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A MODELING GOVERNMENT REVENUE GUARANTEES IN PRIVATELY BUILT TRANSPORTATION PROJECTS: A RISK-ADJUSTED APPROACH

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Abstract. Countries around the world have welcomed Public Private Partnerships (PPPs) as an alternative to finance infrastructure. For strategic projects with high demand uncertainty, a government may decide to provide a concessionaire with a Minimum Revenue Guarantee (MRG) to mitigate revenue risk and to help enhance the project's credit, thereby reducing the financing costs of the project. However, government revenue guarantees can pose fiscal risks to the issuing government if too many significant claims are redeemed at the same time. This undesirable circumstance can be exacerbated during an economic recession in which tax revenues are low and the costs of subsidies are potentially higher than expected. This paper presents a new model of government revenue guarantees by which revenue guarantee thresholds are adjusted over time to reflect the inter-temporal risk profiles of the project. Revenue risk is modeled using a stochastic process called the Variance Model. Then, revenue shortfalls and revenue excesses are modeled as multi-early exercise options, and priced using multi-least squares Monte Carlo method. Finally, an illustrative example of a Build-Operate-Transfer (BOT) highway project demonstrates how the proposed model may be applied in practice at the project evaluation stage. The proposed model may help to promote fairer risk allocation between the host government and the concessionaire.

Keywords: risk analysis; real options; inter-temporal revenue risk; simulation; minimum revenue guarantee (MRG).

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Introduction

Governments around the world face a rapidly increasing need to develop new infrastructure projects and to effectively fund the renewal, maintenance, and operation of existing infrastructure. In addition to using public finance to fund these infrastructure projects, under the current regulatory framework, governments are now exploring all options available for delivery of infrastructure. Public Private Partnership or PPP is one popular choice among these options. PPP is a program by which the private entity provides infrastructure assets and services that traditionally have been provided by public sector, as an alternative means to finance infrastructure (Esty 2003). There are various types of partnership between a host government and a private party. Build-Operate-Transfer (BOT), for example, is a popular contemporary arrangement under PPP programs. In Thailand, the government is increasingly aware of the importance of infrastructure and the need to tap private resources to help finance strategic infrastructure projects. One of the actions being done by Thai government is to develop a master plan for PPP, which is currently being drafted by the National Economic and Social Development Board and the Bank of Thailand.

The main advantages of PPP arrangements for financing infrastructure are twofold. First, the government can tap private funds to finance its infrastructure. This is especially important if the government is facing fiscal constraints, and raising taxes to fund the infrastructure when it is unattractive. Second, through PPP, the government may benefit from the expertise and experience of a private entity to build and operate a facility in a more cost-effective way. Moreover, the private entity or the concessionaire may have several similar projects in its existing management portfolio, which may help reduce operating costs through the economy of scale. These are the principal reasons why PPP has proven to be a viable option for public infrastructure development (Yescombe 2002). Currently, PPP is employed extensively throughout Europe, in the UK (known as Private Finance Initiative or

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PFI), Latin America (Chile and Brazil in particular), and many countries in Asia.

The major criticism of PPP, however, is that it can be expensive: the extra cost of private-sector borrowing may outweigh the benefits. It is well known that the public sector can borrow money at a cheaper rate than can the private sector. The cost of private-sector borrowing can even be higher if the projects face significant *project-specific* risks such as highly uncertain future demand for the service. This is the downside of PPP that no government can afford to ignore it.

Furthermore, several additional risks in PPP projects can be characterized as "inter-temporal" because current decisions affect the decision choices available in the future, which in turn may change the future risk profile of the projects. These factors make it increasingly difficult to quantify the risks correctly.

To promote successful implementation of PPP projects, a government is well advised to form a comprehensive and transparent PPP framework that addresses issues such as legislation, fiscal and technical constraints, and government support. Government support may come in several forms. Among them, a Minimum Revenue Guarantees (MRG) are often employed by host governments to mitigate operating revenue risk (Ashuri *et al.* 2010). The source of revenue risk is mainly demand uncertainty. On the surface, the MRG seems to be a good choice for revenue risk mitigation, as it provides an income safety net for the concessionaire, who can also use it to enhance the financial outlook of the project by lowering the cost of borrowing. This in turn may attract even more private investment into infrastructure projects, thereby increasing competition among prospective concessionaires. As for the issuing government, the MRG serves as a promise of monetary support at *no cost when issued*. The actual cost of an MRG, however, occurs during the concession period, which can range from a decade to many decades. And for those guaranteed projects with long concession periods, an MRG can pose a long-term fiscal risk to the government. To put it simply, the government decision makers who issue the guarantee may not be those ultimately responsible for future results. This issue of accountability has gained more public attention in recent years.

But, what if realized revenues are *higher* than expected? Those revenues will be reaped by the concessionaire rather than the government. One remedy for this shortcoming of the MRG is a banded revenue guarantee, where the MRG is provided with a Maximum Revenue Cap (MRC). This model has been adopted in Chile and Korea, for example. In Korea, the government offers 80% revenue guarantees linked to 120% revenue cap, both based on projected revenues. In Chile, the "Least Present Value of the Revenues" (LPVR) method was introduced to mitigate traffic risk in highway concession projects. Based on the mechanisms of the LPVR, the concession agreement will be awarded to the bidder who requires the LPVRs to recover its costs (Vassallo 2006).

However, as Flyvbjerg (2006) pointed out, "a forecast is always wrong". For solicited projects with government revenue guarantees, the concessionaire may be encouraged to inflate the forecast to make the project look as if it will be profitable. Once the operation begins, actual revenues may fall far below what had been predicted (i.e. inflated estimate). With an MRG, the concessionaire can claim against the government for revenue shortfalls (RSs), and the project is still viable from the concessionaire's perspective. On the other hand, if the actual revenues somehow exceed revenue cap levels, the concessionaire gets some (if MRC) or all (if no MRC) of the profits. However, this upside scenario is less likely to occur when an inflated estimate is exploited.

This paper proposes a new model of government revenue guarantees that promotes fair risk allocation between the government and the concessionaire. The remainder of the paper is structured as follows: Section 1 reviews and discusses existing popular mechanisms of revenue guarantees for infrastructure projects. In Section 2, we present a new model of government revenue guarantees in which key parameters are evolved over time to reflect the inter-temporal risk profiles of the project, and an evaluation method of revenue guarantee is also provided. An illustrative example is given in Section 3. Then, the results are presented and discussed in Section 4. Finally, next section concludes the paper.

1. Literature review

PPP projects often involve the use of government revenue guarantees, which are government interventions intended to reduce the financial costs of risks faced by the private sector (Polackova 1998; Hemming 2006). A revenue guarantee is an insurance contract in which a guarantor promises the guaranteed to pay the RS (K–X) relative to a period of time Δt, i.e. the difference between the minimum guaranteed net revenue, K, and the net revenue, X, accumulated in a period of Δt (Chiara *et al.* 2007). This type of guarantee can be presented as a put option:

$$\Pi(X) = \max(K - X, 0), \tag{1}$$

where: K is the strike price and X is the underlying process.

Therefore, to value the guarantee, in most cases, real options theory is required. Good references on financial and real options can be found in Hull (2005) and Dixit and Pindyck (1994). The abovementioned mechanism of revenue guarantees has been employed in many countries, especially in transportation concessions (Blank *et al.* 2009).

1.1. Models of government guarantees

Two models of government revenue guarantees are presented in this section: Korean and Chilean models.

1.1.1. The Korean model

In Korea, the government provides MRG for both solicited and unsolicited infrastructure projects. The model has been modified several times as shown in Table 1 (Kim 2008).

Until 2006, a 90% MRG was often granted to the concessionaire. With such a high level of guarantee, the government severely exposed itself to fiscal risk because of the significant chance that actual revenues will be below the guarantee level of 90%.

1.1.2. The Chilean model

Three government guarantees are employed in Chile: Minimum Income Guarantee (MIG), LPVR, and Revenue Distribution Mechanism (RDM).

The MIG guarantees the concessionaire the minimum income in net present value (NPV) at 70% of the investment cost and the total maintenance and operation costs estimated by the government (Vassallo 2006). The MIG usually comes with a revenue sharing covenant by which, whenever real revenue is higher than estimated, the excess revenue is shared between the concessionaire and the government. The method of revenue sharing can be either by (1) specifying an upper threshold rate of return on investment (e.g. 15%) or (2) establishing a symmetric mirror band of the MIG, where any excess revenue beyond this threshold must be shared (e.g. 50% of excess revenues between the government and the concessionaire). This mechanism, the MIG, is the one that is the most commonly used by the Chilean government because it offers the following advantages: (1) revenue risk is mitigated to a level that meaningfully reduces the financing costs to the concessionaire and (2) public interest is theoretically protected by revenue sharing clauses. However, a major criticism of this guarantee approach is that, during the economic downfall, the government is likely to experience an increase in compensation for RSs. To make matters worse, during such periods, the government faces a decrease in tax revenues. This double whammy situation had occurred in Argentina and Mexico, leading them to breach contracts by not paying compensation.

Two other, less commonly used, Chilean methods have been introduced as an alternative to the MIG. The details of these methods can be found in Vassallo (2006).

1.2. Mechanisms of government revenue guarantees

Mechanisms of government revenue guarantees can be classified according to coverage features or evolutions of the guarantee terms.

1.2.1. Full coverage and partial coverage revenue guarantee

Government revenue guarantees may be grouped into either *full coverage revenue guarantees* or *partial coverage revenue guarantees*. Full coverage revenue guarantees allow the insured party to redeem RSs in any year for which accumulated yearly revenue falls below guaranteed thresholds. Therefore, for such contracts, a number of rights (M) the insured party has is equal to a number of operating years (N), i.e. $M = N$. Partial revenue guarantees, on the other hand, limit the number of times (years) that the insured party can redeem the shortfalls, i.e. $M < N$.

1.2.2. Static and dynamic revenue guarantee

Static revenue guarantees are those guarantee contracts with a predetermined number of coverage years or with constant guarantee thresholds. Dynamic revenue guarantees, on the other hand, provide the insured party flexibility to choose exercise dates if the remaining rights are still available. Moreover, dynamic revenue guarantees also have guaranteed thresholds that evolve over time.

1.3. Valuing government revenue guarantees

Recently, several researchers have proposed various mechanisms for revenue guarantees and the methods for valuing them. Researchers (e.g. Irwin 2003; Cheah, Liu 2006; Huang, Chou 2006; Wibowo 2006; Chiara *et al.* 2007; Brandao, Saraiva 2008; Jun 2010) modeled underlying risks using a stochastic called Geometric Brownian Motion (GBM) so that they can value the guarantees by employing option pricing methods such as Black–Scholes formula and binomial lattices. However, the main criticism of such modeling technique is that assuming revenue risks to follow GBM is theoretically incorrect. This is because operating revenues

Table 1. Minimum revenue guarantee in Korea

	1998–April 2003	May 2003–2005	Revised in 2006–present
Guaranteed period	20–30 years	15 years	10 years
Coverage	80–90% of estimated operating revenues	80–90% during initial 5 years; 10% yearly reduction after 5 years	Abolished in unsolicited projects; solicited projects: 75% during initial 5 years and 65% during the following 5 years

tend to fluctuate sharply during the "ramp-up" period and then a period-to-period volatility usually decreases over time. As a result, some researchers have resorted to other probabilistic-based simulation or even developed a new one to be used specifically for modeling revenue risks (e.g. Dailami *et al.* 1999; Chiara, Garvin 2008). For valuation methods, different approaches have been proposed. These can be categorized into three types: analytical methods (e.g. Black–Scholes formula), numerical methods (e.g. binomial lattices and finite difference methods), and simulation methods (e.g. Least-Square Monte Carlo or LSM method) (Kokkaew 2010).

2. Models and methods

In this section, we present a proposed mechanism of government revenue guarantees. Then, a related valuation method is provided.

2.1. A new model of government revenue guarantee

First, yearly revenues, the underlying risk factor of the model, are modeled using the Variance Model (VM) proposed by Chiara and Garvin (2008). Then, we model revenue guarantee thresholds that reflect the dynamics of risks in PPP projects. This new approach accounts for the "inter-temporal risk profiles" of PPP projects. Finally, the mechanism of banded government revenue guarantee is introduced through the use of option theory.

2.1.1. Modeling of revenue risk

According to the VM, a risk variable under a real probability space (Ω,F,P) can be modeled as the discrete-time stochastic process X, which is the collection of $\{X_t|t=1,\ldots,N\}$, where each X_t is a random variable, and N is the number of time steps (e.g. years). Given that ΔX_k is the risk variable increment, i.e. $\Delta X_k=(X_k-X_{k-1})$, then:

$$X_t = X_0 + \Delta X_1 + \ldots + \Delta X_t; \tag{2}$$

$$X_t = X_0 + \sum_{k=1}^{t} \Delta X_k. \tag{3}$$

The risk variable increment, ΔX_t, is defined as a stochastic process with two main parts: non-random part $(\Delta\bar{W}_t)$ and random part (x_t). That is,

$$\Delta X_t = \Delta\bar{W}_t + x_t, \tag{4}$$

where: x_t can be assumed to follow any type of probability distributions and $\Delta\bar{W}_t$ is the expected value increment in year t.

That is, $x_t=\sigma\varepsilon_t$, where σ is yearly standard deviation and ε_t is an independent probability distribution with a mean of one and a unit variance.

In this paper, X_t is a revenue risk variable, and $\Delta\bar{W}_t$ is expected revenue increment, all relative to year t.

2.1.2. Modeling of minimum and maximum guarantee thresholds

The guarantee period (t_g) may be defined as $t_g=\alpha T$, where α is coverage ratio $(\alpha=[0,1])$, and T is a number of operating years. For partial coverage guarantees, the coverage ratio is always less than one (i.e. $\alpha<1$). Once the guarantee period is established, the thresholds of revenue guarantees can be modeled as

$$K_t = \left(K_t^{\downarrow}, K_t^{\uparrow}\right), \tag{5}$$

where: $K_t^{\downarrow}=(1-\beta_t)\bar{X}_t$ is minimum revenue threshold, $K_t^{\uparrow}=(1+\beta_t)\bar{X}_t$ is maximum revenue threshold, $\beta_t=[0,1]$ is a parameter of revenue guarantees, all relative to year t.

For example, if the parameter $\beta_{t\in\{1,\ldots,5\}}=0.2$, then minimum and maximum revenue thresholds from year 1 to 5 are 80% and 120% of expected yearly revenue, respectively, i.e. $K^{\downarrow}_{t\in\{1,\ldots,5\}}=0.8\bar{X}_t$ and $K^{\uparrow}_{t\in\{1,\ldots,5\}}=1.2\bar{X}_t$, where $\bar{X}_t$ is the expected revenue in year t.

Fig. 1 exhibits the proposed model of government revenue guarantees.

2.1.3. Modeling of government guarantee mechanism

Option theory can be used to model the payoffs of government revenue guarantees. Since the events that revenues will fall below the minimum guarantee thresholds or will exceed the maximum guarantee thresholds are independent and mutually exclusive, we can model each of them separately (see Fig. 1).

2.1.3.1. RS as a put option

RSs can be modeled as put options. In option theory, a put option gives its holder the right, but not the obligation, to sell a designated asset at a predetermined price (the strike or exercise price). The immediate payoff of exercising the right to redeem RS in any given year, $\prod_{RS}$, can be modeled as

$$\Pi_{RS}\left(X_t;K_t^{\downarrow}\right) = \max\left(K_t^{\downarrow}-X_t,0\right)_{t\le t_g}. \tag{6}$$

2.1.3.2. Revenue excess (RE) as a call option

In banded revenue guarantees, the government will share extra revenues exceeding the maximum revenue threshold. Such revenues can be modeled as call options. A call option is defined as the right, but not the obligation, to buy a designated asset at an exercise price. The immediate payoff of exercising the right to redeem revenue excesses (REs), $\prod_{RE}$, can be modeled as

$$\Pi_{RE}\left(X_t;K_t^{\uparrow}\right) = \delta\left\{\max\left(X_t-K_t^{\uparrow},0\right)_{t\le t_g}\right\}, \tag{7}$$

where: δ is an agreed ratio of the sharing in REs (e.g. $\delta=0.5$ means that the REs $\left(X_t-K_t^{\uparrow}\right)$ will be shared

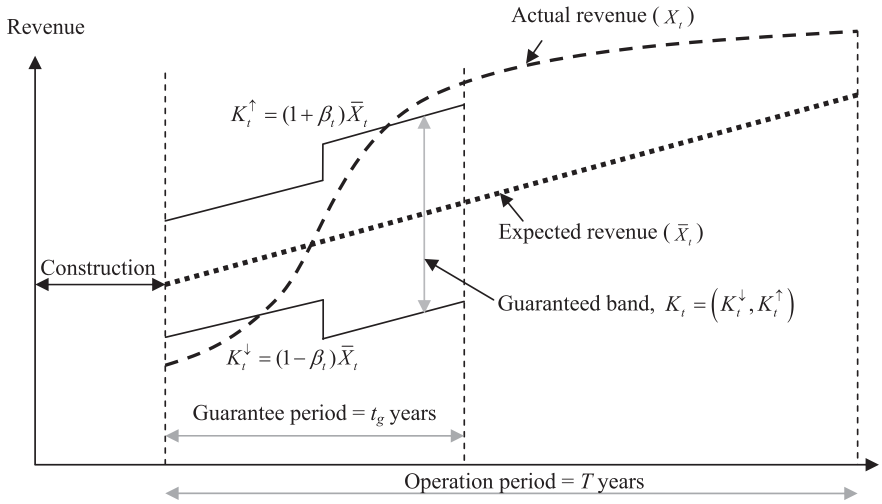

Fig. 1. Modeling of a new banded government revenue guarantee

equally between the government and the concessionaire).

2.2. Valuation method

Because full coverage guarantees can be expensive to the host government and the concessionaire himself may exercise the right to redeem the shortfalls only during the years in which the actual revenues are below the guarantee thresholds, we choose the partial coverage model of revenue guarantees. In partial coverage revenue guarantees, flexibility to exercise the rights can be modeled as Australian options. An Australian option is an option that can be exercised multiple times (M) on specified N dates ($N \geq M$) during its life.

To value Australian put options, Chiara *et al.* (2007) developed the Multi-Least Squares Monte Carlo (MLSM) method by extending the Least Squares Monte Carlo (LSM) method by Longstaff and Schwartz (2001). We adopt the MLSM to value the cost of government revenue guarantees.

As for the amount of REs to be shared by the government, in this paper the MSLM is modified, allowing it to price Australian call options.

Basically, the MLSM consists of two main processes. The first involves forward projections of underlying risk variables using Monte Carlo simulation. The second determines the optimality of decisions at each time step using dynamic programming techniques and least squares regression to estimate an expected continuing payoff, which is the value of not exercising option at this time step. The goal is to compare and choose at each time step the maximum value between (1) an immediate payoff if exercised now and (2) an expected continuing payoff if exercised later. The detailed computational method of the MLSM can be found in Chiara *et al.* (2007).

3. Illustrative case example

An illustrative case example is presented to demonstrate how the proposed model of government revenue guarantee, presented in the previous section, may be applied in practice at the project evaluation stage. The main characteristics of the hypothetical project, a BOT highway project, are shown in Table 2. For the sake of simplicity and to focus on the application of the new model of revenue guarantee, it is assumed that the project will not be expanded during the concession years.

4. Results and discussions

The value of the project may be computed in terms of return on equity (equity cash flow or ECF). The ECF for any given year is computed using the following formula:

$$ECF_t = X_t - C_t - Tax_t - DS_t, \tag{8}$$

where: X_t is yearly revenue, C_t is operating and maintenance costs, Tax_t is tax expense, and DS_t is debt service, all relative to year t.

The expected NPV of the project is computed as

$$E\{NPV(ECF)\} = \sum_{t=0}^{T} \frac{E\{ECF_t\}}{(1+r_e)^t}. \tag{9}$$

From base case analysis using Eqns (8) and (9), the NPV of the project is expected to be \$0.94 million or an internal rate of return of 15.25%, i.e. $E\{NPV(ECF)\} = \$0.94$ million and $IRR = 15.25\%$. By using the new model of revenue guarantee, i.e. Eqns (5)–(7), with the MLSM method, government exposure arising from the MRG and the opportunity to share REs of the project are shown in Table 3.

The costs of government revenue guarantee from the new model are much cheaper than those of conventional guarantees, which have guarantee period (t_g)

Table 2. Characteristics of a BOT highway example project

Construction period	2 years
Operating period	30 years
Capital structure	Equity: $US 40 million; debt: $US 80 million
Cost of capital	Cost of equity = 15%; cost of debt = 10%
Initial annual average daily traffic (AADT) volume	40,000
Maximum AADT	80,000
Guarantee period (t_g)	10 years
Minimum guarantee threshold ($K_t^{\downarrow}$)	80% of estimated operating revenues from years 1 to 5; 70% from years 6 to 10
Maximum guarantee threshold ($K_t^{\uparrow}$)	120% of estimated operating revenues from years 1 to 5; 130% from years 6 to 10
Revenue sharing ratio (δ)	0.5 (equally shared)

Table 3. Results of the analysis using the new model of government revenue guarantees (Eqns (5)–(7)) and the MLSM method

Number of rights (M)	Cost of minimum revenue guarantee ($ millions)	Benefit of revenue sharing ($ millions)
1	1.4696	0.2277
2	1.9931	0.4253
3	2.4901	0.5600
4	2.9276	0.6292
5	3.2987	0.6622
6	3.6137	0.6758
7	3.8349	0.6787
8	3.9783	0.6798
9	4.0602	0.6802
10	4.0906	0.6803

equal to the operation period (T). For example, if 10 rights (comprising full coverage over the 10-year guarantee period) are granted to the concessionaire, then the government is expected to pay the concessionaire about $4.09 million in present value, and it is also expected to receive extra revenues of about $0.68 million from the concessionaire. Therefore, the total cost of revenue guarantee to the government is about $3.41 million ($4.09–$0.68). If, on the other hand, the guarantee period was 30 years, then the cost of full coverage revenue guarantee to the government would be over $37.70 million ($38.78 million from the cost of MRG and $1.08 million from benefit of revenue sharing).

Conclusions

PPP projects have become popular choices in providing public infrastructure in several countries. One of the key factors contributing to the success of PPP projects is fairer risk allocation among the stake holders. Revenue risk is the major risks from external operating environment (such as demand and economy). To mitigate such risk, governments often provide a MRG to the concessionaire. This guarantee is to assure the concessionaire that yearly accumulated revenues will never be lower than the guarantee level. However, the MRG makes no adjustment based on the fact that revenues can also be higher than estimated. Therefore, using MRG without sharing of REs, in light of heavy demand and windfall revenues, can undermine the underlying notion of fair risk allocation in PPP projects.

This paper has presented a new model of revenue guarantees in which MRG thresholds and MRCs evolve over the guarantee period. The guarantee period, beginning immediately after the commercial operation date, is also assumed to be shorter than the operating period, i.e. $t_g < T$. That is because, during such a period, revenues are highly volatile. The results show that the costs of government revenue guarantee from using the new model are more affordable than using the conventional method. Moreover, if revenue windfalls occur, the new model captures the value of revenue sharing, thereby protecting the public interest by not allowing the private to the profits as a windfall. The main challenge in using the model presented in this paper is that the necessary information for the analysis may not be readily available and therefore needs to be estimated. Accordingly, the estimation of relevant parameters should be carefully made, and reference forecasting techniques to avoid cognitive biases are strongly encouraged.

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