de Rus, eds (2008).

²June 6, 2015.

³Demand risk may be macroeconomic or due to variations in regional growth, but if the airport has few close-by substitutes, passenger demand is exogenous from the point of view of the concessionaire.

To understand the economics of the optimal contract, assume first that exogenous aviation revenue is the only source of income. As we have shown elsewhere (see Engel et al. (2001, 2013)), in this case it is optimal to allocate the concession to the lowest PVR bid. The concession ends as soon as the bid revenue has been collected. Because the concessionaire is risk averse and demand risk is exogenous, it is optimal to fully transfer risk to the planner.

Now add ancillary services to the concession and note that the number of potential customers is roughly proportional to the number of passengers at the airport. The reasoning is that passengers visit an airport with the primary objective of traveling and that parking or buying in the shops at the airport is at most a subsidiary objective. The optimal contract exploits the high correlation between the two types of aviation revenues by tying the term of the concession for ancillary services to the term of the concession for aviation services and thus making it also variable. As the term of the concession of ancillary services is also variable, the income from these services depends only on effort and investment, and thus under the contract the concessionaire bears no *exogenous* demand risk.

Once a passenger is in the airport, she will spend more, on average, if the concessionaire dedicates resources to ancillary services. Thus the demand for ancillary services has an endogenous random component, which depends on the concessionaire's investment and effort, but because the term of the contract is variable, there is no exogenous component to demand risk for these services.⁴ As in any standard principal-agent model, the optimal contract is such that the concessionaire receives more revenue and profits if the project succeeds. But because exogenous risk can be fully separated from the endogenous risk component by varying the term of the concession, the variation in the reward of the concessionaire depends only on the fate of the ancillary project and not on the realization of the exogenous demand component.⁵

A second rather surprising feature of the optimal contract is that it can be implemented with a PVR auction such that the concessionaire bids on the present value of aviation revenue only. Again, the fundamental reason is that the number of passengers that use ancillary services is roughly proportional to the total number of passengers. For this reason, there is a linear relationship between per-year aviation revenue and ancillary revenue: if aviation revenue is 10% higher, and the project is successful, ancillary revenue is also 10% higher. We also show that competition in the auction dissipates all rents *ex ante*, including those from ancillary revenues.

Our paper contributes to the literature on PPPs. In our previous work (Engel et al., 2001, 2013) we studied PPPs with a single source of revenue. We showed that when a PPP is financed by user fees and faces exogenous demand risk, a Present Value of Revenue (PVR) contract is optimal.

⁴The intuition is obvious in the case of no discounting. In that case, the contract always ends when a predetermined number of passengers have arrived. Each of these passengers is exposed to the investment effort of the concessionaire in ancillary services, and thus their demand for ancillary services is endogenous to effort.

⁵One of the nice aspects of our setting is that it provides an exception to the rule that in general, principal-agent models do not provide straightforward results, see Laffont and Martimort (2002), for example. In an early working paper version of Engel et al. (2013), Engel et al. (2007), we examined the optimal contract when realized demand depends on costly effort by the concessionaire, but were unable to obtain clearcut results, in contrast to the present case. The difference lies in the particular structure of the airport problem with ancillary revenues, which allows us to obtain an implementable optimal contract.

The government sets the user fee and the discount rate, firms bid on the present value of user fee revenue, and the lowest bid wins. The concession lasts until the concessionaire collects her bid.

We are not aware of studies of optimal PPP contracts when there is ancillary revenue. In practice, however, these revenues are incorporated in the bids for PPP projects.⁶ In fixed term contracts, there are incentives to provide efficient effort on ancillary sources of revenue (if this effort is uncorrelated with other variables, as occurs here), but the discounted value of compensation to the agent is subject to excessive risk, and is non-optimal.

Several papers explore the principal-agent relationship in the context of PPPs; see, for example, Bentz et al. (2005), Martimort and Pouyet (2008), Iossa and Martimort (2011, 2012, 2015) and Auriol (2013). However this literature has not examined the specific case of infrastructure with user fees and ancillary sources of revenues, and its associated moral hazard problems.

The literature on airports has paid attention to the complementarity of infrastructure and ancillary service revenue. In an early paper Zhang and Zhang (1997) showed that a regulatory authority with a break even constraint should cross-subsidize airport operations with commercial revenues, and lower airport user fees. Further contributions by Gillen (2011) considered airports as two-sided platforms where passengers and airlines meet. Therefore cost-based pricing for airline services is an error and prices above or below marginal costs are not evidence of market power or predation, respectively.

More recently, Kratzsch and Sieg (2011) have examined the regulation of non-congested airports with market power and both aviation and non-aviation revenue. They show that when there is sufficient complementarity between these two sources of revenues, even with no regulation, tariffs associated to aviation will be lower, and that regulation that only considers aviation revenues will lead to lower fees and higher demand.

Another strand of literature that is related to this paper is the literature on the economics of malls. Malls obtain their income through their contracts with storeowners, and must therefore provide efficient incentives for effort by these agents. However, in the case of malls, there is the additional problem of attracting consumers to a mall. Thus demand is endogenous, which we do not consider here (for the economics of malls, see, for instance, Pashigian and Gould (1998) and Gould et al. (2005)).

The issue of optimal contracting in concessions where there are ancillary revenues is not restricted to the case of airports, but is an example of a general issue in PPPs.⁷ Some evidence of the importance of ancillary revenues and their components in the case of airports appears in Appendix A.

⁶In the case of El Tepual airport of Puerto Montt, in Chile, the best bid for a short term franchise that began in 2014 asked for zero user fees, and thus all revenues are ancillary.

⁷For example, in highway PPPs, roadside restaurants and gas stations may be licensed from the PPP itself, and the revenue the PPP derives from the contractual agreement is an ancillary revenue that depends roughly linearly on demand for the highway and thus is amenable to our analysis. The land strips given to cross-country railways in the United States in the 19th century were a source of ancillary revenue that depends on demand for the project. In India, this is still a means of financing concessions.

The remainder of the paper is organized as follows: the next section develops the model and the main results. The third section discusses the optimal sharing rule of ancillary revenues, and the final section concludes.

2 The model⁸

A risk-neutral benevolent social planner must design a contract for a public-private partnership to provide infrastructure services that are contractible.⁹ Demand for these services is exogenous and the PPP holder collects a fee from users. The PPP holder also receives ancillary revenues, which increase both with costly effort and with demand for the infrastructure services. For example, in the case of an airport, landing fees correspond to user fees while shopping and parking revenues are examples of ancillary revenues.

The planner hires a concessionaire to finance, build and operate the facility. The technical characteristics of the facility are exogenous, there are no maintenance nor operation costs, the up-front investment does not depreciate, and there are many identical risk-averse expected utility maximizing firms with preferences represented by the strictly concave utility function u that can build the project at cost $I > 0$.

Demand for infrastructure services is uncertain and described by a probability density over the present value of user fee revenue that the infrastructure can generate over its entire lifetime, v . This density is defined over $v_{\min} \leq v \leq v_{\max}$ and denoted $f(v)$, with c.d.f. $F(v)$. This density is common knowledge to firms and the planner, and satisfies $v_{\min} \geq I$ so that the project is self-financing in all states of demand. Also, for simplicity we assume that v equals the present value of private willingness to pay for the project's services.¹⁰

The firm that builds the facility exerts non-observable effort $e \geq 0$ before the facility begins operating. With probability $p(e)$ this generates additional value θv , observable to the government, otherwise it generates no value.¹¹ That is, the extensive margin of the PPP business (e.g., the number of potential shoppers in the case of an airport) is determined by the exogenous demand component, but the intensive margin (how much each potential shopper buys) depends on the firm's effort, for instance, the mix of shops, or the bargaining effort with independent shops. The intuition behind this formulation in the case of shops at an airport is that sales depend mainly on demand for the terminal: it is uncommon to choose an airport restaurant for dinner on a Saturday night. Thus there is a proportionality between the profits from the shops and the demand for the airport, the other source of revenue for the airport.

⁸The model presented here is formally related to the model in Engel, Fischer and Galetovic (2015). There we studied the reasons for the "PPP premium", that is, the observed differential between the interest rates paid by the government when incurring debt to build public infrastructure and those paid by a private party when building a PPP of an equivalent project.

⁹This assumption is reasonable in the case of an airport while less so for health and educational services.

¹⁰We have assumed that demand is totally inelastic to prices. In previous papers (Engel et al. (2001), for instance), we have shown that removing this assumption does not affect the main economic results.

¹¹This simplification of the effects of effort on project value is standard in the literature.

Denote by $R_f(v)$ and $R_s(v)$ the total revenue received by the PPP under failure and success respectively. Thus $R_s(v)$ represents user fees plus sales revenue while $R_f(v)$ corresponds to user fees only. Since the planner can observe whether the operator is successful, the contract specifies two schedules $\{R_f(v), R_s(v)\}$, with $R_f(v) \leq v$ and $R_s(v) \leq (1 + \theta)v$ since we assume no subsidies. In each case, the planner receives the complement: $v - R_f(v)$ if she fails and $(1 + \theta)v - R_s(v)$ if she succeeds.

The probability of success depends on the effort exerted by the concessionaire. More formally, the probability of success, given effort $e \geq 0$, is denoted $p(e)$ and satisfies $0 \leq p(e) < 1$, $p' > 0$ and $p'' < 0$. The cost of effort is linear in effort: ke , with $k > 0$.

2.1 Planner's problem

The planner faces the problem of designing a contract for a concessionaire that will operate and maintain the infrastructure project, while at the same time providing him with incentives to exercise the efficient amount of effort. The contract is awarded in a competitive auction.

We assume that, as in Laffont and Tirole (1993, Ch. 1), the regulator does not value leaving rents in the hands of the concessionaire. There may be redistributive concerns or the private party may be foreign-owned. Thus the planner ignores the welfare of the concessionaire in the maximand, the participation constraint holds with equality and the planner solves

$$\max_{\{R_f(v), R_s(v), e\}} p(e) \int [(1 + \theta)v - R_s(v)] f(v) dv + (1 - p(e)) \int [v - R_f(v)] f(v) dv \quad (1)$$

$$\text{s.t. } u(0) + ke = p(e) \int u(R_s(v) - I) f(v) dv + (1 - p(e)) \int u(R_f(v) - I) f(v) dv, \quad (2)$$

$$e = \operatorname{argmax}_{e' \geq 0} \{p(e') \int u(R_s(v) - I) f(v) dv + (1 - p(e')) \int u(R_f(v) - I) f(v) dv - ke'\}, \quad (3)$$

$$0 \leq R_s(v) \leq (1 + \theta)v, \quad (4)$$

$$0 \leq R_f(v) \leq v, \quad (5)$$

$$e \geq 0. \quad (6)$$

Government maximizes the net expected value of the project, which is in demand state v is equal to $p(e)[(1 + \theta)v - R_s(v)] + (1 - p(e))[v - R_f(v)]$. The first and second constraints are, respectively, the participation constraint and the incentive compatibility constraint of the PPP. The third and fourth constraints are the no-subsidy constraints.

The solution to this problem is found by combining several steps. We begin by looking for a solution to the simpler problem where we do not impose the no-subsidy constraints (4) and (5) which we verify later. The role of $R_s(v)$ in the resulting optimization problem does not depend on v and, likewise, the role of $R_f(v)$ does not depend on v either. We then have that for all v $R_f(v) = R_f$ and $R_s(v) = R_s$. We assume that $R_s \leq (1 + \theta)R_f$, which is equivalent to putting a lower bound on the degree of risk aversion of the PPP holder.

A second important assumption is that we can use the first order conditions of the incentive constraint instead of the original constraint. Thus, denoting by $\bar{v} \equiv \int v f(v) dv$ we can rewrite the

planner's problem as:

$$\max_{\{R_f, R_s, e\}} p(e)[(1 + \theta)\bar{v} - R_s] + (1 - p(e))[\bar{v} - R_f] \quad (7)$$

$$\text{s.t. } u(0) + ke = p(e)u(R_s - I) + (1 - p(e))u(R_f - I), \quad (8)$$

$$k = p'(e)[u(R_s - I) - u(R_f - I)], \quad (9)$$

$$e \geq 0. \quad (10)$$

2.2 Optimal contract under public provision

Following Hart (2003), where PPPs are characterized as long term contracts with bundling of activities, in our setting a PPP is contract in which the firm decides how much effort to exert during the construction phase and can share in the extra revenues that result. It is natural to define the case where no such compensation is possible as "public provision".

It is straightforward to show that under public provision the optimal contract sets $e = 0$, since the planner cannot award rents to the concessionaire. Hence there is no reason to have the concessionaire bear any demand risk and the optimal contract sets $R_f = R_s = I$.¹²

Proposition 1 *Under public provision we have $R_s = R_f = I$. The concessionaire bears no risk and exerts no effort.*

2.3 Improving on public provision

We begin by finding conditions that ensure that a PPP contract improves upon public provision.

Define $e^* > 0$ as the level of effort needed to satisfy the incentive compatibility constraint (9) when $R_f = I$ and $R_s = (1 + \theta)I$:¹³

$$k = p'(e^*)[u(\theta I) - u(0)]. \quad (11)$$

This combination of effort and revenues will improve upon public provision if it increases the planner's objective function (7) and satisfies the firm's participation constraint (8). The first condition is easier to satisfy when the probability of success is very responsive to increases in effort so that the welfare gains from an increase in effort are large. By contrast, the second condition is easier to satisfy when the probability of success responds little to increases in effort.

It follows from (7) that the increase in consumer surplus is equal to:

$$\Delta CS = (p(e^*) - p(0))\theta\bar{v} - p(e^*)\theta I \geq p'(e)e\theta\bar{v} - p(e)\theta I,$$

¹²Note that this contract satisfies the planner's problem described in (7)–(10). Since $e = 0$ is a corner solution, the first order form of the incentive-compatibility constraint (10) must be replaced by the original constraint (before taking the first order condition), which is satisfied by the solution offered.

¹³As shown in Appendix B, more general but less elegant conditions are obtained if we derive conditions under which $R_f = I$ and $R_s = (1 + \alpha\theta)I$, with $0 < \alpha < 1$ improves upon public provision.

where the inequality uses concavity of $p(e)$. It follows that consumer surplus increases if

$$\frac{p'(e^*)e^*}{p(e^*)} \geq \frac{I}{\bar{v}}.$$

From (8) it follows that the firm's participation constraint will hold if

$$p(e^*)[u(\theta I) - u(0)] \geq ke.$$

Substituting k by the expression that follows from (11) yields

$$\eta(e^*) \leq 1,$$

where $\eta(e) \equiv p'(e)e/p(e)$ denotes the effort-elasticity of the probability of success. As shown in Appendix B, the assumptions we made for $p(e)$ —that it is increasing and concave, and $p(0) \geq 0$ —imply that $\eta(e) \leq 1$ for all e . We have therefore established the following result:

Lemma 1 *Define e^* via (11) and assume $\eta(e^*) > I/\bar{v}$. Then the contract with zero effort and $R_f = R_s = I$ is not optimal and there exists a PPP contract with strictly positive effort that does better than public provision.*

2.4 Optimal contract under PPP

Next we fix $0 \leq \alpha \leq 1$ and find the optimal contract among those that set $R_s(v) = (1 + \alpha\theta)R_f(v)$, that is, among those contracts where the concessionaire receives a fraction α of ancillary revenues, in return for effort. We refer to this contract as the “optimal α -contract.” We only consider values of α for which the optimal contract entails strictly positive effort, from Lemma 1 we know that this is the case for $\alpha = 1$. We also show that the optimal α -contract can be implemented via a simple auction.

First, observe that by competition among bidders we must have that the efficient values of R_f satisfies:

$$\frac{I}{1 + \alpha\theta} < R_f^* < I.$$

The RHS inequality holds because otherwise, from (9) we have $R_s > R_f$, and the concessionaire would have non-negative profits in both states, even with no effort, which is incompatible with competition. The LHS inequality holds because otherwise the concessionaire would have losses even when successful. The inequality is strict because even in the case with no effort, $p(0) < 1$, i.e., there is a positive probability of failure.

The next step in the proof is to find conditions under which, given α , there is a strictly decreasing relationship between effort e and the reward R_f . We denote by $e(R_f)$ the solution to the incentive compatibility conditions (12), i.e., $e(R_f)$ solves

$$k = p'(e)[u((1 + \alpha\theta)R_f - I) - u(R_f - I)]. \quad (12)$$

If we can find conditions that ensure that the expression within the square parenthesis ($u((1 + \alpha\theta)R_f - I) - u(R_f - I)$) is decreasing as a function of R_f , then $p'(e)$ must be increasing for the equation to continue to hold. By the properties of p , this requires that e be decreasing in R_f . Thus, we have found a condition that ensures that as $R_f \uparrow$, $e(R_f) \downarrow$. To simplify the notation, let $R_\alpha \equiv (1 + \alpha\theta)R_f$, for $\alpha \in [0, 1]$.

Definition 1 Let $\rho(z) = -zu''(z)/u'(z)$ be the coefficient of relative risk aversion of the concessionaire.

Lemma 2 A sufficient condition for $e'(R_f) < 0$ is that

$$\rho(R_\alpha - I) > \frac{\alpha\theta}{(1 + \alpha\theta)}, \quad \forall R_f \in [I, (1 + \theta)I].$$

Proof: Let

$$J(R_\alpha, \theta) \equiv u((1 + \alpha\theta)R_f - I).$$

Since $J \in \mathcal{C}^2$, it is submodular if

$$\frac{\partial^2 J}{\partial R_f \partial \theta}(R_f, \theta) < 0,$$

Since this condition is satisfied,

$$J(R_\alpha, \theta) - J(R_\alpha, 0) = u((1 + \alpha\theta)R_f - I) - u(R_f - I)$$

is decreasing in R_f . By the reasoning following (12), this implies that $e'(R_f) < 0$. Thus we require conditions that ensure that

$$\frac{\partial^2 J}{\partial R_f \partial \theta}(R_f, \theta) < 0.$$

Now,

$$\frac{\partial^2 J}{\partial R_f \partial \theta}(R_f, \theta) = \alpha R_\alpha u''(R_\alpha - I) + \alpha u'(R_\alpha - I)$$

and thus, for this expression to be negative, we require

$$-\frac{R_\alpha u''(R_\alpha - I)}{u'(R_\alpha - I)} > 1 \implies \rho(R_\alpha - I) > \frac{R_\alpha - I}{R_\alpha}.$$

Thus

$$\rho(R_\alpha - I) > 1 - \frac{I}{(1 + \alpha\theta)R_f}.$$

As $R_f < I$, we can replace the RHS by the stricter condition

$$\rho(R_\alpha - I) > 1 - \frac{1}{1 + \alpha\theta} = \frac{\alpha\theta}{1 + \alpha\theta}.$$

Hence this condition ensures that $e'(R_f) < 0$. ■

Given $\alpha \in (0, 1]$, we can rewrite both the planner's and the firm's utility, when the Incentive Compatibility Constraint (ICC) holds, as functions of R_f :

$$V(R_f) = [1 - p(e(R_f))](\bar{v} - R_f) + p(e(R_f))[(1 + \theta)\bar{v} - (1 + \alpha\theta)R_f], \quad (13)$$

$$U(R_f) = p(e(R_f))u((1 + \alpha\theta)R_f - I) + [1 - p(e(R_f))]u(R_f - I) - ke(R_f). \quad (14)$$

We have

$$V'(R_f) = \theta p'(e(R_f))e'(R_f)[\bar{v} - \alpha R_f] - 1 - \alpha\theta p(e)$$

which implies that $V'(R_f) < 0$ for $R_f \in (I/(1 + \alpha\theta), I)$. Also, using the ICC we have that $U'(R_f)$ simplifies to:

$$U'(R_f) = p(e(R_f))u'((1 + \alpha\theta)R_f - I) + (1 - p(e(R_f)))u'(R_f - I) > 0.$$

The fact that the utility functions of planner and firm are monotone functions of R_f is a key property of the problem, and uncommon in more general moral hazard problems. This fact explains why the solution we obtain has a relatively simple characterization and why it can be implemented via a simple competitive auction.

We showed before that bidding competition implies that $U(I/(1 + \alpha\theta)) \leq u(0) < U(I)$.¹⁴ By continuity and because $U'(R_f) > 0$, $U(I/(1 + \alpha\theta)) < u(0)$ and $U(I) > u(0)$, there exists a unique $R_f^* \in (I/(1 + \alpha\theta), I)$ that solves $U(R_f) = u(0)$. This value of R_f solves the planner's problem: smaller values do not satisfy the firm's participation constraint (this follows from $U' > 0$) while larger values lead to lower social welfare (this follows from $V' < 0$). As $R_f^* < I$ it also satisfies the self-financing condition $R_f^* \leq v$ that we had omitted when solving the problem. We also have $R_s = (1 + \alpha\theta)R_f \leq (1 + \theta)v$. The associated level of effort along the ICC is $e^* = e(R_f^*) > 0$. Maximizing this solution over $\alpha \in [0, 1]$ we obtain the optimal contract, with $R_f^* < I$.

Proposition 2 *Assume $\alpha \in (0, 1]$ fixed and $\rho(c) > \theta/(1 + \theta), \forall c \in [0, \theta I]$. Also assume optimal effort is strictly positive and denote by $R_f^*(\alpha)$ the unique solution to the planning problem. We then have that $R_f^*(\alpha)$ is the unique solution to $U(R_f; \alpha) = 0$ and the planner's solution is obtained by finding the value of α for which $V(R_f^*(\alpha); \alpha)$ is maximum.¹⁵ Furthermore, if the condition of Lemma 1 holds, there exist values of α for which the contract thus obtained is better than the optimal contract under public provision.*

The proposition implies that, given its conditions, the contract that solves the program (7)–(10) is obtained by finding the value of $\alpha \in (0, 1]$ for which the optimal α -contract attains the highest social welfare. The solution to this program must entail positive effort, since a value for α for which the optimal contract entails zero effort is dominated by public provision, which in turn is dominated by a contract with strictly positive effort, as shown in Lemma 1.

Optimal effort in the solution of the planner's problem will depend on the response of the probability of success to effort, $p(e)$, and on the sharing rule, α . In the optimal contract, the firm

¹⁴Recall that $u(0)$ is the outside option.

¹⁵ $V(R_f; \alpha)$ and $U(R_f; \alpha)$ are defined by (13) and (14) where now we make explicit the dependence on α .

does not assume exogenous risk, i.e., risk that depends on demand for the project. However, the firm assumes endogenous risk, because the ancillary revenue depends on the effort e made by the firm. The extent to which it assumes endogenous risk is determined by the value of α . Since R_f^* is independent of the state of demand v , and competition leads to $U(R_f) = u(0)$,¹⁶ we also have that:

Corollary 1 *If the planner sets the optimal value of α , the optimal contract is implemented by a first price sealed bid auction where firms bid on R_f , i.e., a Present-Value-of-Revenue (PVR) auction. In this auction firms bid on R_f and the lowest bid wins the concession. The contract lasts until the present value of user fees collected by the concessionaire reaches the value of the winning bid. Income from ancillary services are not included in the winning bid nor do they influence the duration of the concession contract.*

3 Optimal choice of α

This section examines the optimal choice of α , i.e., the share of ancillary revenues that is appropriated by the firm. In the case in which the government cannot observe the revenues of the firm (the effects of cost reduction measures, for example), the only possible value of this parameter is $\alpha = 1$. In the general case the optimal choice of this parameter is a difficult problem, because α not only affects the revenues directly, but also the effort of the concessionaire. Moreover, since the other source of funds for the concessionaire has exogenous risk, the ratio of the two sources of revenue will affect the choice of effort through the risk aversion of the firm.

We have shown that a small amount of effort is always preferred to zero effort, and thus the optimal value of α is strictly positive. However, it is difficult to solve the problem analytically, so we have recourse to simulations. The simulations show that it is feasible for the value of α to satisfy $0 < \alpha < 1$.

For the utility function we use $u(c) = \frac{(c+1)^{1-\rho}}{1-\rho}$ and for the probability of success given effort e , we assume that $p(e) = p_0 e^\gamma$, which increases in effort. The figures below show the value for the planner for different values of α . In each case we have a central value and then we vary one of the parameters by $\pm 25\%$. Figure 1 shows the effects of variations on the value of distribution p_0 ; Figure 2 shows the effects of variations in the cost of effort k and Figure 3 shows the effects of changes in the parameter of risk aversion ρ .¹⁷ In all the cases, the maxima (denoted by a small circle) occur in the interior of the interval, i.e., when there is sharing of ancillary revenues with the planner.

Note that in all the cases, the maximum value of the planner's objective function is found where there is some sharing of profits between the PPP holder and the planner. When the scale parameter in the probability of success is higher the optimal sharing rule provides fewer incentives to effort and the optimal value of α is smaller. Similarly, when the cost of exerting effort is higher

¹⁶The fact that U is strictly increasing in R_f is crucial here.

¹⁷The initial values of the parameters are: $p_0 = 0.5, \gamma = 0.5, \rho = 2, \theta = 0.5, k = 0.1$ and $\bar{v} = 1.2$.

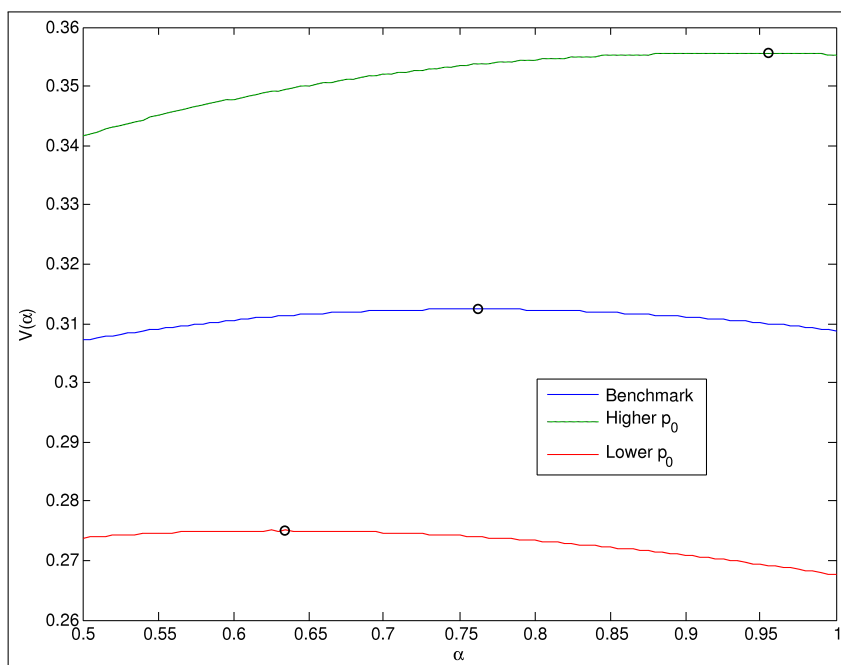


Figure 1: Planner's objective function for different values of p_0 .

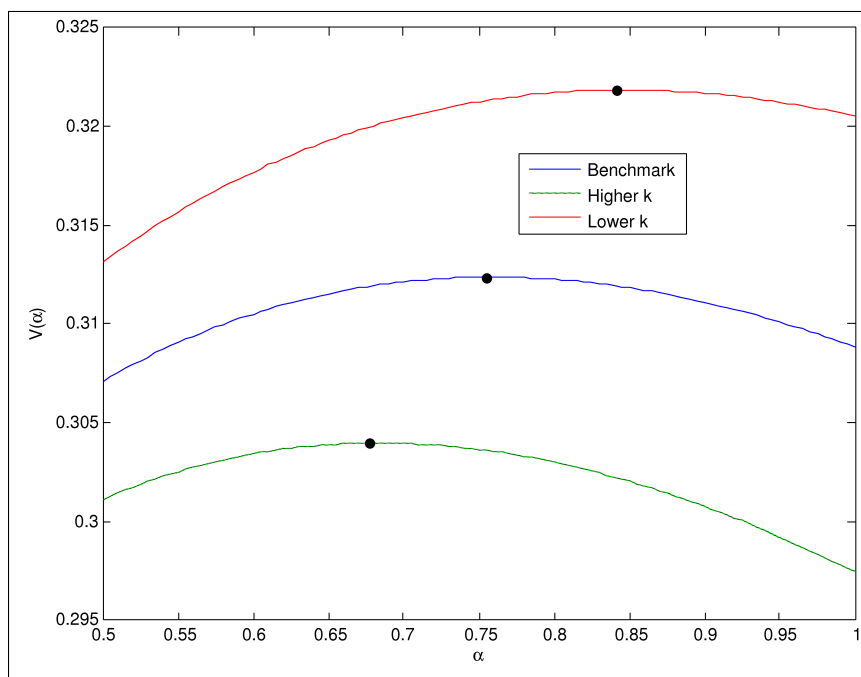


Figure 2: Planner's objective function for different values of k .

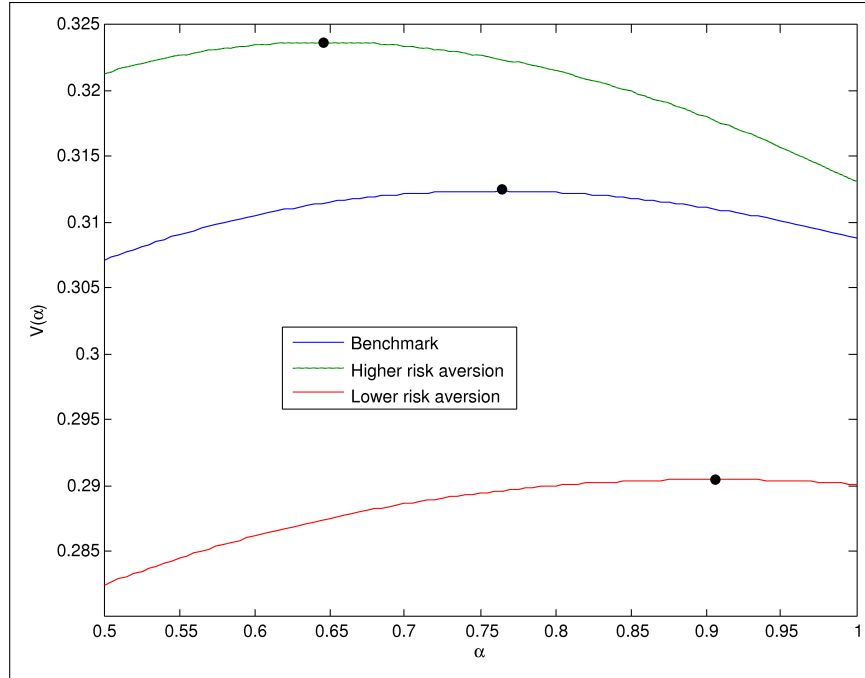


Figure 3: Planner's objective function for different values of ρ .

and the planner requires less effort of the firm. Finally, the risk aversion is higher, the share in ancillary revenues of the firm is lower, to avoid providing it with more risk.

4 Conclusion

A major extension of El Loa Airport in northern Chile was tendered as a PPP by the Ministry of Public Work (MPW) in January, 2011, after the expiration of the first contract. The El Loa airport serves about 1.2 million passengers a year. The project considered 8.100 m² of new terminal space for shops and other ancillary businesses. Nonetheless, the winning firm concluded that the optimal increase in commercial space required an additional 2.000 m² to the terminal. The concessionaire obtained permission from the MPW to build a larger terminal. According to the concessionaire, the enlargement of the commercial area played a major role in the high profits reported by the concession during its first year of operation, 2014.

This example illustrates the motivation for this paper. Under a PPP the provider of airport services has strong incentives to invest during the construction phase to enhance the value of non-aviation services provided by an airport once it becomes operational. These incentives are likely to be weaker, if present at all, under public provision.

In this paper we have shown that the optimal PPP contract when there are observable ancillary revenues –linear in demand– has the same form as the efficient contract when there are no ancillary revenues, i.e., a contract that eliminates all exogenous risk for the concessionaire, while retaining a fraction of the endogenous risk, which is required for efficient effort on ancillary rev-

enues. Moreover, this contract can be implemented by a simple bidding procedure, the PVR auction proposed by Engel et al. (2001), given a choice of the extent to which profits that result from non-aeronautical incomes are shared. We also show that in our examples, the fraction of ancillary revenues received by the agent is smaller than total ancillary revenues, i.e., part of the benefits from effort are shared with the Planning Authority. The choice of the profit sharing parameter is not obvious, but our numerical calculations provide some guidelines.

When the probability of success of effort is higher, the fraction of revenues needed to provide incentives is smaller, so a smaller fraction of ancillary revenues goes to the private firm. The same thing happens if the cost of effort goes down. Finally, as risk aversion increases, the firm requires a larger share of ancillary revenue.

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A Non-aviation revenues in airports

Airport revenues are usually divided into two classes, aviation and non-aviation. Aviation revenues are those directly related to the aviation business. They include passenger charges, landing charges, terminal rental, security charges, ground handling, with the remaining covering items such as boarding bridge, cargo, fueling, airplane parking, utility and environmental and other minor charges. Non-aviation revenues are the other important source of income for airports. In 2012 U.S. airports had total revenues of \$ 17,2 Billion and 45.2% came from non-aviation services.^{18, 19} According to the GAO report, since 2004 non-aviation revenues have been growing at 4% annually, while aviation related revenues grew at the slower rate of 1.5%.

Table 1 shows that the share of non-aviation revenue varies from a low of 32% in Africa to a high of 50% in Asia-Pacific. Because this numbers are for airports *in toto*, which are managed by a Transport Authority, they probably underestimate the share of non-aviation revenues. Indeed, most airport PPPs do not include all aviation revenue in their accounts, because landing fees are usually still assigned to the Authority responsible for air security and navigation. In Chile's main airport, for example, non-aviation fees represented 62.8% of total revenues in 2011 of the PPP (up from 58.3% in the previous year). Another reason for the importance of non-aviation related revenues is that, as we have mentioned before, Graham (2009) shows that non-aviation revenues are more profitable for airports, and thus have more influence in their behavior.

Table 1: Industry Revenue

Region	Total	Aeronautical	Non-aeronautical	% Non-Aero.
Africa	2.8	1.9	.9	32
Asia-Pacific	31.6	15.8	15.8	50
Europe	44.3	26 .1	18.2	41
LA+Carib	6.5	4.2	2.3	35
North America	25.3	14.3	11.0	43
Total	117.0	65.8	51,2	44

Notes: 2013 ACI Economics Report, Preview Edition.

¹⁸Government Accounting Office, "Airport Funding: Aviation Industry Changes Affect Airport Development Costs and Financing," Washington DC: Government Accounting Office, 2014. Similarly, the 2013 ACI-NA Concessions Benchmarking Survey of November 2013 shows that of US\$16.87 Billion in total operational revenues at all airports in 2012, 44.8% was non-aeronautical revenue.

¹⁹The composition of non-aviation revenues is as follows: parking and transportation charges: 40.9%; rental car services: 19.7%; retail and duty free: 8,3%; food and beverages, 6,9%; terminal services, 5%; other services, 10.4%.

B Improving upon public provision

In Appendix B we prove that the assumptions we made for $p(e)$ imply that $\eta(e) \leq 1$ for all e and generalize the result in Lemma 1.

Lemma 3 *Assume $p(e)$ defined for $e \geq 0$ is strictly increasing, strictly concave and satisfies $p(0) \geq 0$, Then $\eta(e) \leq 1$ for all $e \geq 0$.*

Proof: From the Mean Value Theorem and concavity of p it follows that, for any $e > 0$ there exists $\xi(e) \in [0, e]$ such that

$$p(e) - p(0) = p'(\xi(e))e \geq p'(e)e,$$

and therefore

$$\frac{p'(e)e}{p(e) - p(0)} \leq 1.$$

Since $p(0) \geq 0$ we also have:

$$\eta(e) \equiv \frac{p'(e)e}{p(e)} \leq \frac{p'(e)e}{p(e) - p(0)}.$$

Combining both expressions derived above yields $\eta(e) \leq 1$ for all $e \geq 0$. ■

Lemma 4 *Define e^* as in Lemma 1 and $R_s(e)$ via*

$$k = p'(e)[u(R_s(e) - I) - u(0)].$$

Assume there exists $e \in (0, e^]$ such that:²⁰*

$$\eta(e) > \frac{R_s(e) - I}{\theta v}.$$

Then the contract with zero effort and $R_f = R_s = I$ is not optimal and there exists a PPP contract with strictly positive effort that does better than public provision.

Proof: Analogous arguments to the ones we used in the proof of Lemma 1 show that the contract that stipulates effort e , $R_s = R_s(e)$ and $R_f = I$ increases social welfare and satisfies the participation constraint if the two conditions below hold:

$$\begin{aligned} \eta(e) &> \frac{R_s(e) - I}{\theta v}, \\ \eta(e) &\leq 1. \end{aligned}$$

The result now follows directly. ■

²⁰In Lemma 1 we considered the case where $e = e^*$.