Fiscal Impact of Government Guarantees on Highway Concession Projects

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Abstract

PPPs are adopted worldwide to provide public infrastructure since they offer numerous benefits for public and private partners. Yet, they may present problems due to the multiple uncertainties embedded in the projects. Therefore, in order to attract private investment some form of mitigation of risks may be required. These risk mitigation mechanisms may take many forms, such as the Minimum Traffic Guarantee (MTG) in highway concessions, which provides the concessionaire a floor on demand uncertainty. On the other hand, these mechanisms also place a contingent liability and financial burden on the government budget, which must be adequately priced. Some of these government supports can be modeled as derivative securities such as options, as their value derives from pre-established triggers on the stochastic behavior of roadway traffic, in the case of the MTG. Thus, the cost to the government of these mechanisms must be appropriately determined under option pricing methods. This article contributes to the analysis of these projects through the governmental perspective and how this impact, if incorrectly measured, can adversely affect government finances.

Keywords: Real Options; Public finance; Government guarantees; Public-Private Partnerships; Highway Concession.

1. Introduction

Investment in public infrastructure is essential to the development of a country´s economy and plays an important role in supporting a nation's socioeconomic stability, promoting prosperity and attracting foreign investment (ALMASSI; MCCABE; THOMPSON, 2012). Infrastructure projects require significant capital investments which may not be available from public sources, which has led to solutions that involve partnerships with a private firms to supply the capital required to carry out these projects. These arrangements, known as Public Private Partnerships (PPP), offer numerous benefits for public and private partners in the development of infrastructure projects. The main reason for governments to be interested in this type of cooperation is the use of necessary funds for crucial financial infrastructure projects. Private partners, on the other hand, are more interested in the economic viability and expected returns of the project and, therefore, are mainly concerned with in revenue risk (BUYUKYORAN; GUNDES, 2018).

PPPs are adopted worldwide to provide public infrastructure, which, despite the attractiveness of the PPP structure, may present problems due to the multiple uncertainties embedded in the projects. Private investors may require some form of mitigation of these risks by the government for high risk projects (CARBONARA; COSTANTINO; PELLEGRINO, 2014).

These risk mitigation mechanisms may take many forms. One of the most common is the Minimum Traffic Guarantee (MTG) which provided the concessionaire some formo f support if demand turns out to be significantly lower than expected. In this way, the government shares a portion of the risk with the concessionaire, which makes the project more attractive to private investors and, thus, the projects can be developed.

In the context of large infrastructure projects, the valuation presents some additional challenges since the amount of resources involved are often significant, and the economic implications of an incorrect valuation of projects can be substantial (HAWAS; CIFUENTES, 2017). Some kinds of government support, such as guarantees and subsidies, can be interpreted as options since some pre-established conditions trigger the obligations. Thus, the value of these options under option pricing methods must be appropriately determined to obtain a better balance between risk and benefit (CHEAH; LIU, 2006).

These risk mitigating mechanisms, however, while providing value to the private sector, also place a contingent liability and financial burden on the government budget which must be adequately priced. Thus, governments worldwide must be able to determine if the project's risk is mitigated to a level which is acceptable to the private party, while at the same time decide if the level of future obligations and financial burden they entail remains within the fiscal capacity of the government (ALMASSI; MCCABE; THOMPSON, 2012).

The theory of real options offers an approach to the evaluation of investments in real assets based on the methodology developed for financial options. An essential aspect of this investment evaluation method is to consider the managerial flexibility of the projects, evaluating them and incorporating them in the model for continuous decision making. These flexibilities translated into Real Options reflect the alternatives existing within a project, giving the right, but not the obligation, to a specific action on a real asset at a cost during the life of the option. The real asset can be an opportunity to invest in an existing project or asset, and the decision is whether or not to exercise one or more options.

While much of the work related to public guarantees for private infrastructure investment is concerned with analyzing the economic viability of the projects from the point of view of the private investor, in this article we seek to measure and analyze their impact on government budgets. This article contributes to the analysis of these projects through the governmental perspective and how this impact, if incorrectly measured, can adversely affect government finances.

This article is organized as follows: After this introduction we provide a review of the literature and next the methodology is addressed, as well as the model used to assess the impact of these government guarantees. In section four we apply the real options approach to the case of a bridge concession in Brazil and following that we discuss the results. Finally, we conclude.

2. Literature Review

Infrastructure projects demand high investments on the part of the government, which may seek partnerships with private initiative in order to implement. However, some of these projects may present a degree of uncertainty and risk that make it difficult to attract private capital investment. In order to solve this problem, governments may seek to reduce these risks by providing some form of risk mitigation such as traffic or demand guarantees. In this way, the government shares part of the risks of the project which makes it more attractive to the private party.

One of the main factors that contribute to the success of PPP projects is the adequate risk allocation among stakeholders. Revenue risk is the leading risk in the external operating environment (KOKKAEW; CHIARA, 2013). Government guarantees allow the private investor to recover part of their losses, given that, if a project performs poorly in a given year, the investor has the option of requiring the government to refund it up to a guaranteed level pre-established. Due to these characteristics, the valuation of these guarantees involves the use of option pricing methods known as analysis of Real Options (BRANDAO; SARAIVA, 2008).

Different levels of guarantees affect the risk profile of the project and provide suggestions on how the government can use this information to minimize its costs. In this sense, it is essential to seek the best levels of guarantee to reduce project risks and minimizes the impacts on public accounts, while maintaining the attractiveness for the private sector. Real options solves the need for an approach to infrastructure management and assessment that captures the value of flexibility, which should be taken into account in infrastructure projects, as failure to incorporate flexibility can significantly change the value of a project (MARTINS; MARQUES; CRUZ, 2013).

Government intervention can take many forms. One of the most common ways of government support instruments is the Minimum Revenue Guarantee (MRG), in which the government ensures a minimum revenue amount for a project (HUANG; CHOU, 2006; ASAO et al., 2013; CARBONARA; COSTANTINO; PELLEGRINO, 2014; POWER et al., 2016; HAWAS; CIFUENTES, 2017; BUYUKYORAN; GUNDES, 2018).

The real options model of Minimum Traffic Guarantee (MTG) can also be used to assess the value of government guarantees, allowing the government to analyze the cost-effectiveness of each level of support and propose an alternative to limit government exposure while maintaining the benefits for the private investor (CHEAH; LIU, 2006; BRANDAO; SARAIVA, 2008; GALERA; SOLIÑO, 2009; BRANDÃO et al., 2012; BLANK et al., 2015).

Other models are often used in infrastructure projects such as the abandonment option (HUANG; CHOU, 2006; RAKIĆ; RADENOVIĆ, 2014; BLANK et al., 2015; CABERO COLÍN; SÁNCHEZ SOLIÑO; LARA GALERA, 2016), the maximum traffic ceiling (BLANK et al., 2015; BUYUKYORAN; GUNDES, 2018) and even the maximum interest rate guarantees (MIRGs) (PELLEGRINO; CARBONARA; COSTANTINO, 2019),

The real Options approach can combine different types of options in the same model, obtaining different results for each configuration. Huang e Chou (2006) used Real Options to assess the minimum revenue guarantee (MRG) gone with the abandonment option of infrastructure pre-construction project in the built-operation-transfer (BOT) model. First, two pricing models with a single option were developed to evaluate the MRG and the abandonment option. Then, a composite option model was developed, combining the MRG with the abandonment option. The models used European options, whose practical application was carried out in the Taiwan High-Speed Railway project. The authors observed that both the MRG and the abandonment option could bring meaningful results to the project, however by increasing the level of MRG, the value of the abandonment option was reduced until, at a certain level, that the option to abandon will be useless.

The Subway System Concession (Line 4) in the city of São Paulo considered the estimated flow of passengers to determine government guarantees through belts of passenger flows that sought to mitigate the risk of the bidding winner. This project was analyzed by Brandão et al. (2012) using a real options approach, the results of which indicated that the proposed guarantees were effective in reducing the risk of the project and increased the net present value of the project. As well, they showed that the best risk reduction mechanisms were those that included a more significant share of minimum traffic guarantees concerning the payment of the subsidy.

Blank et al. (2015) proposed a hypothetical concession of toll roads in Brazil using the minimum traffic guarantee, a maximum traffic limit, and an implicit abandonment option. They concluded that the abandonment option affects the level of guarantees to be given and that governments should calibrate an optimal level of guarantees to avoid unnecessarily high costs, protect the sponsor's returns and decrease the likelihood of abandonment.

A model that combines the Minimum Revenue Guarantee (MRG) and the Maximum Revenue Cap (MRC) was proposed by Buyukyoran and Gundes (2018), concluding that the identified range of MRG and MRC allows the structuring of a flexible trading environment for both parts.

3 Model

A stochastic process describes the behavior of a variable whose changes are uncertain over time, in other words, it is a random process as a function of time. Stochastic processes can be classified as continuous or discrete times: If continuous changes can occur at any time, otherwise, they only happen at fixed points in time.

One of the most common and widely used stochastic processes is the Geometric Brownian Motion diffusion process. It is commonly assumed that traffic and revenues will vary stochastically over time following an MGB (Brandao & Saraiva, 2007).

3.1 Geometric Brownian motion (GBM)

The Geometric Brownian motion (GBM) is the most popular in the modeling of financial and real assets, which can be explained by the simplicity of application and mainly by its easy understanding. It is an appropriate process for variables that grow exponentially at an average rate α and proportional volatility at the level of variable X.

In GBM, the stochastic equation for a variable X that varies over time is defined by the following stochastic equation:

$$dX = \alpha X dt + \sigma X dz \tag{1}$$

onde X = stochastic variable; dX = instantaneous variation of X, α = drift of the stochastic variable; dt = time differential; σ = instantaneous volatility of the stochastic variable; dz = Wiener increment.

According to Dixit, Dixit e Pindyck (1994):

$$dz(t) = \varepsilon(t)\sqrt{dt} \ , where\ \varepsilon(t) \sim N(0{,}1)$$

$$E(dz) = 0$$

$$Var(dz) = E[\,(dz^2)] - [\,E(dz)]^2 = E\,[(dz^2)] = dt$$

As demonstrated by Dixit, Dixit e Pindyck (1994), for a variable X(*t*) that follows a GBM and has a lognormal distribution, the mean and variance are given by:

$$E[X(t)] = X_0 e^{\alpha t}$$

$$Var[X(t)] = X_0^2 e^{2\alpha t}(e^{\alpha^2 t} - 1)$$

Thus, if X follows a GBM, at any future time, X has a lognormal distribution in which the trend (expected value curve) is exponential growth at an α (if α < 0 an exponential decay) and with increasing variance with time (DIXIT; PINDYCK, 1994). In GBM the variance increases in an unlimited way with time, that is, considering that one usually has the variance grows unlimited over time, that is, assuming that usually $> -\frac{\sigma^2}{2}$:

$$X \sim GBM \Rightarrow Var[X(t)] \to \infty \ \ se\ t \to \infty$$

3.2 Mininum Traffic Guarantee

Consider a contractual guarantee where the government is required to compensate the concessionaire whenever the traffic level falls below a pre-established floor during a certain period of time. Define Rt as the observed revenue of the project ($R_t = Traffic \times tariff$) in year *t* and RMt as the minimum revenue guaranteed by the government in that year. Assuming that the tariff is constant, revenues will follow the same stochastic process as traffic uncertainty.

The resulting revenue for the concessionaire in year *t* is $R(t) = maximum(R_t, RM_t)$, while the $G(t)$ value of the government guarantee in year *t* is $\mathrm{G}(t) = maximum(0, RM_t - R_t)$.

The GBM (eq. (1)) can be represented through its returns, as shown below:

$$dlnX = \left(\alpha - \frac{\sigma^2 X}{2}\right) dt + \sigma dz$$

Furthermore, it can be discretely modeled in annual periods compared to the previous period:

$$R_{t+1} = R_t e^{\left(\alpha - \frac{\sigma^2 X}{2}\right)\Delta t} + \sigma\varepsilon\sqrt{\Delta t}$$

The risk-neutral process is used to assess the guarantees in which the risk premium is subtracted from the expected rate of return on the underlying asset. The appropriate risk premium, however, cannot be determined directly because markets are incomplete for traffic and revenue. Under the MTG model, Brandao e Saraiva (2008) shows that the parameters for the revenue risk premium can be estimated from the stochastic process of the project value.

Assuming that the revenue process is defined by (1) and that revenues provide the only source of uncertainty for the project, the evolution of the project value $V = f(R)$ is defined, in which $dV = \mu V dt + \sigma_P V dz$ where σ_P is the volatility of the project. From the Itô process, we have:

$$dV = \left(\alpha R \frac{\partial V}{\partial R} + \frac{\partial V}{\partial t} + \frac{1}{2}\alpha^2 R^2 \frac{\partial^2 V}{\partial R^2} + \frac{\partial V}{\partial R}\right) dt + \sigma R \frac{\partial V}{\partial R} dz \quad (2)$$

From the capital asset pricing model (CAPM), we have:

$$\mu = r + \beta_P(E[R_M] - r) \quad (3)$$

where μ e β_P are the risk-adjusted discount rate and the project beta, respectively.

From (3), we have:

$$\mu - r = \beta_P(E[R_M] - r)$$

The project risk premium can also be expressed as $\lambda\sigma_P$, therefore:

$$\mu - r = \lambda\sigma_P \quad (4)$$

Substituting (2) in (4) and making some algebraic manipulations, we find the following differential equation:

$$R(\alpha - \lambda\sigma_P)\frac{\partial V}{\partial R} + \frac{\partial V}{\partial t} + \frac{1}{2}\alpha^2 R^2 \frac{\partial^2 V}{\partial R^2} - rV = 0$$

Brandao e Saraiva (2008) then determine the following expression for the revenue risk premium as a function of the project risk and volatility premium and revenue volatility, which are known constants:

$$\lambda_{\sigma_P} = \beta_R(E[R_m] - r)\frac{\sigma_R}{\sigma_P}$$

The revenue risk-neutral process found is:

$$dR = (\alpha - \lambda_{\sigma_P})Rdt + \sigma_R R dz$$

3.3 Traffic Guarantees Measurement

The value of government guarantees can be modeled as a series of independent European options with annual maturities, the value of guarantee options being determined by a Monte Carlo simulation of the level of stochastic traffic.

The government guarantees the minimum traffic limit ($LIM_{inf}\ A$) that will be guaranteed when the real traffic ($TRAFF_{real}$) is less than this level. Besides that, one new traffic belt is included whose demand risk will be shared between the public and private partners. Thus, if the actual traffic ($TRAFF_{real}$) is above the previous minimum traffic limit ($LIM_{inf}\ A$) and below the new limit ($LIM_{inf}\ B$), the government would guarantee a percentage (d) the difference between this new limit ($LIM_{inf}\ B$) and the actual traffic ($TRAFF_{real}$) observed.

On the other hand, if the actual traffic ($TRAFF_{real}$) is higher than the maximum traffic limit ($LIM_{sup}\ A$), the government will retain all traffic revenue that exceeds this limit. Additionally, one new traffic belt is included whose traffic revenue will be shared between the public and private partners. Thus, if actual traffic ($TRAFF_{real}$) falls below the previous maximum traffic limit ($LIM_{sup}\ A$) and above the new limit ($LIM_{sup}\ B$), the government will retain a percentage (d) of the difference between this new limit ($LIM_{sup}\ B$) and actual traffic ($TRAFF_{real}$)

The guarantee options will be exercised for each year according to table 1, in which the option value will be 0 (zero) when it does not satisfy the imposed condition.

Table 1: Value of options by year *t*

CONDITION	**OPTION VALUE**
$TRAFF_{real} \geq LIM_{sup}\ A_t$	$CALL_A = Tariff * \left(TRAFF_{real} - LIM_{sup}\ A_t\right)$
$LIM_{sup}\ A_t > TRAFF_{real} \geq LIM_{sup}\ B_t$	$CALL_B = Tariff * (TRAFF_{real} - LIM_{sup}\ B_t) * d$
$LIM_{sup}\ B_t > TRAFF_{real} \geq LIM_{inf}\ B_t$	0
$LIM_{inf}\ B_t > TRAFF_{real} \geq LIM_{inf}\ A_t$	$PUT_B = Tariff * (LIM_{inf}\ B_t - TRAFF_{real}) * d$
$TRAFF_{real} < LIM_{inf}\ A_t$	$PUT_A = Tariff * (LIM_{inf}\ A_t - TRAFF_{real})$

Thus, the government must guarantee for *T* years:

$$Outgoings = \sum_{1=1}^{T}(PUT_{A_i} + PUT_{B_i}) \quad (5)$$

On the other hand, the government will retain revenue from the demand for *T* years:

$$Incomes = \sum_{1=1}^{T}(CALL_{A_i} + CALL_{B_i}) \quad (6)$$

Thus, the difference between both equations will give the Liability of guarantees in the government budget during the *T* years of guarantees:

$$\text{Liability} = Outgoings - Incomes$$

$$\text{Liability} = \sum_{1=1}^{T}(PUT_{A_i} + PUT_{B_i}) - \sum_{1=1}^{T}(CALL_{A_i} + CALL_{B_i}) \quad (7)$$

4 Numerical Application

4.1 The Salvador – Itaparica Bridge

We analyzed the case of the Public-Private Partnership project for the construction, operation and maintenance of the Salvador - Itaparica Bridge road system, located in the state of Bahia, Brazil which involved the granting of a Minimum Traffic Guarantee to the concessionaire.

The system involved two toll bridges, the Salvador-Itaparica Bridge and Funil Bridge, however, traffic demand guarantees were provided only for on the Salvador-Itaparica Bridge, which will be the 2nd longest bridge in Latin America, with 12.4 km. The Salvador - Itaparica Bridge road system auction took place in December of 2019, and the winner should offer the lowest amount of "maximum annual financial compensation", i.e., the lowest amount offered by the Concessionaire in its Bid, corresponding to the maximum amount compensation to be paid annually by the Government to the Concessionaire. The winner of the auction was a consortium formed by three Chinese firms that will have 5 years to build the bridges and another 30 years to maintain and operate the system. The economic and financial assumptions are shown in table 2.

The traffic estimated by the government used in this work is per "annual equivalent volume", that is, all categories of vehicles and own tariffs are standardized to a single type of vehicle, corresponding to the average toll amount of R$ 32.71 per equivalent vehicle.

Table 2: Economic and financial assumptions

Construction Term	5 years
Concession Term	30 years
CAPEX	R$ 5,342 million
OPEX	R$ 59.36 million (per year)
Reinvestments	R$ 8.80 million (per year)
Government Financial Support	R$ 1,500 million (during construction)
Government Financial Compensation	R$ 56.2 million (per year)
Average Tariff	R$ 32.71
WAAC	7.56%
Risk-free rate	3.20%

The state government of Bahia decided to share the traffic risk through the use of traffic guarantees in this road system project, which will be applied annually in the first 15 years of operation of the concession, observing the actual traffic related with the estimated traffic. The impact of these guarantees for the concessionaries will be:

a) If the real traffic in the period greater than or equal to 90% ($LIM_{inf}\ B$) and less than or equal to 110% ($LIM_{sup}\ B$) of the estimated traffic, there will be no government interference;

b) If real traffic in the period is less than 90% ($LIM_{inf}\ B$) and greater than or equal to 80% ($LIM_{inf}\ A$) of the estimated traffic for the same period, the government will refund the Concessionaire the amount of 70% of the revenue corresponding to the difference between real traffic and 90% (LIM_{inf} B) of the estimated traffic;

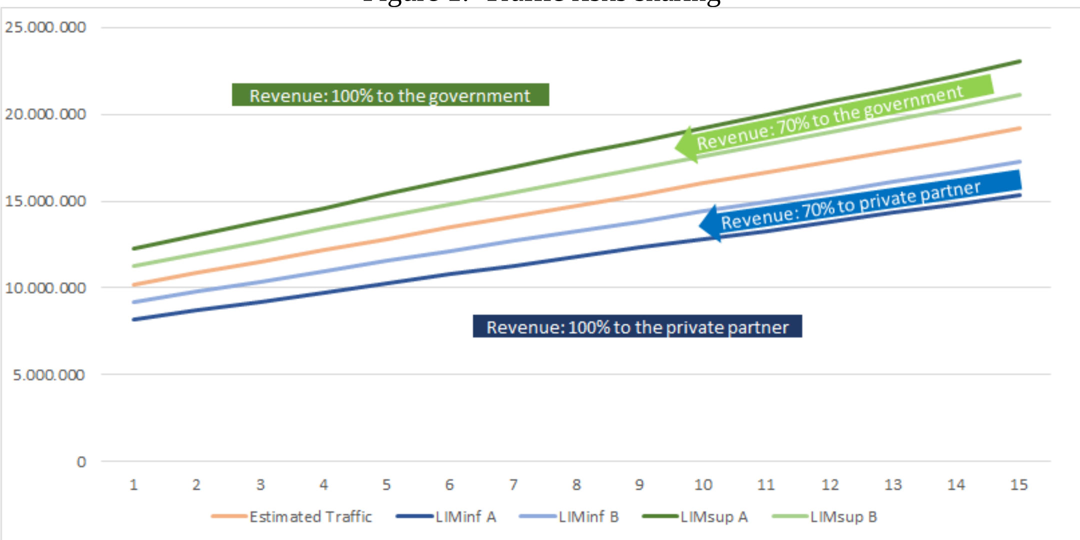
c) If real traffic in the period is greater than 110% (LIM_{sup} B) and less than 120% (LIM_{sup} A) of the estimated traffic for the same period, the government will receive from the Concessionaire the amount of 70% of the revenue corresponding to the difference between real traffic and 110% (LIM_{sup} B) of the estimated traffic ;

d) If real traffic in the period is less than 80% (LIM_{inf} A)of the estimated traffic for the same period, the government will refund the Concessionaire the amount of 100% of the revenue corresponding to the difference between the real traffic and 80% (LIM_{inf} A) of the estimated traffic;

e) If real traffic in the period is greater than 120% (LIM_{sup} A) of the estimated traffic for the same period, the government will receive from the Concessionaire the amount of 100% of the revenue corresponding to the difference between real traffic and 120% (LIM_{sup} A) of the estimated traffic;

The traffic risk sharing belts from the traffic estimated by the government and the listed risk-sharing rules are shown in figure 1.

Figure 1: Traffic risks sharing



The cost of these guarantees for the government represent a potential liability which is contingent on the future behavior of traffic demand on the bridge. According to the bid documents made publicly available, two scenarios were considered. In the first scenario, if future demand falls between 80% and 90% of the expected values, the cost for the government will be R$ 260,214,124. Otherwise, if future demand turns out to be below 80% the cost will be R$ 118,035,272.

4.2 Real Option Valuation of Government Liability

The MTG of the Salvador - Itaparica Bridge highway system project was modeled as a series of independent European options with annual maturities. Option values for both the Call option, which represent expected cash inflows to the government, or assets, and Put options, which represent potential cash outflows, or liabilities, were then determined by a Monte Carlo simulation of the stochastic traffic level under the risk neutral measure. The results indicate that the net expected cost to the government considering the 15-year duration of the MTG will be significantly higher than predicted by the government studies. The values obtained for each guarantee level are shown in table 3.

Table 3: Government Liability: Expected cost of the MTG (values in BRL millions)

Impact	Ref.	Condition	Expected Value
Liabilities	eq. (5)	$LIM_{inf}\ B > TRAFF_{real} \geq LIM_{inf}\ A$	
		$TRAFF_{real} < LIM_{inf}\ A$	
Assets	eq. (6)	$TRAFF_{real} \geq LIM_{sup}\ A$	
		$LIM_{sup}\ A > TRAFF_{real} \geq LIM_{sup}\ B$	

5 Discussion

6 Conclusions

7. References

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