Optimal incentives to public-private partnerships for airport investments under market segmentation*

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Abstract

This paper analyzes how certain incentives given to private airport concessionaires should be optimally determined to promote immediate investment, in a real options framework. Recognizing the recent and increasing trend of low cost airlines, we value different investment strategies comparing a single airport, serving two types of demand, with segmented airports, and their implications for defining optimal incentives. We also show that both strategies dominate for different ranges and that there is an incentive to delay the choice of the best alternative when both strategies produce closer values.

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1 Introduction

Large scale infrastructure investments have been increasingly promoted as Public-Private Partnerships (PPP) under a variety of arrangements. Those arrangements define the risk and return transferred from the public to the private sector. A correct valuation of the contractual arrangements is crucial for the bidding and negotiation of the PPP. Frequently, these projects are "out-the-money" and need investment incentives to be implemented. Some of these incentives are granted in the form of "contingent claims" or real options.

This paper studies the incentives which may be needed in an airport investment when the government seeks immediate investment. Under uncertainty of future cash flows, there is an incentive to delay investment (McDonald and Siegel 1986). The optimal threshold for investment occurs later than the traditional Net Present Value (NPV) rule suggests. Even when the NPV is positive, delaying investment may be optimal. The incentives given by the government entity, that grants the PPP concession, cannot ignore this option to defer effect, otherwise an insufficient incentive could delay investment, even after the concession is granted.

PPP and their incentives with real options features have been studied previously in the literature. PPP arrangements in infrastructure projects and their risks are discussed by Grimsey and Lewis (2002). In the present paper we focus on the revenue risk, but other sources of risk can be considered at the cost of a more complex model.

Alonso-Conde, Brown and Rojo-Suarez (2007) study the Melbourne CityLink Project PPP conditions, treated as real options, and how these options affect the incentive to invest. The value transferred from the public to the private sector through government guarantees is analyzed. The options valued are the private concessionaire option to defer the payments and the State option to cancel the concession. They show that, although the guarantees provided an investment incentive, the State has transferred considerable value to the private sector.

Different subsidies, guarantees and other incentives in PPP infrastructure projects have been previously studied by Cheah and Liu (2006) and Chiara, Garvin and Vecer (2007). They focus on the demand guarantee which enhance project value. Our analysis goes a step further, showing how some incentives should be arranged to induce optimal investment under uncertainty and when demand is segmented.

Debt guarantee provided by the government reduces the cost of capital and raises the project value. This type of incentive is valued by Ho and Liu (2002), who model a PPP with value and investment cost behaving stochastically and accounting for the bankrupcy risk.

Moel and Tufano (2000) study the bidding terms of a copper mine privatization where the probability of investment was preferred to the cash proceeds from the privatization. They suggest that, reducing the committed investment (exercise price), while reducing the option premium, induces more investment.

The real options embedded in airport projects have been studied by Smit (2003) combining real options and game theory to value airport expansion investments. Pereira, Rodrigues and Armada (2007) model an airport investment when the revenues and the number of passengers behave stochastically and negative or positive jumps occur randomly. Gil (2007) present a description of a wide range of real options embedded in airport investments.

A significant and recent trend in the airport industry is the rise of the low-cost airlines. de Neufville (2008) suggests that this trend along with the recognition of the uncertainty of the long term forecasts, has important implications for the airport design planning. Low cost carriers and passengers have different characteristics of the traditional full-service carriers. Usually they demand less quality of the infrastructure in exchange of a lower price. On the other hand these carriers have different strategies, preferring "point-to-point" flights over the traditional "hub" strategy.

Recognizing this, we model demand of a destination as two segments - low-cost and full-service - with different expected growth rates and volatility. To meet the segmented demand, building a single airport serving both segments or segmented airports may be optimal, while delaying the choice of the best strategy adds value.

The paper unfolds as follows. Section 2 describes and value some of the investment incentives when a single demand segment is considered. We present a comparison of the immediate and future cash flows of the different incentives. We extend our analysis, comparing different investment strategies when the demand is modeled as two segments, the full-service and low-cost passengers, in section 3. Building a single airport or segmented airport alternatives are compared is this section and their implication for the incentives needed to prompt investment are analyzed. Section 4 concludes.

2 Incentives to build immediately

Let P be the number of passengers demanding a destination under the following stochastic process:

$$dP = \alpha P dt + \sigma P dZ \tag{1}$$

where α is the (expected) growth rate of the number of passengers, σ the standard deviation, dZ an increment of a Wiener process.

Each passenger produces a net deflated revenue, R, that is assumed to be constant.

Building or expanding an airport can take several years, making the decision of choosing the appropriate capacity an important issue in this type of projects. However, we start by assuming that the scale of the project is decided when the project begins, which means that the present value, at time t, of the investment needed to meet the expected demand is given by:

$$I(t) = K + kC(t) \tag{2}$$

where k is the variable investment cost, by passenger, and C the expected capacity, i.e. :

$$C(t) = E[P(t+m)] = P(t)e^{\alpha m} \tag{3}$$

where m is the time horizon considered, which may be the concession period.

The equivalent risk-adjusted process of equation 1 is:

$$dP = (r - \delta)Pdt + \sigma PdZ \tag{4}$$

where $\delta = \mu - \alpha$ and μ is the equilibrium rate of return. As the stochastic variable is not a traded asset, a general equilibrium model (e.g.: CAPM) can be used to compute the risk premium (λ). The equilibrium rate of return is:

$$\mu = r + \lambda\sigma \tag{5}$$

with $\lambda = \rho_{PM}\frac{r_M - r}{\sigma_M}$

Using the standard procedures, we have the ordinary differential equation that must be followed by the project value, $V(P)$:

$$\frac{1}{2}\sigma^2 P^2 \frac{\partial^2 V}{\partial P^2} + (r-\delta)P\frac{\partial V}{\partial P} - rV = 0 \tag{6}$$

The following boundary conditions are used to find the solution:

$$V(0) = 0 \tag{7}$$

$$V(P^*) = P^*\frac{\varphi}{\delta} - K \tag{8}$$

$$V'(P^*) = \frac{\varphi}{\delta} \tag{9}$$

where $\varphi = R\left(e^{-\delta n} - e^{-\delta m}\right) - \delta k e^{\alpha m}$.

Boundary equation 8, the so-called value matching condition, gives the Net Present Value (NPV) of the project for the moment when it is optimal to invest. We are assuming that either the concession period (m) is finite or that, after m, the NPV is null.

The general solution for equation 6 takes the form:

$$V(P) = AP^{\beta} \tag{10}$$

where β is:

$$\beta = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(-\frac{1}{2} + \frac{r-\delta}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} \tag{11}$$

Determining A and P^* using boundary equations 8 and 9, we get the following solutions for $V(P)$ and P^*:

$$V(P) = \begin{cases} \frac{K}{\beta-1}\left(\frac{P}{P^*}\right)^{\beta} & \text{for } P < P^* \\ \\ P^* \frac{\varphi}{\delta} - K & \text{for } P \geq P^* \end{cases} \tag{12}$$

$$P^* = \frac{\beta}{\beta-1}\frac{\delta}{\varphi}K \tag{13}$$

It is well known that δ must be negative, i.e. $\alpha < \mu$, otherwise the investment will be delayed until the last available moment. For the perpetual options case, as above, investment would never be optimal. If immediate investment is required by the government, there is no "optimal" incentive to prompt immediate investement, except for the case of a finite concession, starting immediately after the concession is granted and before the construction phase. Nevertheless, value is allways destroyed, being finite for the case of a finite lived option and infinite for a perpetual option.

Unless $P > P^*$, investment will be delayed. If immediate investment is intended, several incentives can be given. All of them must make the option to delay worthless ($V(P) = NPV$), which implies allways a cost of $V(P) - NPV$. We proceed now to quantify the amount of the incentive and when it is due.

Fixed investment subsidy

A common incentive is to subsidize investment. Let S be the subsidy needed to make immediate investment optimal:

$$S(P) = K - P\frac{\beta-1}{\beta}\frac{\varphi}{\delta} \tag{14}$$

Lowering P^* to P, demands S immediately, but also increases the value of the project to:

Parameter	Description	Value
P	Current number of passengers per year	15 million
α	Expected growth rate of P	0.02
σ	Standard deviation of P	0.04
R	Current mean net revenue per passenger	7
r	Risk-free interest rate	0.02
λ	Risk premium	0.3
n	Years of construction of the airport	7
K	Airport fixed investment cost	1000 million
k	Airport variable investment cost	25
m	Number of years of the concession	30

Table 1: Base-case parameters

$$V|_{K=K-S(P)}\left(P\right)=\frac{K-S\left(P\right)}{\beta-1}=P\frac{\varphi}{\delta}-\left(K-S\left(P\right)\right) \tag{15}$$

The additional value, induced by the subsidy, is:

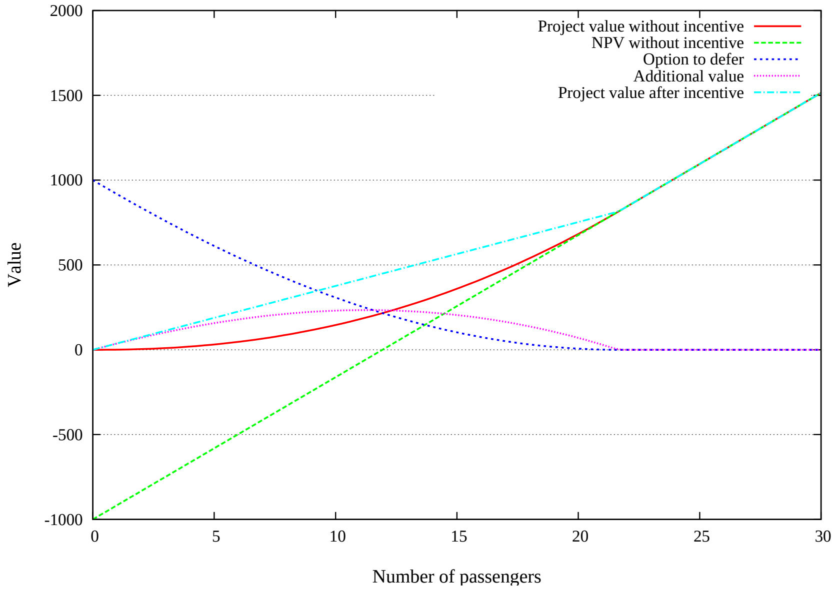
$$\begin{aligned} A\left(P\right)=V|_{K=K-S(P)}\left(P\right)-V|_{K=K}\left(P\right) &= \frac{K-S\left(P\right)}{\beta-1}-\frac{K}{\beta-1}\left(\frac{P}{P^{*}}\right)^{\beta} \\ &= \frac{K}{\beta-1}\left(1-\left(\frac{P}{P^{*}}\right)^{\beta}\right)-\frac{S\left(P\right)}{\beta-1} \end{aligned} \tag{16}$$

If the government pursues immediate investment, a subsidy of $S\left(P\right)$ must be given to to the concessionaire who, in turn, is willing to pay $A\left(P\right)$, additionally to $V\left(P\right)$ and immediately, if that is intended. The net cost of this type of incentive is then:

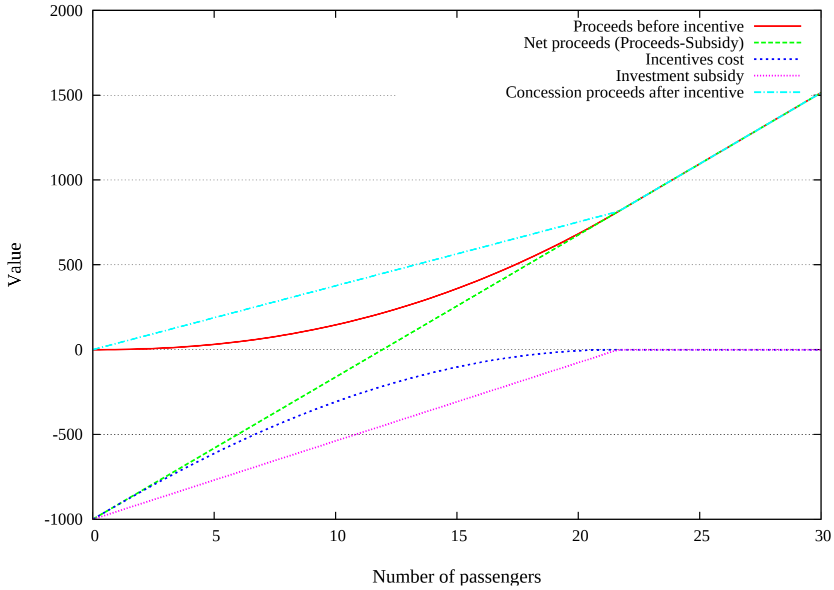
$$\begin{aligned} S\left(P\right)-A\left(P\right) &= S\left(P\right)-\frac{K}{\beta-1}\left(1-\left(\frac{P}{P^{*}}\right)^{\beta}\right)+\frac{S\left(P\right)}{\beta-1} \\ &= S\left(P\right)\frac{\beta}{\beta-1}-\frac{K}{\beta-1}\left(1-\left(\frac{P}{P^{*}}\right)^{\beta}\right) \end{aligned} \tag{17}$$

Figure 1 shows a sensitivity analysis of the value and incentives to the number o passengers, using parameters from Table 1. A higher number of passengers makes the project more valuable and reduces the value of the option to defer, thus reducing the need to have incentives to build immediately the airport. From the government perspective, the maximum value that can be expected to receive from the concession, net of the incentives cost, is exactly the NPV of the project. The investment subsidy has, however, to be greater than the negative NPV (which would be the incentive needed under certainty) to make investment optimal. Part of the subsidy is recovered by the increased value of the project.

A similar analysis for the volatility is shown in Figure 2. As we are doing a static



(a) Concessionaire



(b) Government

Figure 1: Fixed investment subsidy - Number of passengers

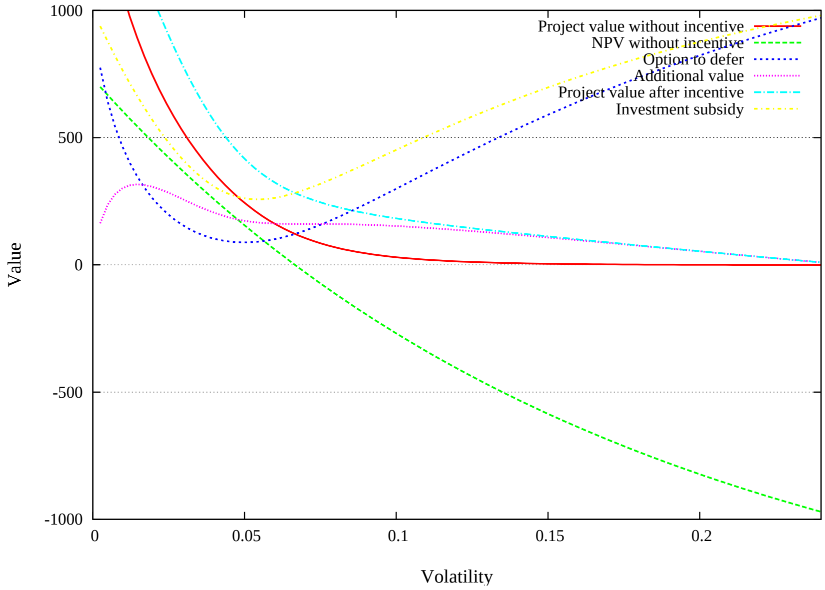


Figure 2: Fixed investment subsidy - Volatility

analysis, λ and α remain constant, meaning that μ adjusts to σ variations, implying a negative relationship between uncertainty and the NPV and the project value. This also implies that the option to defer starts deacreasing with volatility and then increases with volatility. The same relathionship holds for the investment subsidy.

Revenue subsidy

Another incentive could be given in the form of a variable subsidy per passenger, increasing the revenue from R to $R + s(P)$. $s(P)$ must be enough to make φ equal to:

$$\begin{aligned}
\varphi|_{R=R+s(P)} &= \frac{\beta}{\beta-1}\frac{K}{P}\delta \\
(R+s(P))\left(e^{-\delta n}-e^{-\delta m}\right)-\delta k e^{\alpha m} &= \frac{\beta}{\beta-1}\frac{K}{P}\delta \\
s(P) &= \frac{\frac{\beta}{\beta-1}\frac{K}{P}\delta-\varphi|_{R=R}}{e^{-\delta n}-e^{-\delta m}} \qquad (18)
\end{aligned}$$

The present value of the subsidy is given by:

$$S(P)=\frac{s(P)\left(e^{-\delta n}-e^{-\delta m}\right)}{\delta} \qquad (19)$$

The additional value induced by the subsidy is:

$$
\begin{aligned}
A(P) = V|_{R=R+s(P)}(P) - V|_{R=R}(P) &= \frac{K}{\beta-1} - \frac{K}{\beta-1}\left(\frac{P}{P^*}\right)^{\beta} \\
&= \frac{K}{\beta-1}\left(1 - \left(\frac{P}{P^*}\right)^{\beta}\right) \qquad (20)
\end{aligned}
$$

The main differences between a revenue subsidy and an investment subsidy are the moment when they occur and the amounts involved. While the net cost is the same (equal to the value of the option to defer), an investment subsidy is paid immediately and the revenue subsidy is paid in the future. On the other hand, the additional value that the concessionaire is willing to pay, is also different and higher for the revenue subsidy case (Equations 16 and 20).

Figure 3 shows that the revenue subsidy, per passenger, needs to increase up to infinity as we move closer to zero passengers. Differently from the investment subsidy, the project value before the threshold is constant and equal to the NPV at the threshold level.

Guaranteed number of passengers

If the government guarantees the revenues of $\underline{P}$ passengers, whatever the number of passengers might be, the NPV of the project becomes:

$$
\begin{aligned}
NPV(P, \underline{P}) &= P\frac{\varphi}{\delta} - K + R\underline{P}\left(\frac{e^{-rn} - e^{-rm}}{r} - \frac{e^{-\mu n} - e^{-\mu m}}{\mu}\right) \\
&= P\frac{\varphi}{\delta} - K + R\underline{P}\psi \qquad (21)
\end{aligned}
$$

where $\psi = \dfrac{e^{-rn} - e^{-rm}}{r} - \dfrac{e^{-\mu n} - e^{-\mu m}}{\mu}$

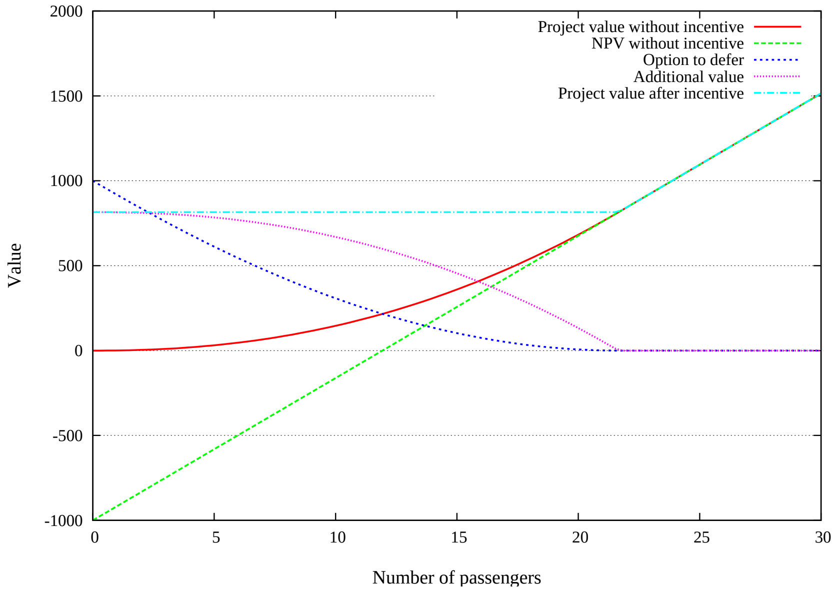
The new threshold is:

$$
P_1^* = \frac{\beta}{\beta-1}\frac{\delta}{\varphi}\left(K - R\underline{P}\psi\right) \qquad (22)
$$

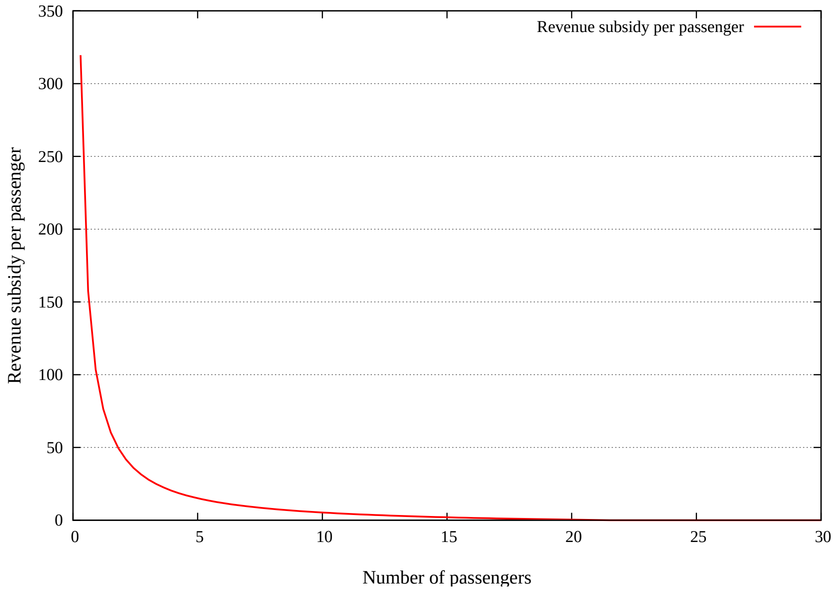
The number of guaranteed passengers, $\underline{P}$, must be such that:

$$
\begin{aligned}
P &= \frac{\beta}{\beta-1}\frac{\delta}{\varphi}\left(K - R\underline{P}\psi\right) \\
\underline{P} &= \frac{K - \frac{\beta-1}{\beta}\frac{\varphi}{\delta}P}{R\psi} \qquad (23)
\end{aligned}
$$

The present value of the subsidy is given by:



(a)



(b)

Figure 3: Revenue subsidy

$$S(P) = R\underline{P}\psi \tag{24}$$

The additional value induced by the subsidy is the same as in Equation 20 or can be obtained with the following equation:

$$\begin{aligned} A(P) = NPV(P, \underline{P}) - V(P) &= P\frac{\varphi}{\delta} - K + R\underline{P}\psi - \frac{K}{\beta-1}\left(\frac{P}{P^*}\right)^\beta \\ &= P\frac{\varphi}{\delta}\frac{\beta}{\beta-1} - \frac{K}{\beta-1}\left(\frac{P}{P^*}\right)^\beta \end{aligned} \tag{25}$$

Figure 4 (b) shows that the number of guaranteed passengers must grow linearly as the "moneyness" of the option to invest decreases. The proceeds from the concession are similar to the case of a fixed investment subsidy (Figure 4).

Concession period

The concession period can be extended by s to make immediate investment optimal. $s(P)$ must be enough to make φ equal to:

$$\begin{aligned} \varphi|_{m=m+s(P)} &= \frac{\beta}{\beta-1}\frac{K}{P}\delta \\ RP\left(e^{-\delta n} - e^{-\delta(m+s)}\right) - \delta k e^{\alpha(m+s)} &= \frac{\beta}{\beta-1}\frac{K}{P}\delta \end{aligned} \tag{26}$$

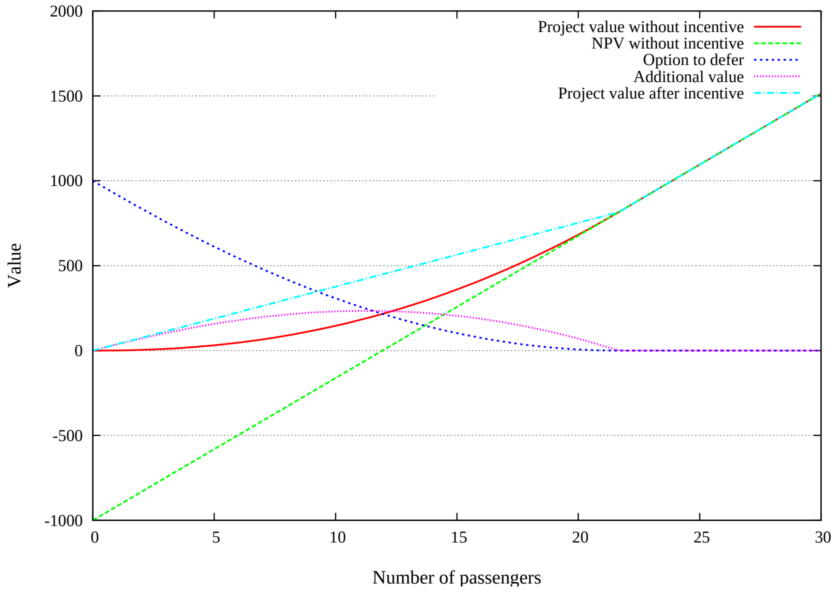
Equation 26 must be solved numerically.

Figure 5 shows that, after a certain point, the NPV decreases with the concession duration. This is due to the variable investment component of the NPV. Such a result implies that we are unable to prompt immediate investment for low numbers of passengers (Figure 6). The incentives are similar to the revenue subsidy, except that we can only induce investment for P greater than 10 million.

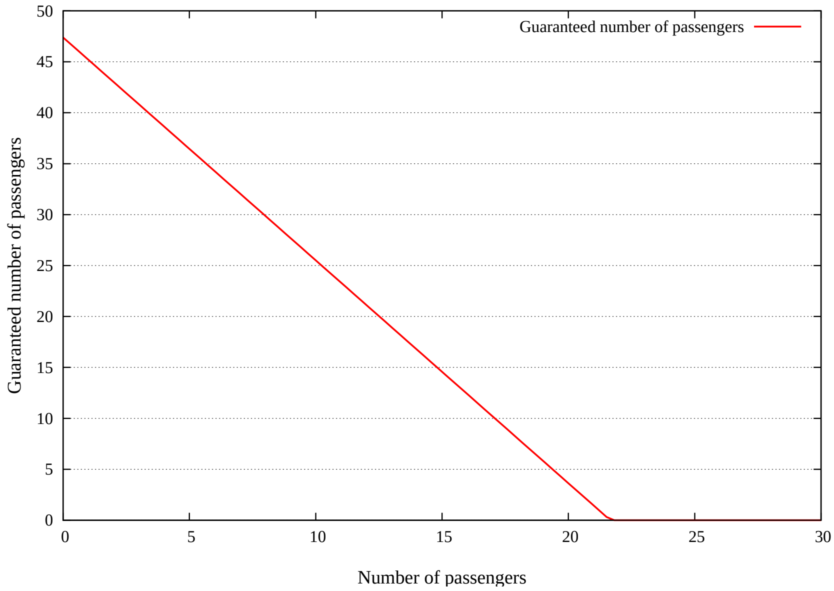
Immediate vs future cash flows

We now compare the moment of the payment of the incentives and the net proceeds from the incentives. Figure 7 shows the government cash flows induced by the incentives. The investment subsidy is the only incentive, of those presented above, that is due immediately[1]. All the other types of incentives are due after concession is granted, with positive cash flows, related with the additional project value, received immediately. The revenue

[1]To be more precise, any incentive can be deferred or anticipated at the risk-free rate.



(a)



(b)

Figure 4: Guaranteed number of passengers

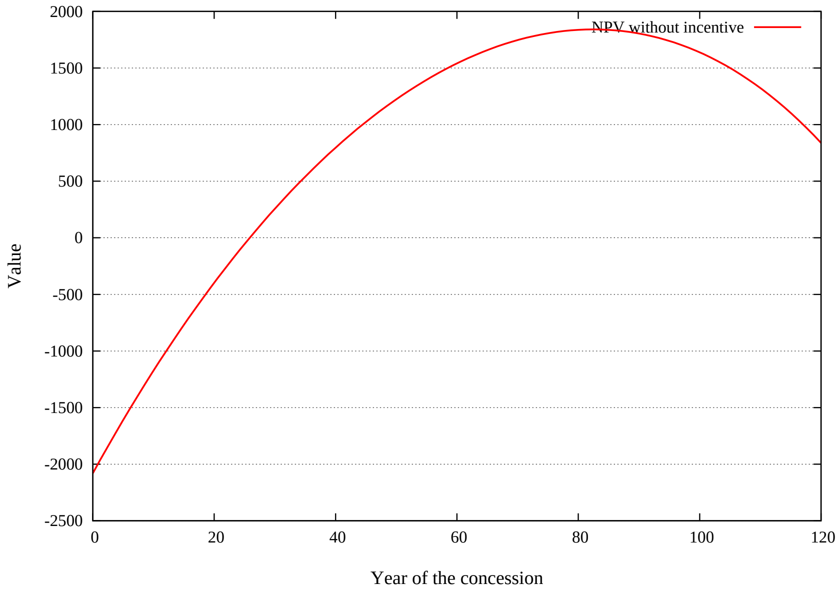


Figure 5: NPV - concession period

subsidy and the guarantee of a certain number of passengers, are the incentives which delay more the payments and anticipate more the receipts. These type of incentives may be more likely to be given by governments which are less committed to future tax payers generations.

3 A single full-service airport or segmented airports

Let us assume that there are two types (segments) of passengers demanding a destination:

$$dP_l = \alpha_l P_l dt + \sigma_l P_l dZ_l \tag{27}$$

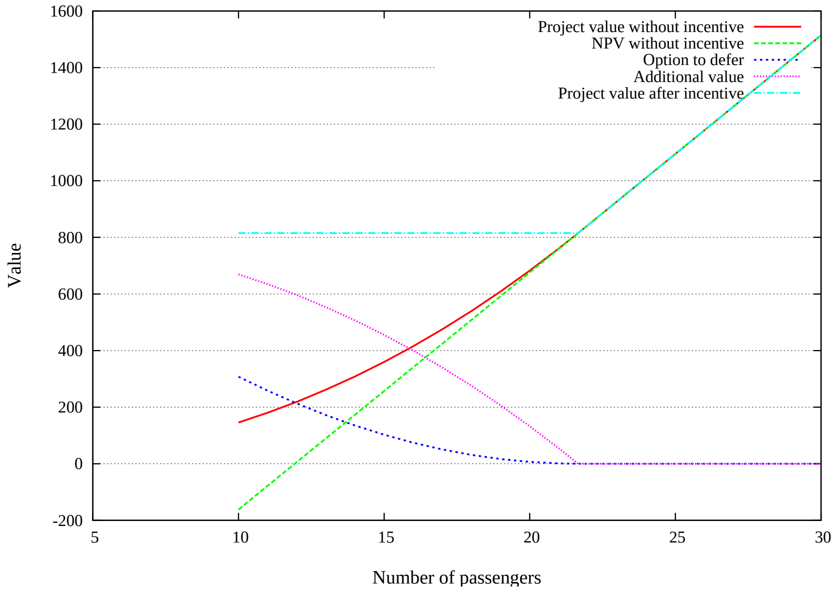
$$dP_f = \alpha_f P_f dt + \sigma_f P_f dZ_f \tag{28}$$

$$E\left[dZ_l dZ_f\right] = \rho dt$$

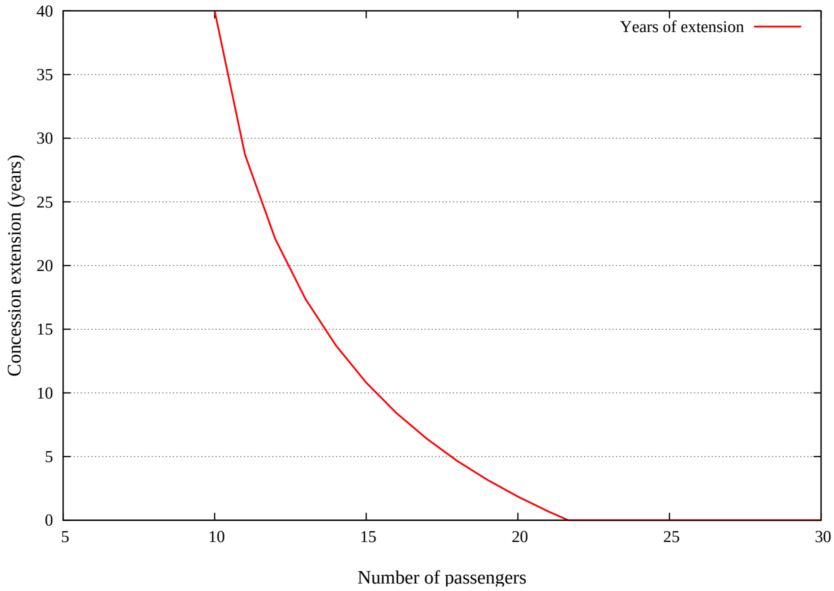
where α_l and α_f are the (expected) growth rate of the number of low cost and full service passengers, σ_l and σ_f the respective standard deviations, dZ_l and dZ_f increments of Wiener processes and ρ the correlation coefficient.

An important issue is whether a single aiport, serving both segments, or segmented airports are the optimal strategy.

As in the previous section, each passenger produces a net revenue R_i $(i = l, f)$, that is assumed to be constant. We also assume that, for the case of a single airport, the

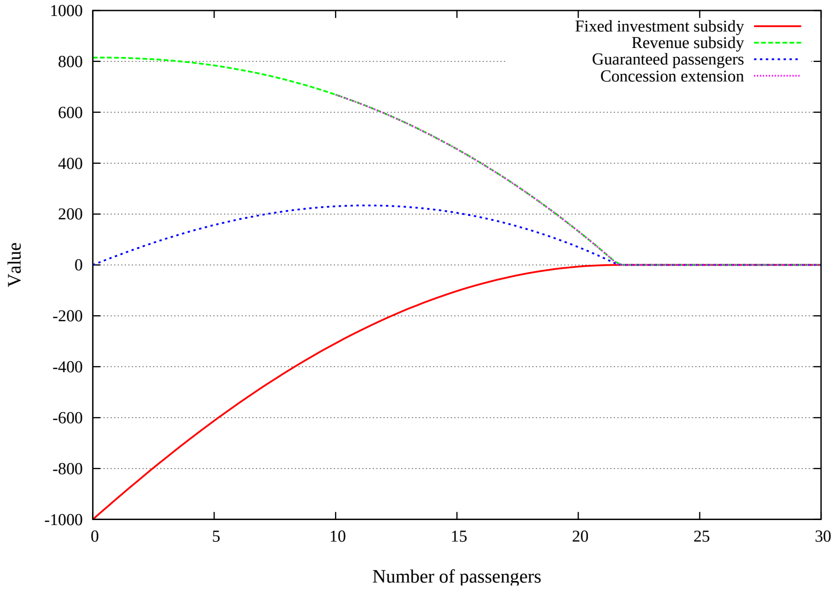


(a)

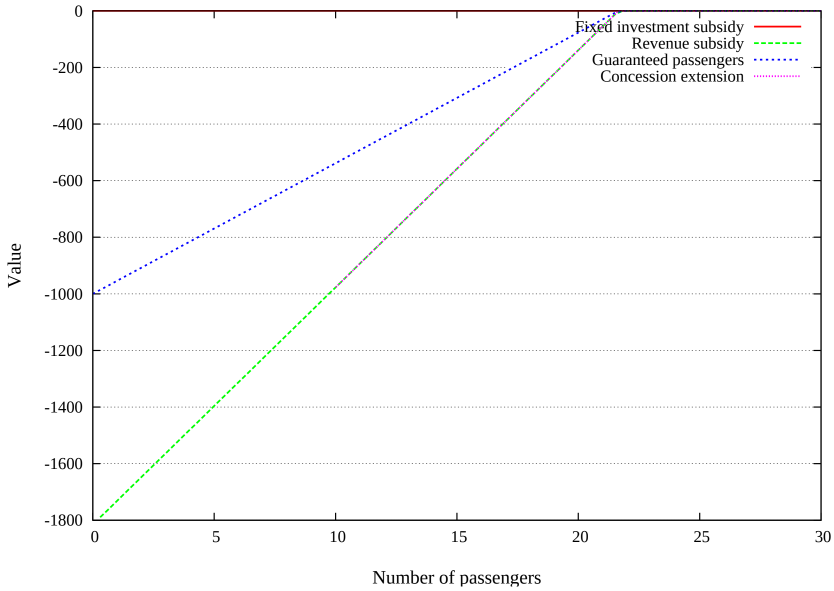


(b)

Figure 6: Concession extension



(a) Immediate



(b) Future

Figure 7: Immediate vs future cash flows

revenue, R_s, is equal for both segments. If the traffics are segmented by two airports, it is reasonable to assume that $R_l < R_f$.

The present value of the investment, needed to meet the expected future demand, is given by:

$$I_i = K_i + k_i C_i \tag{29}$$

where k_i is the variable investment cost per passenger, C_i the expected capacity, as follows:

$$C_i\left(t\right) = E\left[P_i\left(t+m\right)\right] = P_i\left(t\right) e^{\alpha_i m} \tag{30}$$

and m is the concession period. Note that, for the case of a single airport, the capacity is $C_l + C_f$.

It also reasonable to assume that the low cost segment has higher expected growth rates ($\alpha_l > \alpha_f$) and higher uncertainty ($\sigma_l > \sigma_f$).

The decision to invest in segmented airports

Although the traffics are correlated, the decisions to build two segmented airports are independent, if that decision is only determined by economic factors.

The project value is the same as in the previous section:

$$V_i(P_i) = \begin{cases} \frac{K_i}{\beta_i - 1}\left(\frac{P_i}{P_i^*}\right)^{\beta_i} & \text{for } P_i < P_i^* \\ \\ P_i^* \frac{\varphi_i}{\delta_i} - K_i & \text{for } P_i \geq P_i^* \end{cases} \tag{31}$$

$$P_i^* = \frac{\beta_i}{\beta_i - 1}\frac{\delta_i}{\varphi_i} K_i \tag{32}$$

where $\delta_i = r + \lambda_i \sigma_i - \alpha_i$ and $\varphi_i = R_i\left(e^{-\delta_i n_i} - e^{-\delta_i m}\right) - \delta_i k_i e^{\alpha_i m}$.

The decision to invest simultaneously in segmented airports

When the concessionaire is committed to build simultaneously the two airports, the project value function, $V\left(P_l, P_f\right)$, must satisfy the following PDE:

$$\begin{aligned} &\frac{1}{2}\sigma_l^2 V^2 \frac{\partial^2 V}{\partial P_l^2} + \frac{1}{2}\sigma_f^2 V^2 \frac{\partial^2 V}{\partial P_f^2} + \rho \sigma_l \sigma_f P_l P_f \frac{\partial^2 V}{\partial P_f \partial P_l} \\ &\quad + \left(r - \delta_l\right) P_l \frac{\partial V}{\partial P_l} + \left(r - \delta_f\right) P_f \frac{\partial V}{\partial P_f} - rV = 0 \end{aligned} \tag{33}$$

This PDE can only be solved numerically using finite differences methods, or $V\left(P_l, P_f\right)$

can be found with a binomial tree method or by simulation. In all cases we have to use a finite maturity.

We compute the project value using the Boyle, Evnine and Gibbs (1989) binomial method. At each time-step of the binomial tree, the payoff of immediate exercise of the option to invest must be compared with the continuation value. That payoff, when the decision to invest must be made simultaneously for the two airports, is given by:

$$\Pi_{2s}(V_l, V_f) = P_f \frac{\varphi_f}{\delta_f} - K_f + P_l \frac{\varphi_l}{\delta_l} - K_l \tag{34}$$

The decision to invest in a single airport

The value of the project for the case of a single airport, serving both traffics, must satisfy the same PDE (Equation 33). The payoff is now given by:

$$\Pi_1(V_l, V_f) = P_f \frac{\varphi_f}{\delta_f} + P_l \frac{\varphi_l}{\delta_l} - K_s \tag{35}$$

where K_s is the single airport fixed investment cost, $\varphi_i = R_s \left(e^{-\delta_i n_s} - e^{-\delta_i m}\right) - \delta_i k_s e^{\alpha_i m}$.

Delaying the choice of the best alternative

All the previous alternatives have been valued independently and with the assumption of choosing immediately the best alternative. The best strategy is contingent on the values of the underlying stochastic variable and delaying the decision may add value to the project. The option to delay the choice can be valued as before, but with the following exercise payoff:

$$\Pi_b(V_l, V_f) = \max\left[\Pi_{2i}(V_l, V_f), \Pi_{2s}(V_l, V_f), \Pi_1(V_l, V_f)\right] \tag{36}$$

where $\Pi_{2i}(V_l, V_f) = V(P_l) + V(P_f)$ is the payoff of investing in segmented airports.

When we value the option with numerical methods, we are confined to finite lived options. A fair comparison of the different alternatives, should be done for the same maturity, which means that we have also to resort to numerical methods even for the case of the two segmented airports. As those options only have a single underlying asset, we value them using the Cox, Ross and Rubinstein (1979) binomial method.

Parameter	Description	Full-service	Low-cost	Single airport
P	Current number of passengers per year (million)	15	5	
α	Expected growth rate of P	0.02	0.04	
σ	Standard deviation of P	0.04	0.1	
R	Current mean net revenue per passenger	7	5	7
r	Risk-free interest rate		0.02	
λ	Risk premium	0.3	0.35	
n	Years of construction of the airport	7	3	7
K	Airport fixed investment cost (million)	1000	300	1000
k	Airport variable investment cost	25	5	25
m	Number of years of the concession		30	
T	Maturity of the option to invest		30	

Table 2: Base-case parameters

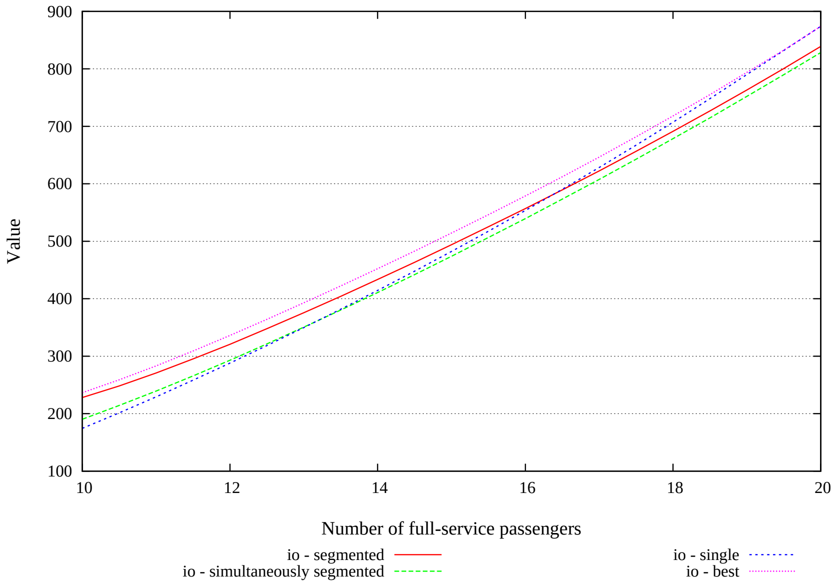
Comparison of the four alternatives

We now compare the four investment strategies using the parameters presented in Table 2.

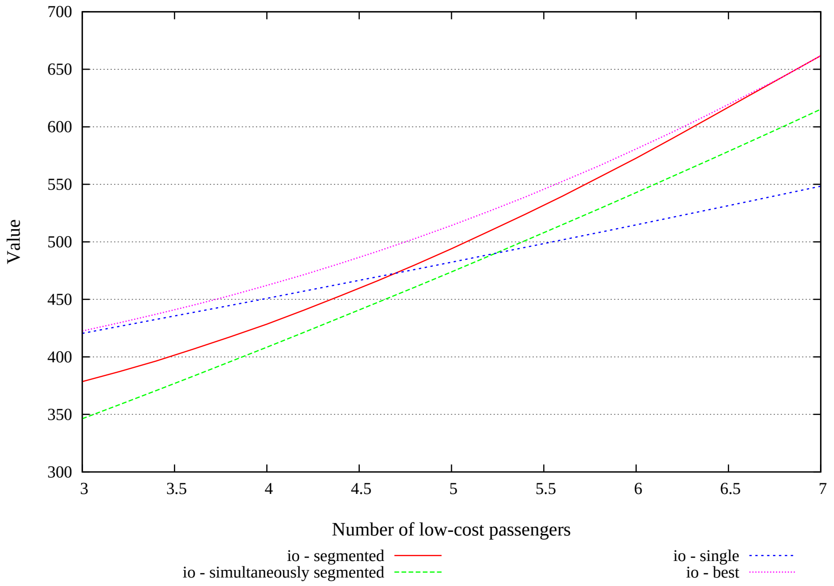
Figure 8 shows the impact of the number of passengers. Building two segmented airports simultaneously is allways less valuable than building them independently. A single airport is more valuable the higher the number of full-service passengers (Figure 8 (a)) and the lower the number of low-cost passengers (Figure 8 (b)). These results come from the fact that the trigger value (when the option to defer is null), is lower for the single airport than for the segmented airports (Figures 8 (c) and (d)). A higher number of low-cost passengers, on the other hand, increases the incentive to build a low-cost airport, raising the value of the segmented airports alternative.

Delaying the choice of the best alternative has allways value, but that value converges to zero, i.e. equals the single airport alternative or the segmented airport alternative, as we move to extremes. On the other hand, giving the concessionaire the option to delay, demands a higher incentive to make immediate investment optimal. The value of the option to defer (Figures 8 (c) and (d)) measures the net incentives needed. For the base-case parameters, prompting immediate investment in a single airport is allways cheaper for the range analyzed.

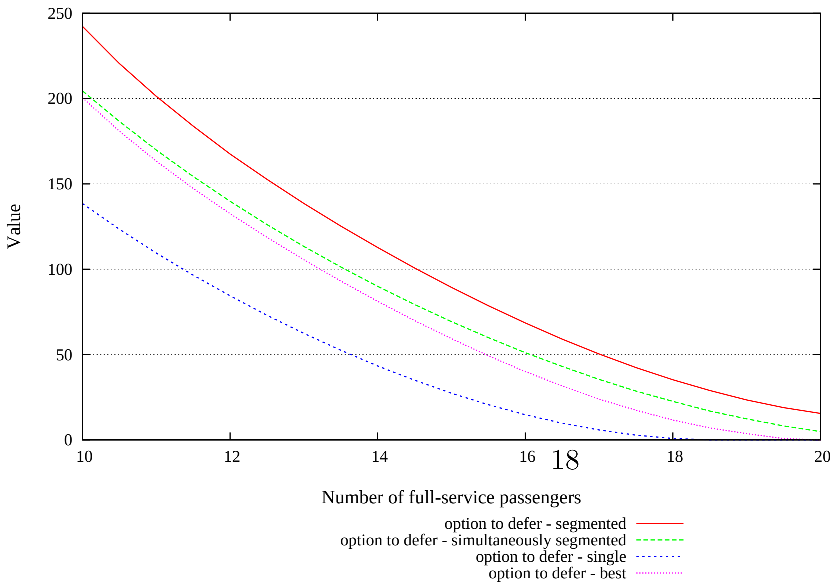
The effect of volatility is presented in Figure 9. As in the previous section, a higher volatility increases the required rate of return, which in turn, reduces the "moneyness" of the projects. As we move to the extremes, the segmented airports strategy is more valuable, whereas for intermediate value of volatility we have closer values of the two strategies. In fact, for different base-case parameters, we could have higher values for the single airport strategy, for the intermediate volatility levels.


Value
Number of full-service passengers
io - segmented
io - simultaneously segmented
io - single
io - best

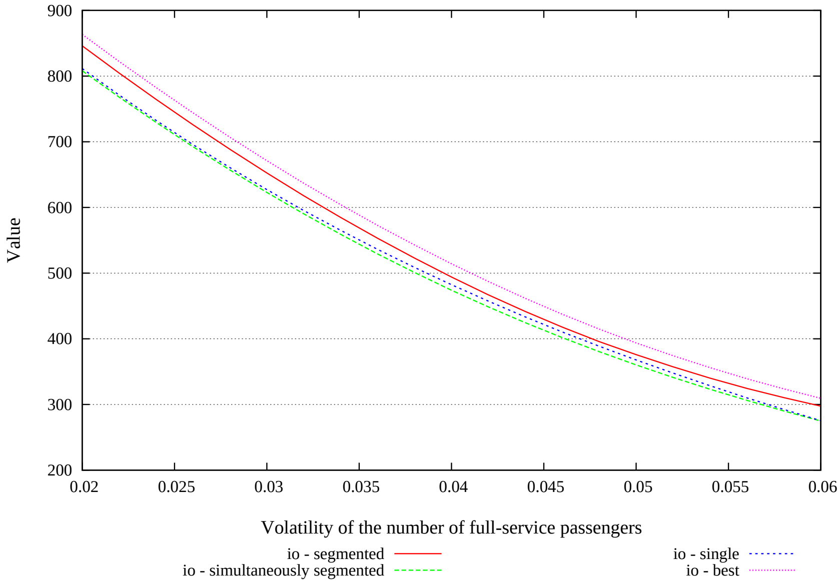
(a)


Value
Number of low-cost passengers
io - segmented
io - simultaneously segmented
io - single
io - best

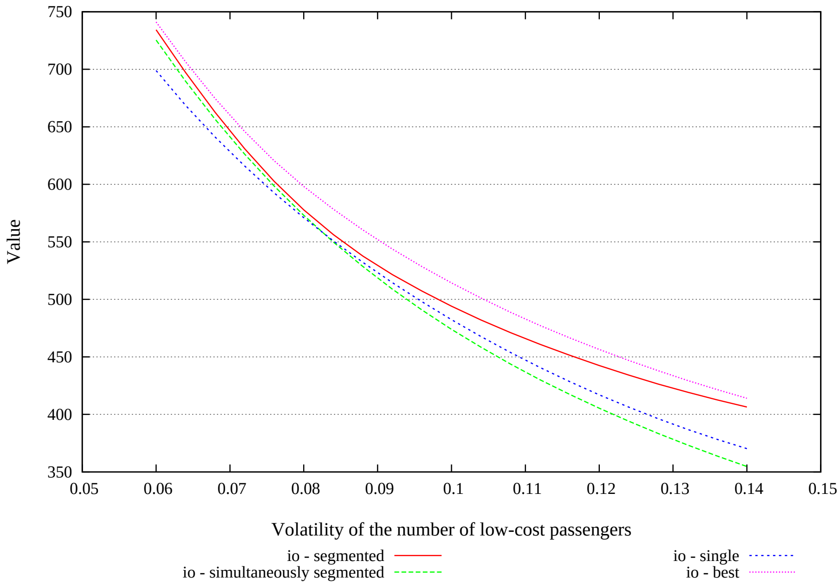
(b)


Value
Number of full-service passengers
option to defer - segmented
option to defer - simultaneously segmented
option to defer - single
option to defer - best

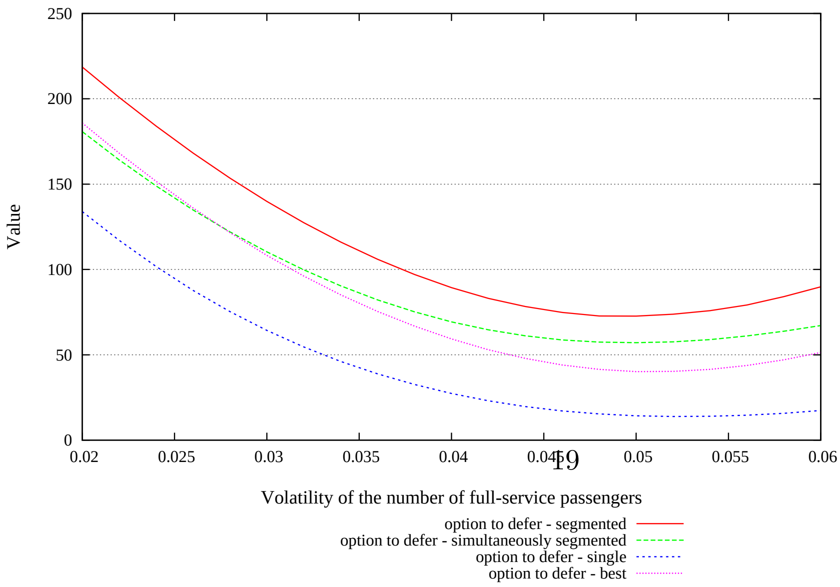
(c)


Value
Volatility of the number of full-service passengers
io - segmented
io - simultaneously segmented
io - single
io - best

(a)


Value
Volatility of the number of low-cost passengers
io - segmented
io - simultaneously segmented
io - single
io - best

(b)


Value
Volatility of the number of full-service passengers
option to defer - segmented
option to defer - simultaneously segmented
option to defer - single
option to defer - best

(c)

4 Concluding remarks and future research

Building an airport involves large sunk costs which, as is suggested by the real options literature, under uncertainty, produces an incentive to delay investment. These projects have been frequently developed by public-private partnerships and, usually, the government who grants the concession, seeks immediate investment. A correct valuation of these incentives is crucial to promote the desired outcome and to avoid an excessive value transfer to the private sector.

We quantify the optimal investment subsidy, revenue subsidy, guaranteed number of passengers and concession extension that prompts immediate investment. Furthermore we show that these type of incentives are due in different amounts and moments, with the revenue subsidy and concession extension incentives being more likely, when the government favors current to future tax payers.

We extend our analysis to the optimal investment strategy and incentives when we model demand with two segments recognizing the rise of the low-cost carriers which have different characteristics when compared to the traditional full-service demand. We show that the alternative strategies of building a single airport, serving both segments, or segmented airports, dominate for different parameters values. Nevertheless, delaying the choice of the best alternative increases project values and thus increases the need for incentives to promote immediate investment.

Several extensions can be made to this paper. Other options, as the expansion or the bankruptcy options can be added to the model. Optimal capacity choice is another important issue in large scale projects. Other assumptions about the stochastic behavior of the two segments, namely mean-reverting processes, could be considered. Adding more stochastic variables is also another feasible extension.

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