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NON-COMPETITION GUARANTEED VALUE AND EFFECT ON THE TOLL ROAD PROJECT

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Abstract. A non-competition guarantee has been widely used for financing the toll road project. However, to our best knowledge, there seems to be no research about the value and incentive effect of the non-competition guarantee. In the competitive and non-competitive condition respectively, this paper constructs the models of investment value and investment threshold by adopting the option game theory and measurement approach. The results of theory derivation indicate that the non-competition guarantee plays a strong role in investment incentives by reducing investment threshold. The simulation results indicate that the non-guaranteed value increases as the expected growth rate of traffic flow increases, and decreases as volatility increases.

Keywords: non-competition guarantee, toll road project, option game, investment threshold.

1. Introduction

Considering requirements for private investors to reduce risk and avoidance of excessive competition, the government often provides a certain degree of a non-competition guarantee for private investors in many toll road projects (Zhang *et al*. 2010). A non-competition guarantee, which is also called a restrictive competition guarantee, refers that in order to encourage investors to invest in infrastructure projects, the government promises not to invest or limit investments on similar projects in the same area within a certain number of years for the purpose of avoiding the negative effect of excessive competition on the return and profit of the existing investment. It is primarily used in toll road projects, toll bridges, toll tunnels and other transport projects. It is an indirect revenue guarantee provided by the government for non-state-owned capital, which has become the regular practice of financing the toll road project. According to different time and scope, the non-competition guarantee can be classified into two main forms: one of those directly makes the commitment of preventing from building the same or a similar project at the same area during a certain period, for example, the British Channel Tunnel project in which the Governments of the United Kingdom and France promised that they would not build another link facility across the English Channel in 33 years. The other is that the government will not allow building similar projects in the agreed regions when traffic flow maintains in a certain range, which is very common in China.

The non-competition guarantee provided by the government entitles the project investors to the exclusive operation right of the toll project at a certain area within a certain period, avoids a part of the demand risk of investors and is helpful for the entry of private investment into infrastructure. Definitely, it is valuable. However, nearly no literature on how to objectively evaluate the value of the non-competition guarantee and what role the latter plays in decisions made by investors is available. Taking into account the above discussed points, this paper will construct a valuation model of the non-competition guarantee. Section 2 analyzes the problem of the non-competition guarantee. Section 3 develops the valuation model of the non-competition guarantee with a real option. Section 4 deduces the result of the guaranteed value with respect to the non-competition guarantee. This section incorporates sensitivity analysis and demonstrates the guaranteed value upon traffic flow, the expected growth and volatility of traffic flow, and finally draws some referential implication for government's guaranteed decision-making.

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2. Problem Analysis

The non-competition guarantee is relative to competitive investment. We haven't found quantitative research literature on the non-competition guarantee but investigation into investment decision-making under the context of competition is very common. Under the situation of competition, the investors investing in the same project have investment options. Their investment decisions affect one another. One of the parties implements the investment option while the value of the option of the other party will be greatly reduced. Affected by the before discussed situation, an investor as a follower can get the opportunity to invest only when market demand is further expanding. In the case of the non-competition guarantee, the government would regulate the competition to encourage investors to invest as soon as possible and ensure the leader obtains reasonable investment return; for the followers, once they lose the opportunity to lead investment, which also means that only when the non-competition guarantee expires, they can obtain the opportunity to invest. Clearly, when studying a competitive environment of investment, decision-making becomes the premise of studying the non-competition guarantee.

The option game theory has been widely used in investment decision-making in the competitive environment. As a combination of the real option theory and game theory, the option game theory is used for evaluating the value of the project including a real option on the basis of the ideology and methods of the option pricing theory. At the same time, the option game theory, which makes the use of the ideology and modelling method of the game theory, is a theoretical method of making scientific management and decision in the investment project. It is proposed for the problems and shortcomings while evaluating and making decisions on investments in the projects of the old-fashioned enterprises, i.e. it not only assesses the value of investment projects by making the use of the option method but also provides the basic method of making a decision under an uncertain environment by making the use of game theory analysis. Smets (1991) was the first to introduce the game theory about the framework for real options analysis and established a duopoly basic model used for studying two companies competing for direct foreign decisions on investment timing. His model is one of the basis for continuous-time option games, whereas the existing option game model mostly is the extension of that. Dixit and Pindyck (1994) made a further extension to the model of the value function of investment stimulated by the leading and following investors as well as offered means of calculating investment threshold. Huisman and Kort (1999) provided complete information on the static game model under duopoly conditions and solved the 'coordination problem' in which enterprises will invest when 'the first to equilibrium' exists in the game. In the project investment decision-making process, enterprises must take into account the market structure, market conditions, investment decisions of competitors etc., and then make a scientific decision on different market structures and a situation of competitors (Amram, Kulatilaka 1998). At present, the option game theory has been widely used in R&D investment decision-making (Shackleton *et al.* 2004; Doraszelski 2004), real estate development (Grenadier 2005; Wang, Zhou 2006), business valuation (Kong, Kwok 2007; Smit, Trigeorgis 2006) and many other fields.

In the current study, the option game theory is mostly carried out under the conditions in the duopoly the ideas of the general study of which are as follows. In a competitive environment, taking into account continuous time $t \in [0,\infty)$ and assuming that two companies have the same opportunities, the enterprise that invests for the first time is called the leader (*the leader*, below 'l' means 'leader'), whereas the other is called the follower (*the follower*, below 'f' means 'follower'). Assuming that two enterprises have the same products and face the same customers and the market, the goal of decision-making is to choose the best investment opportunities to maximize the value of their investment. Therefore, under competitive conditions, there are a number of threshold values for state variables $Y(t)$ (e.g. project earnings, traffic volume, project value etc.):

1) when $Y(t) < Y_l$, where Y_l is the threshold value of the investment of the leader, waiting (an investment option) is optimal. When $Y(t) \geq Y_l$, investing (implementation option) is optimal;
2) when $Y(t) < Y_f$, where Y_f is the follower's investment threshold of time, waiting (an investment option) is optimal.

When $Y(t) \geq Y_f$, investing (implementation option) is optimal. The order of investments in a competitive investment environment is shown in Fig. 1, where T_l is the best investment opportunities for the leader, which is the moment stating variable $Y(t)$ for the first time to reach (up through) $Y = Y_l$, i.e. $T_l = \inf(t \mid Y(t) \geq Y_l)$ is the same token $T_f = \inf(t \mid Y(t) \geq Y_f)$ and T is the concession period.

Jones and Mason (1980) used the option theory to study the value of the guarantee and pointed out that the value of the project guaranteed could be regarded the guaranteed value and the value of the project unguaranteed, i.e. the guaranteed value equals to the value of the project guaranteed minus the value of the project unguaranteed. The study by Jones and Mason's reveals a line for the thought of studying such government-guarantee. After the problem of the project value under a competitive environment has been resolved referring to the option game theory, the key is to solve the value problem of the non-competition guaranteed project considering the non-competition guarantee. Taking into account that the non-competition guarantee is the government's guarantee that mainly attracts investment and protects the interests of investors, it targets mainly the leader's earnings (e.g. investment income of the leader) in infrastructure projects and guarantees them a monopoly on operating their investment in infrastructure projects in a certain period under certain conditions. Therefore, it is necessary to analyze the pathway of the non-competition guarantee in the competitive environment.

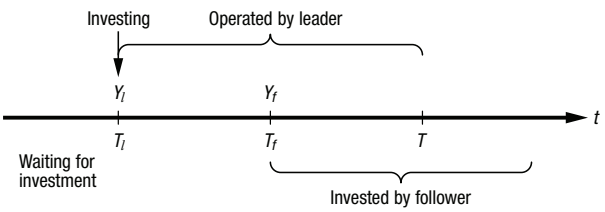

Fig. 1. Investment sequence of conditions for competition

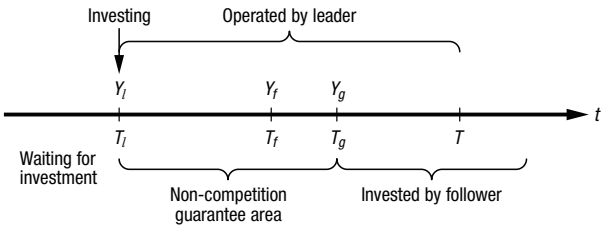

Fig. 2. Investment sequence of conditions for the non-competition guarantee

Fig. 2 depicts investment order regarding the non-competition guarantee provided by the government where T_g is the expiration date of the non-competition guarantee, T_g is the revenue stream of the corresponding project representing the level of governmental guarantees. Clearly, the effective interval of the non-competition guarantee is $t \in [T_f, T_g)$, in which the leader's interests receive effective protection.

3. Basic Model

Taking into account the above discussed points, this section will study the non-competition guarantee drawing option game modelling and the value estimating approach to government guarantees. First, in the competitive environment, we construct the investment value model of the follower and his/her formula for calculating investment threshold by using backward induction based on constructing the investment value model of the leader. Second, under non-competitive conditions, we construct the investment value model of the follower and his/her formula for calculating investment threshold. Finally, we construct a value model of the non-competition guarantee.

3.1. Basic Assumption

Traffic flow $Y(t)$ in the toll road project, which is affected by various factors such as population, economic growth etc., presents certain uncertainty. Brandao and Saraiva (2008), in their study on the government's guarantee for the least return of investment in toll road, viewed such uncertainty as Geometric Brown Movement, on the basis of which they further built an evaluation model. Francis *et al.* (2004) indicated that non-negative demand for material products related to time span and independent across different periods could be characterized as Geometric Brown Movement. Thus, we adopt the assumption of GBM for traffic flow in the toll road project.

$$dY(t) = \mu Y(t)dt + \sigma Y(t)dz, \tag{1}$$

where: μ denotes the expected growth rate of traffic flow indicating an increase in the potential of traffic flow; σ indicates the volatility of traffic flow as the key parameter representing the uncertainty of traffic flow (for the existing toll road projects, its volatility can be evaluated by the analysis of data on the history of traffic flow; for a newly-built toll road, volatility can be evaluated by the standard assumption of a positive correlation between traffic flow and GDP (Banister 2006)); dt indicates time increment; dz an increment in a standard wiener process.

All investors are assumed to be risk-neutral with risk-less interest rate r and act to maximize their profits. They adopt competitive behaviour with rational expectation for their potential competitors. The charge for a vehicle is assumed to be constant, R, given that the government always holds a relative stable charge policy in such infrastructure project. The inverse demand function of project revenue at time t is:

$$P(t) = R\gamma(N)Y(t)dt, \tag{2}$$

where: $P(t)$ denotes revenue flow with the given parameters of market demand; $N = \{1.2\}$ points to the number of projects; γ $(0 < \gamma < 1)$ – to the followers' shunting coefficient of traffic flow.

3.2. A Model for Investment Value in Competitive Context

The essence of backward induction is 'looking forward, reasoning backward', i.e. for leaders, the optimal investment decision should be made with a rational expectation of the followers' reaction. We use backward induction to obtain an optimal follower's strategy and analyze investment strategy and its threshold of the leading investor.

3.2.1. The Option Value of the Follower

Under the strategy given by leading investors, we consider an optimal investment decision of the follower, the value of which can be written as $F(Y)$. A rational follower must make an optimal decision with the realization of its following status. The follower's investment value can be deduced from the following ordinary differential equation by means of the optimal Behrman equation combined with *Itô* lemma:

$$\frac{1}{2}\sigma^2 Y^2 F_{YY} + \mu Y F_Y - rF = 0, \tag{3}$$

where: r denotes the riskless interest rate.

The general solution is:

$$F(Y) = AY^{\beta_1} + BY^{\beta_2}. \tag{4}$$

β_1 and β_2 are both roots of characteristic equations, where $\beta_1 > 1$, $\beta_2 < 0$. $Y = 0$ means no return and the option value of follower $F(0) = 0$, thus $B = 0$ and equation (4) becomes:

$$F(Y) = AY^{\beta_1}. \tag{5}$$

Under conditions that the follower invests, the value of the project with concession period T is:

$$V(Y)=\frac{R\gamma Y}{\delta}(1-e^{-rT}), \tag{6}$$

where: $\delta = r - \mu$ at the follower's investment threshold Y_f; according to the follower's value, matching conditions and critical investment conditions, we obtain:

$$F(Y_f)=V(Y_f)-I; \tag{7}$$

$$F_Y(Y_f)=V_Y(Y_f). \tag{8}$$

When solving equations(7)and(8), we obtain:

$$Y_f=\frac{\beta_1\delta}{\beta_1-1}\frac{Ie^{rT}}{R\gamma(e^{rT}-1)}; \tag{9}$$

$$A=\frac{R\gamma}{\beta_1}\frac{(1-e^{-rT})}{\delta Y_f^{\beta_1-1}}. \tag{10}$$

When substituting A and Y_f into equation (5), the option value of the follower should be:

$$F(Y)=\begin{cases}\frac{R\gamma Y_f}{\beta_1}\frac{(1-e^{-rT})}{\delta}(\frac{Y}{Y_f})^{\beta_1} & Y<Y_f;\\ \frac{R\gamma Y}{\delta}(1-e^{-rT})-I & Y\geq Y_f.\end{cases} \tag{11}$$

3.2.2. The Option Value of Leader's Investment

Due to the insistence of the followers on their optimal investment strategy, they start investing at the time, namely T_f, when random demand shock Y reach Y_f for the first time.

We assume that $G(Y) = L(Y) + I$, where $L(Y)$ denotes the value of the leader's option and $G(Y)$ – the total value including leader's investment I. The leader's investment value can be deduced from the following ordinary differential equation by means of the optimal Behrman equation $rG(Y)dt=E(dG(Y)+YRdt)$ combined with $It\hat{o}$ lemma.

$$\frac{1}{2}\sigma^2Y^2G_{YY}+\alpha YG_Y-rG+RY(1-e^{-rT})=0. \tag{12}$$

The general solution is:

$$G(Y)=CY^{\beta_1}+DY^{\beta_2}+\frac{RY}{\delta}(1-e^{-rT}), \tag{13}$$

where: $\frac{RY}{\delta}(1-e^{-rT})$ is a special solution to equation (13); C and D are constants to be determined.

When $Y = 0$, the leader's investment option value – $G(0) = 0$. Thus, $D = 0$ and equation (13) becomes:

$$G(Y)=CY^{\beta_1}+\frac{RY}{\delta}(1-e^{-rT}). \tag{14}$$

For the leader, when $Y = Y_f$, $G(Y)=F(Y)$ exists as the condition for matching the value:

$$CY_f^{\beta_1}+\frac{RY_f}{\delta}(1-e^{-rT})=\frac{R\gamma Y_f}{\delta}(1-e^{-rT}). \tag{15}$$

A solution to equation (15) is:

$$C=R\frac{\gamma-1}{\delta Y_f^{\beta_1-1}}(1-e^{-rT}). \tag{16}$$

When substituting equation (16) into equation (14), the solution of the leader's investment option value is:

$$L(Y)=\begin{cases}\frac{RY}{\delta}(1-e^{-rT})-RY_f(\frac{Y}{Y_f})^{\beta_1}\frac{1-\gamma}{\delta}(1-e^{-rT})-I, & Y<Y_f;\\ \frac{R\gamma Y}{\delta}(1-e^{-rT})-I, & Y\geq Y_f.\end{cases} \tag{17}$$

Due to threat when entering the first one and the fact that the government would never permit monopoly gains in a competitive context, the investment threshold of the leader Y_l when $L = F$, i.e.:

$$\frac{RY}{\delta}-RY_f(\frac{Y}{Y_f})^{\beta_1}(\frac{\beta_1-\beta_1\gamma+\gamma}{\beta_1\delta})-\frac{Ie^{rT}}{e^{rT}-1}=0. \tag{18}$$

There is no analytical solution, only a numerical solution to Y_l.

3.3. The Investment Value Model under Non-Competition Guarantee Context

Let T_g is corresponding to non-competition guarantee Y_g provided by the government and satisfies $T_g>T_f$ from a perspective of competitive investment. The followers will not be permitted to invest during period $t\in[T_f,T_g)$ due to the government's guarantee, namely, the investment timing of the follower is postponed from $t = T_f$ to $t = T_g$. Thus, at $t\in[0,T_g)$, the leader obtains monopoly gains; at $t = T_g$, the follower invests; at $t\in[T_g,\infty)$, the leader and follower operate simultaneously. According to value matching condition $L_g(Y) = F(Y)$ at $t = T_g$, we can obtain the function of the leader's investment value under the government's non-competition guarantee as follows:

$$L_g(Y)=\begin{cases}\frac{RY}{\delta}(1-e^{-rT})-RY_g(\frac{Y}{Y_g})^{\beta_1}\frac{1-\gamma}{\delta}(1-e^{-rT})-I, & Y<Y_g;\\ \frac{R\gamma Y}{\delta}(1-e^{-rT})-I, & Y\geq Y_g.\end{cases} \tag{19}$$

The main purpose of the government offering the non-competition guarantee is to encourage investors to invest as soon as possible. Therefore, before investing, every investor has the intention of investing first when investment threshold comes. Let Y_{Lg} to be the investment threshold of the leader under the government's guarantee of non-competition. Apparently, Y_{Lg} corresponds to $L(Y_{Lg}) = F(Y_{Lg})$, which can be simplified as:

$$\frac{RY}{\delta}-RY_g(\frac{Y}{Y_g})^{\beta_1}(\frac{\beta_1-\beta_1\gamma+\gamma}{\beta_1\delta})-\frac{Ie^{rT}}{e^{rT}-1}=0. \tag{20}$$

There is no analytical solution, only a numerical solution to Y_{Lg}.

3.4. A Model for the Non-Competition Guaranteed Value

The non-competition guaranteed value is the difference between the leader's project value under the guarantee and that without the guarantee. By means of equation (19) minus (17), the value of the non-competition guarantee is:

$$V_g(Y)=\begin{cases} R(Y_f(\frac{Y}{Y_f})^{\beta_1}-Y_g(\frac{Y}{Y_g})^{\beta_1})\frac{1-\gamma}{\delta}(1-e^{-rT}), & Y<Y_f; \\ R(Y-Y_g(\frac{Y}{Y_g})^{\beta_1})\frac{1-\gamma}{\delta}(1-e^{-rT}), & Y_f\le Y<Y; \\ 0, & Y\ge Y_g. \end{cases} \tag{21}$$

Equation (21) indicates that the value of the non-competition guarantee is affected not only by competition, but also by the non-competition guarantee.

4. Analysis

This section mainly analyzes the impacts of guarantee level Y_g, the rate of increase and the volatility of traffic flow on the value of the non-competition guarantee. We also investigate the incentives of the guarantee level on leader's investment.

4.1. The Guaranteed Value with Respect to the Non-Competition Guarantee Level

In equation (21), the derivative of $V_g(Y)$ with respect to Y_g is denoted as follows:

$$\frac{dV_g}{dY_g}=\begin{cases} (\beta_1-1)R(\frac{Y}{Y_g})^{\beta_1}\frac{1-\gamma}{\delta}(1-e^{-rT})>0, & Y<Y; \\ 0, & Y\ge Y_g. \end{cases} \tag{22}$$

This indicates that the value of non-competition increases as the level of the guarantee goes up within a certain scope. Notably, there is a cap for the guarantee level, which means that the value of the guarantee cannot keep increasing by pushing up the guarantee level unlimitedly. From a perspective of constraints on the concession period, $T_g=\inf(t|Y(t)\ge Y_g)$ exists; thus, the value of non-competition increases as the level of the guarantee goes up only at $T_g\le T$. From the perspective that the toll road project has limited traffic load, when Y_g exceeds the maximum traffic load, an excessive emphasis on the non-competition guarantee without permission of new similar projects will lead to the development that does not meet demand for economic growth, which is not realistic.

4.2. Investment Incentives of the Non-Competition Guarantee

Investment threshold is a key parameter for investment decision making. Investment in the project will become feasible only when the initial value of the project (such as the initial traffic flow, the initial revenue flow and other indicators) is not less than investment threshold. In toll road projects, with a certain charge standard, traffic flow is one of the important determinants of investment revenue. The investors will consider about investment only if traffic flow exceeds a certain level. In the absence of an analytical solution to the investment threshold of the leader (equations (18) and (20)), we analyze numerically the impact of different guarantees of the government on the investment threshold of the leader. Fig. 3 displays some basic parameters, including risk-free interest rate r which is initially 0.07 at t = 0, the expected growth rate of μ which is 0.03, variance σ^2 which is 0.09, charge for per vehicle R which is 73 CNY, concession period T which is 25 years, investment cost I counting 2.28 billion CNY and the shunting coefficient γ of the follower which is 0.5.

As can be seen from Fig. 3, under the non-competition guarantee, only single investment threshold may exist, which is independent from revenue flow. For the leader, if revenue flow is below investment threshold, it is rational not to invest until revenue flow exceeds investment threshold; if given the government's non-competition guarantee, investment threshold will decrease as the level of the guarantee increases. The latter situation demonstrates that, when the initial revenue flow is below investment threshold, the government reduces the threshold of revenue flow by means of offering the non-competition guarantee, and thus encourages investment in projects.

On the other hand, notably, a reduction in investment threshold is gradually flatting as the level of the guarantee increases, which implies that an excessive increase of the guarantee level would not produce an additional incentive. In fact, besides the concession period and maximum traffic load, there are two factors determining the level of the guarantee: first, excessive competition would result in a waste of resources, whereas in contrast, when a single project is unable to meet demand, an excessive stress on investment incentives for the non-competition guarantee of the leader investor is bound to harm the interests of consumers. However, this is a non-rational decision like one to put the cart before the horse. Second, considering the characteristics of project financing, if the revenues of the project were too low to

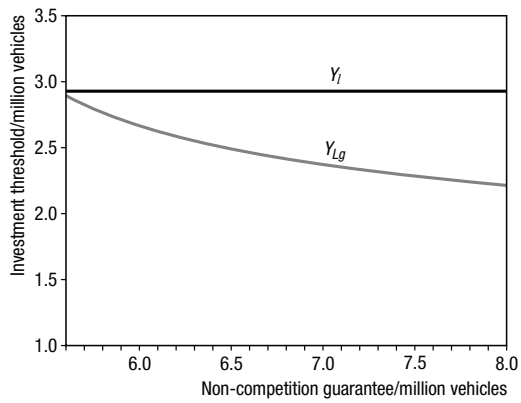

Fig. 3. The impact of different guarantees of the government on the investment threshold of the leader

fulfil repayment, even low investment threshold would become unattractive for investors with the intention of financing a project. Therefore, the government's guarantee should aim at 'no excessive competition' which is of strong practical significance to simulate investment by the non-competition guarantee with the premise of the reasonable extent of competition.

4.3. Non-Competition Guaranteed Value with Respect to Traffic Flow

The expected growth rate and volatility are two key factors describing changes in traffic flow. When given settings for certain parameters, we analyze numerically how the expected growth rate and volatility of traffic flow make an impact on the value of the non-competition guarantee.

Fig. 4 illustrates the dependence of the guaranteed value on volatility. Fig. 4 shows that non-competition guarantee Y_g is equal to 9 million vehicles, and the other necessary parameters are the same as those in Fig. 3. Fig. 4 indicates that when the other parameters are constant, the value of the non-competition guarantee improves as the expected growth rate goes up. Holding the expected growth rate, the value of the non-competition guarantee also increases as the initial traffic flow increases. Even though the government does not incur any payment or liabilities resulting from offering the guarantee, the value of the non-competition guarantee exists objectively and is affected by traffic flow, which should be taken into account when evaluating the value of the non-competition guarantee scientifically.

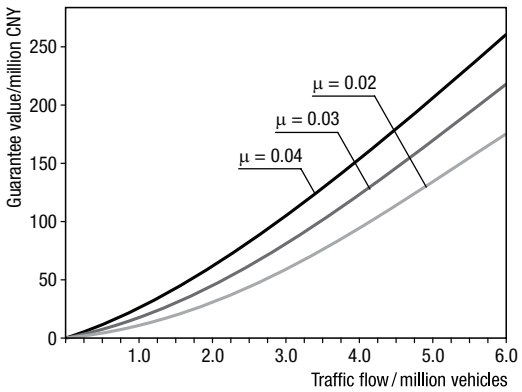

Fig. 4. The impact of the expected growth rate on the value of the non-competition guarantee

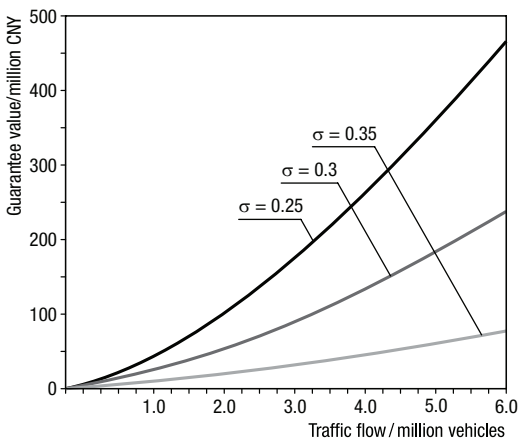

Fig. 5. The impact of volatility on the value of the non-competition guarantee

Fig. 5 illustrates the dependence of the guaranteed value on volatility where all parameters are the same as in Fig. 4. Fig. 5 shows other related parameters of how the value of the non-competition guarantee decreases as volatility increases, which is clearly different from the general situation that the value of real options increase as its volatility increases. A reasonable explanation may be that along with high volatility, traffic flow is more likely to reach the level of non-competition provided by the government, which reduces the effectiveness of the non-competition guarantee and further decreases its value.

5. Conclusions

The non-competition guarantee has been widely used for financing toll road projects and has an important impact on investors' decision-making. This paper constructs a model for evaluating the value of the non-competition guarantee by the adoption of the options game theory and develops the measurement approach to the value of the government guarantee. Theoretical derivation and numerical analysis show that:

1) the value of the non-competition guarantee increases as its guarantee level increases;
2) the non-competition guarantee plays an important role in simulating investment by reducing investment threshold of investors (it promotes investors to invest as soon as possible and further helps with fulfilling infrastructure project successfully);
3) an increase in the rate and volatility of traffic flow both have a strong influence on the value of the non-competition guarantee (specifically, the value of the non-competition guarantee increases as the rate of increase goes up and decreases as volatility increases).

The non-competition guarantee by the government taking into account the project of toll transport plays a fundamental role in investment incentives. However, considering traffic load, constraints on the concession period, requirements for minimum revenue flow and avoidance of an excessive guarantee, we cannot lay too much emphasis on the role of the non-competition guarantee. Only with the premise of no excessive competition, the non-competition guarantee is of practical significance.

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