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Real Options and Government Supports to Infrastructure Investments: An Empirical Study

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This paper provides evidence for the relationship between various forms of real options in infrastructure projects and the types and levels of government supports to the infrastructure investments. It analyzes the common real options and real options-based strategic investments and aligns them with the common types of public-private partnership (PPP) infrastructure projects. It then develops models to show that the real options incorporated into the different types of PPP infrastructure projects affect the level of direct government cash supports to the projects and hence the viabilities of such projects. The paper however shows that the relationship between the embedded real options and viabilities of infrastructure projects can be influenced by such factors as contract period and percentage of private sector contributions to the projects.

Keywords: real options, infrastructure investments, public-private partnership (PPP), government support

Introduction

Ever since the term was coined from financial options by Stewart Myers of MIT Sloan School of Management in 1977, real options theory has found wide applications in diverse areas of management. The interests of academic and practitioners alike were borne out of the fact that this new capital appraisal technique encourages active approach to the valuation of capital projects as opposed to the traditional passive management of investment projects. Real options techniques have been applied to investments in natural resource extraction (Brennan & Schwartz, 1985; Davis, 1998; Paddock, Siegel, & Smith, 1988; Trigeorgis, 1993a), real estate development (Titman, 1985), biotechnology (Benninga & Tolkowsky, 2002; Ottoo, 1998), information & communication technology (Arya & Glover, 2003; Benaroch & Kauffman, 1999; 2000; Panayi & Trigeorgis, 1998; Schwartz & Zozaya-Gorostiza, 2000), infrastructure (Brandao & Saraiva, 2008; Cardin & de Neufville, 2009; Caselli, Gatti, & Marciante, 2009; Cheah & Liu, 2006; Doan & Menyah, 2013; Huang & Chou, 2006; Kulatilaka, 1993; Rose, 1998; Smit & Trigeorgis, 2009) and other capital-intensive capital projects. In addition, real options frameworks have been argued to aid managers in taking strategic business decisions (Adams, 2004; Luehrman, 1998; McGrath, 1997; Tong, Reuer, & Peng, 2008). Of all the investment categories, infrastructure investments have enjoyed wide applications of real options techniques because of their highly irreversible nature and uncertainties in project revenues and in most cases project costs.

Valuing investments in infrastructure using the traditional discounted cash flow (NPV and IRR) techniques can greatly undervalue the projects as the techniques usually fail to value the flexibilities, in form of real options, embedded in the projects. It has been argued that real options valuations are usually fruitful in an investment

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proposal when there is a contingent investment decision, when uncertainty is large enough that it is sensible to wait for more information and when the project value depends on the possibilities for future growth options (Amram & Kulatilaka, 1999). Other criteria, according to the authors, include when uncertainty is large enough to make flexibility a consideration and when there will be project updates and mid-course strategy corrections. Virtually all investments in infrastructure (transport - rails, roads and ports, energy, telecommunication and water resources) meet these criteria, thus making them highly suitable for real options applications. However, in practice, the level of formal adoption of real options techniques in capital budgeting including in infrastructure investments is still low (Ahmed, Elharidy, Fu, & Northcott, 2011; Block, 2007; Denison, Farrell, & Jackson, 2012; Triantis, 2005). The non-consideration of flexibilities or real options in infrastructure investments has impacted negatively on the financial viabilities of these projects. Infrastructure investments have thus been traditionally left in the hands of governments who invest in them for the socio-economic benefits of the people. Even the new trend of private sector participation in infrastructure investment through public-private partnership (PPP) has not sufficiently made infrastructure projects financially viable. Government supports to the projects still come in various forms such as fixed or variable government payments, payment guarantee, development cost guarantee, revenue and interest/exchange rate guarantees among others. This study aims to determine how the degree of flexibilities embedded in infrastructure projects determines the projects' viabilities.

It is expected that if PPP infrastructure projects are appraised using real option techniques, various real options can be built into the projects to enhance their values. The enhancements of the project values using real options will make the projects more valuable and thus reduce the level of fixed government support to the project. This paper sets out to examine the different forms of real options in infrastructure investments and how they affect the viabilities of the infrastructure projects. It uses data from the global PPP infrastructure project database for the empirical analysis. The paper argues that various types of infrastructure investments have, incorporated into them, different combinations of real options. If real options expand the values of investment projects, it is therefore expected that infrastructure projects with more real options will be more valuable than the infrastructure project types with fewer real options. It is thus expected that projects with more real options will require less fixed government support. Using the data on infrastructure projects and the types and levels of government supports provided, the paper shows empirically the relationship between real options and the levels of government supports to infrastructure projects.

Incorporations of real options into infrastructure investments are expected to expand the values of the projects and in the process make them to require little or no fixed government support. This will thus lead to deployment of more infrastructure projects with the same government budget and the attendant improvements in socio-economic well-being of the people. The long-term nature of PPP infrastructure contracts affords the parties the opportunities to embed different types of real options, in forms of clauses, into the contracts. The clauses will limit downside losses from the project in an unfavourable economic situation while the investors will maximize upside potentials in favourable conditions. Both the government and the private sector participants will thus benefit from successful deployments of these PPP projects. The private sector players earn commensurate returns from their investments while the public sector party also provides key infrastructure to the citizenry at favourable costs to the government. The final users equally enjoy these infrastructure projects at affordable user fees. The paper therefore extends the literature on real options by examining the effects of real options in PPP infrastructure projects on government supports to these projects and hence the viabilities of the projects.

This section discusses the background of the study and its general introduction. The next section reviews the literature on real options theory as it relates to investments in infrastructure. The section reviews extant literature on real options types in infrastructure investments and the various forms of government supports to infrastructure projects. It furthers discusses how incorporations of real options and their subsequent formal valuations in infrastructure projects affect the levels of fixed government supports and hence the viabilities of these projects. The third section discusses the data and the sample used in the study and develops statistical models to show the relationship between the categories of common real options in various infrastructure types and the levels of fixed government supports to the infrastructure projects. The section also explores the non-fixed government supports and their distribution among the project types. The fourth section discusses the findings and their contributions to extant literature on real options. The section also discusses the limitations of the study and possible areas for future research. Section five concludes the paper.

Real Options and Government Supports to Infrastructure Projects

Traditional investment appraisal techniques have been shown to ignore values from active management of investment projects (Trigeorgis, 1993b). The different types of real options identified in the literature (Amram & Kulatilaka, 1999; Trigeorgis, 1993a; 1993b) have been shown to expand the values of investment projects. The common types of real options that can be embedded into investment projects include option to defer, time-to-build option, option to alter operating scale, option to abandon, option to switch, growth option, and multiple interacting option (Trigeorgis, 1993a). Yet from another perspective, the different types of investments incorporating real options include irreversible, flexibility, insurance, modular, platform, and learning investments (Amram & Kulatilaka, 1999). The real options incorporated into these capital investments give managers the flexibilities for active management of the projects and the accompanying expansion of the project values. The options enable managers to respond favourably to unfolding developments in the construction and/or operation of the projects. Thus, if the options are included and correctly valued in these projects, they will enable the managers to take better investment decisions.

Although valuations of real options in investment projects usually involve relatively complex mathematical techniques, simpler and more tractable real option techniques are now common and are now being considered by managers. It is now even more common for managers to intuitively incorporate real options into their investment projects. Managers can break the development of projects into stages (time-to-build option), wait for the resolution of a key macroeconomic variable before investing (option to defer), build a project with two or more inputs or a project with two or more outputs (option to switch) and/or start a project small or big and then expand or contract it later (option to alter operating scale). Managers can also intuitively consider opportunities for follow-on investments (growth option) in their investment decisions and possibilities of abandoning and selling the project assets for their salvage values (option to abandon) in very extreme unfavourable market conditions. These are common practices in today’s project management approaches. Proofs-of-concept (POCs) or pilot implementations are first carried out before full-scale deployments of capital projects to identify potential risks and management responses to them. These all affect the project costs and proposed revenues and can be regarded as intuitive incorporation of real options into capital projects. These are even more common in highly capital-intensive infrastructure projects. This paper thus proposes that the presence of these risk management flexibilities or real options will positively affect the viabilities of PPP infrastructure projects.

Real Options and Infrastructure Investments

Investments in infrastructure are key to economic growth and development of a nation. Even at the level of a firm, investment in key infrastructure provides opportunities for follow-on investments which can lead to the firm's growth should the operating environment turns out to be highly favourable. Public utilities, known as infrastructure, are vital to the nation's production and distribution of economic output as well as to its citizens' overall quality of life (Algarni, Arditi, & Polat, 2007). In order to fast-track economic development with the limited government revenues, governments of nations around the world now tap into the financial resources of the private sector through the PPP. Private sector participations in the delivery of infrastructural services vary from a relatively short-term (1-5 years) partnership of operating, maintaining, and managing the infrastructure to longer-term (10-30 years) contracts of designing, financing, operating, and owning the infrastructure. The long-term nature of the contracts enables the private investors to recoup their investments from user fees. However, the long-term contracts also come with unpredictable social, economic, and political environments which can adversely affect the viabilities of the projects. Incorporation of risk management measures into these PPP projects can therefore enhance their values and make them more attractive to private sectors. Real options analysis of the key infrastructure projects: energy, transport (road, rail, airport, seaport, urban transport), telecommunication and water & sewerage (water transfer systems, water treatment plants and utility), shows that the projects have potentials for varying degrees of real options types and hence projects values.

Energy PPP infrastructure projects mostly involve electricity generation and in some cases natural gas transmission and distribution. The projects are usually marred with a lot of uncertainties not only in the demand for the power output but also in the volatilities in prices of the commodities used as inputs for the generation of electricity. The projects thus have the potential for incorporating virtually all the options types as shown in Table 1. In the same way, real options categories that can be embedded in transport, telecommunication and water & sewerage projects types are also as shown in Table 1. Table 1 is the authors' adaption of Trigeorgis' (1993a) common real options.

Table 1

Common Real Options and Infrastructure Types

Category	Description	Can be embedded in
Option to defer	Management can wait to see if input/output prices justify developing and/or operating a capital project	Energy, transport, telecoms, water
Time-to-build option	Developing capital projects in stages with option to wait or even abandon mid-stream into development and/or operation	Energy, transport, telecoms, water
Option to alter operating scale	If market conditions are more favourable than expected, the capital project can be expanded and vice versa	Energy, transport, telecoms, water
Option to abandon	If market conditions decline severely, management can abandon the capital project for its salvage value	Energy, telecoms
Option to switch	If prices or demand change, management can change the output mix or same outputs using different input	Energy
Growth option	An early investment is a prerequisite for follow-on investments opening up future growth opportunities	Energy, transport, telecoms, water
Multiple interacting real options	Collection of various options categories usually found in real-life capital projects	Energy, transport, telecoms, water

In a similar manner, the infrastructure types can also be categorized using the Amram and Kulatilaka's (1999) perspectives of real options. Table 2 shows the adaptation of this author's classifications of strategic investments based on real options classifications of Amram and Kulatilaka (1999). The PPP infrastructure types are grouped based on real options types that are predominant in the investment type. For example, all the infrastructure types - energy, transport, telecoms and water - are irreversible investments.

Table 2

Real Options Perspectives and Infrastructure Types (Amram & Kulatilaka, 1999)

Investment type	Description	Infrastructure types
Irreversible investments	Once these investments are in place, they cannot be reversed without losing much of their value	Energy, transport, telecoms, water
Flexibility investments	Investments that incorporate flexibility in the form of options into the initial stage	Energy, transport, telecoms, water
Insurance investments	Investments that reduce the exposure to uncertainty	Energy, telecoms
Modular investments	Investments that create options through product design	Energy, transport, telecoms
Platform investments	Investments that create valuable follow-on contingent investment opportunities	Energy, transport
Learning investments	Investments that are made to obtain information that is otherwise unavailable	Energy, transport, telecoms, water

Tables 1 and 2 show similar trends in the predominance of real options in the various types of infrastructure investments. It is thus argued that real options in forms of risk management measures are mostly common in energy infrastructure projects. The development and operations of electricity generation plants, for example, are usually bedevilled with great uncertainties in both output market demand and input costs. It is hypothesized that this high level of real options which are usually included in forms of clauses in the contract will make the projects more viable and reduces the level of fixed government support. Although transport (road, rail, port and urban transit), telecom and water & sewerage infrastructure projects potentially include valuable options in them, it is argued that they embed less options and are expected to be less viable and thus require higher levels of fixed government support.

Government Support in Infrastructure Investment

Valuation of infrastructure investments using the traditional NPV technique usually results in “reject” investment decisions as the techniques often time fail to include values that can be derived from embedding real options into the projects. The participation of private investors in the delivery of infrastructural services through PPP has led to more complex analyses of the projects. The private partners are traditionally more interested in earning returns commensurate with the opportunity costs of their investments. To encourage the investors and to also ensure that the projects are delivered for the socio-economic benefits of the people, the parties usually include a number of negotiated clauses into the contracts. For example in a power plant, such clauses may include those that ensure that gas is supplied regularly to the plant under some agreed conditions and that a power purchase agreement is in place for the power output. In a toll road, government may be required to guarantee minimum yearly revenues from the road project while in water infrastructure project government may subsidize the cost by making a particular payment to the private investors. All these require rigorous valuations and negotiations from both parties to determine whether government support will be required and the forms and the levels of the government supports.

Researchers have attempted to value various types of government supports to infrastructure projects using real options valuation techniques. For example, the valuation of minimum revenue guarantee in toll road infrastructure projects using real options (Brandao & Saraiva, 2008; Cheah & Liu, 2006; Doan & Pate, 2010; Huang & Chou, 2006) and the pricing of final indemnification payments to private sponsors in a PPP project (Caselli et al., 2009). However, some other studies used a different pricing methodology. For example, the valuation of government support to infrastructure projects using Capital Asset Pricing Model (CAPM) based valuation technique (Wibowo, 2006). The enormous PPP infrastructure risks are usually allocated to parties best able to manage them. This in a way complicates the traditional trade-off between risk and returns of investments in finance. In infrastructure investments, the expected returns from the projects are usually limited by the socio-political factors that affect the pricing of the output even in the face of the enormous risks. Government supports to the projects are thus necessary to make the projects more viable. Other factors that may necessitate the provision of government supports are mismatches in revenue and/or debt currencies (Ye & Tiong, 2007).

Real Options and Government Supports to PPP Infrastructure Projects

Government supports to infrastructure projects usually take the forms of fixed government payments, construction cost guarantee, debt guarantee, revenue guarantee, interest & exchange rates guarantees, payment guarantee and variable government payments. Fixed government payments are certain payments made by the government to support the infrastructure projects. They are usually in form of cash supports or grants from government and encourage private partners to develop projects that are otherwise not viable. It is thus expected that the higher the level of fixed government payment to a project, the less the initial viability of the project. As argued earlier, infrastructure projects have real options incorporated into them to optimize returns on the investments. Also, the different types of infrastructure projects have varying degrees of common real options. Therefore, the analysis of the relationship between infrastructure project types and the level of fixed government support to these projects is expected to also explore the relationship between common real options in infrastructure investments and the level of fixed government support to the investments.

The other types of government supports are not fixed and are subject to uncertainties in factors such as project revenues, project costs, and interest/exchange rates. Governments therefore give these forms of supports to improve the viabilities of the projects by managing the uncertainties inherent in those factors. Revenue and payment guarantees ensure that the infrastructure project earn a minimum guaranteed revenue. It limits the loss from downside risk and improves the upside potential for the private investors. This is thus a form of real options. This form of real options also applies to variable government payment type of government support. Construction cost guarantee manages the uncertainties in project cost. It ensures that there is a cap on project construction cost. It therefore limits the project loss if the cost exceeds the cap and improves the project revenues for construction costs that are less than the guaranteed amounts. This is another form of real options in infrastructure projects. In the last set of government support, debt, interest and exchange rate guarantees; governments minimize project loss by setting a cap on the interest/exchange rate. On the other hand, project viabilities are improved if the rates turn out to be favourable. These government supports are yet another set of real options. The data from the global database of infrastructure projects are analysed for relationship between the project types and these other forms of government supports or real options.

This paper therefore examines the relationship between PPP infrastructure projects embedding common real option and the levels of fixed government supports to the projects. It also examines the relationships between infrastructure project types and the other forms of government supports or real options reported for the projects. Aligning the common real options from real options literature with the identified infrastructure types provides the opportunity to analyse viabilities of infrastructure investments based on the number of real options categories present in them. It also provides an opportunity to explore how the different real options are structured into the PPP infrastructure contracts to better manage the risks inherent in the projects and hence expand the project values. It will be interesting to see if there is any relationship between infrastructure projects with different types of real options and the level of fixed government supports to the projects. The analysis in this paper also examines the relationship between PPP infrastructure projects types and the variable forms of government supports to the projects. These variable government supports are more or less different forms of real options. These relationships are explored using the multivariate regression models and statistical tables/charts.

Methodology

The paper sets out to develop statistical models showing the relationship between real options categories incorporated into infrastructure projects and the levels of government supports to the projects. It thus intends to extend the literature on real options by investigating how real options affect the provision of government support to infrastructure projects and hence the viabilities of these projects. The paper uses the project data from World Bank's Private Participation in Infrastructure (PPI) database with financial closure from 1984 to 2013 for all regions and all countries of the world. The project data cut across all income groups and all infrastructure project types. The size of the total investments per infrastructure project also varies from few hundred thousand dollars to several billions of dollars.

Sample and Data

The data of 481 infrastructure projects for which government support types are reported are used in this study.

The types of government support. The distribution of the various types of government supports is as shown in Figure 1. About half of the reported infrastructure projects (233 projects) have government supports in form of fixed government payments. The fixed government payments were made mainly as government cash assistances to the projects. This thus suggests that the projects, without the cash supports, are not viable. It is therefore worthwhile to know the nature of these projects in terms of common real option types incorporated into them. The findings will give an insight into how the nature of infrastructure projects, in terms of real options found in them, affects government cash supports to the projects.

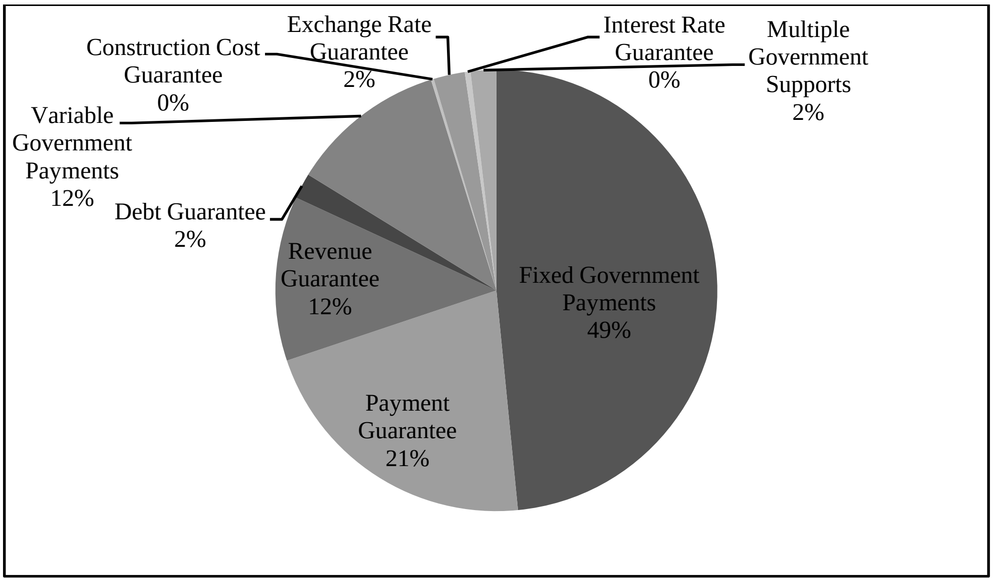

Figure 1. Types of government supports.

Valid cash support data are reported for 133 projects in millions of dollars. To control for the size of the project, each cash support figure is measured as a percentage of the reported total investment in the project. The cash support is used as the dependent variable in the models of this study and the effects of the infrastructure types, including the real options they incorporate, are then investigated. For other forms of government supports that are not directly measureable, the infrastructure investment types having them are also investigated.

The primary sectors of the infrastructure projects. The infrastructure projects cut across four major primary sectors: energy, transport, telecoms and water & sewerage. The primary sectors and the sub-sectors of the reported infrastructure types are as shown in Table 3.

Table 3

Primary Sectors and Sub-sectors of the Infrastructure Projects

Primary sector	Sub-sector
Energy	Electricity, natural gas
Telecom	Telecom
Transport	Airports, railroads, roads, seaports
Water & sewerage	Water transfer system, treatment plant, utility

The primary sectors of the 481 reported infrastructure projects are as shown in Figure 2.

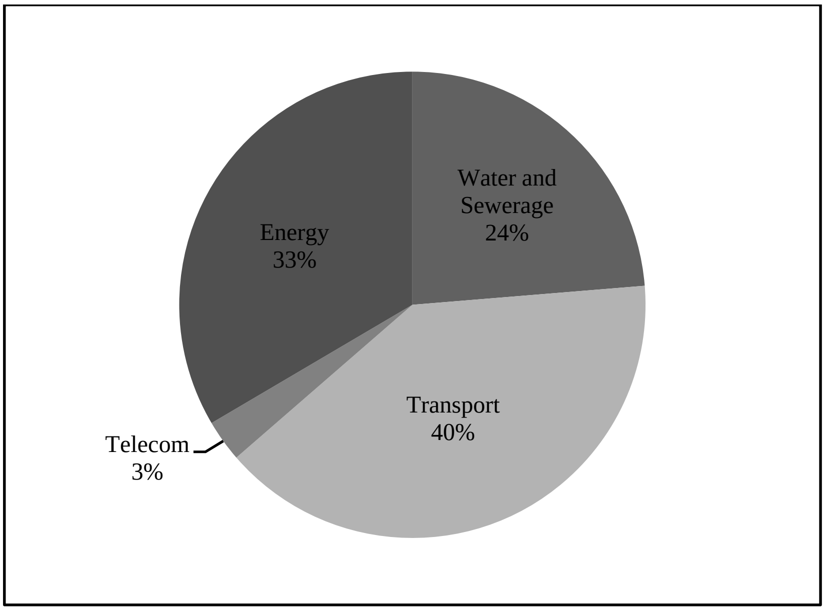

Figure 2. Projects by primary sectors.

The reported primary sector data are measured as categorical data and used in the models developed in this study. The infrastructure types; transport, telecom, water & sewerage, and energy are coded 1, 2, 3, and 4 respectively. In regression analysis, this is implemented using the binary data in three binary groupings. In a binary group, the binary data 1 is entered for the infrastructure type variable if the reported data are of a particular infrastructure type while the binary data 0 is given to the other infrastructure types. For example, if the primary sector of the reported project is transport, the value of the infrastructure type variable is 1 for transport binary group and 0s for energy, water & sewerage, and telecom.

Other reported project data used in this study include project contract period, percentage of private sector contribution, and income group of the project's country. It is argued that project contract period can affect the level of government support to an infrastructure project. Long years of contract period can increase the revenues from the project and hence improves the viability of the project thereby reducing government support to the project and vice versa. On the other hand, long contract periods can lead to sharp falls in project net cash flows as operating environment becomes unfavourable. This study will also examine whether the percentage of private sector contribution to the project and income group of the project's country have any interactions with the infrastructure type to affect the government cash supports.

The Models

The models are developed using multivariate regression statistical analysis in Stata statistical package. The models explore the relationship between real options types in the primary sectors of the infrastructure projects and the levels of government cash supports to the projects. By including such factors as project contract period, percentage of private sector contribution, and income group of the country, this study explores how these factors interact with the infrastructure types to affect government cash supports to infrastructure projects. The first set of models shows the regression of government cash support with the infrastructure types as shown by the primary sectors of the infrastructure projects. The second model includes the project contract period as the independent variable along with the infrastructure project types. The third set of models explores further the relationship between government cash supports and the infrastructure types with the real options embedded in them. The models now include the percentage of private sector contributions to the project in the relationship. The fourth and the last set of model examine the effect of including the income group of the project's country in the relationship. It sets out to investigate the combined effects of the country's income group and infrastructure types on the level of government cash supports to infrastructure projects.

Government cash support and infrastructure types. The general model showing the relationship between government cash supports and the primary types of the infrastructure projects is shown below:

$$Cash\_Support = \beta_0 + \beta_1 Infra\_Type + \varepsilon_0 \quad (1)$$

where *Cash_Support*, the dependent variable, is the ratio of government cash support to total investment in each infrastructure project; *Infra_Type* is the independent variable for infrastructure type using categorical variable 1 for transport, 2 for telecom, 3 for water & sewage, and 4 for energy. β_0 and β_1 are the constant and the coefficient of the model respectively. The error term in the model is represented by ε_0.

Model (1) is implemented in multivariate regression using three dummy variables for the *Infra_Type* variable resulting in three sub-models. When the *Infra_Type* is 1, the model for transport infrastructure type is developed with transport dummy variable as shown in Model (1a) below. The values of telecom, water & sewerage, and energy infrastructure types are zero:

$$Cash\_Support = \beta_0 + \beta_{Transport}(1) + \varepsilon_1 = \beta_0 + \beta_{Transport} + \varepsilon_1 \quad (1a)$$

Model (1a) is the model for transport and shows that if the infrastructure type is transport, the expected increase in government cash support to the project will be $\beta_0 + \beta_{Transport}$. ε_1 is the error term.

If the infrastructure type is telecom, the *Infra_Type* in Model (1) assumes the binary value 1 for a new dummy variable, telecom, while the values of the remaining two infrastructure types, water & sewerage and energy are zero. This results in a sub-model for telecom in Model (1b):

$$Cash\_Support = \beta_0 + \beta_{Telecom}(1) + \varepsilon_2 = \beta_0 + \beta_{Telecom} + \varepsilon_2 \tag{1b}$$

The model shows that the expected increase in government cash support for telecom infrastructure type is $\beta_0 + \beta_{Telecom}$, while the error term is ε_2.

In a similar way, for the model for water and sewerage infrastructure type, *Infra_Type* variable has the value of 1 while for the only remaining infrastructure type, energy, the *Infra_Type* variable is zero. The dummy variable for water & sewerage infrastructure type is *Water_Sewage* and the sub-model is shown below:

$$Cash\_Support = \beta_0 + \beta_{Water\_Sewage}(1) + \varepsilon_3 = \beta_0 + \beta_{Water\_Sewage} + \varepsilon_3 \tag{1c}$$

From Model (1c), the expected increase in government cash support to the infrastructure project if the project is water and sewerage project is $\beta_0 + \beta_{Water\_Sewage}$.

The last sub-model is the model for energy infrastructure type and is the resulting model when *Infra_Type* variable is zero. The model is the Model (1d) shown below:

$$Cash\_Support = \beta_0 + \beta_{Energy}(0) + \varepsilon_4 = \beta_0 + \varepsilon_4 \tag{1d}$$

Model (1d) shows that the expected increase in government cash support for energy infrastructure projects is β_0.

The models above show the relationship between government cash supports and the types or the primary sectors of the infrastructure projects using the World Bank's global database of infrastructure projects.

Three other variables are added to the models to explore their effects on the government cash supports along with the infrastructure types. The variables are the project's contract period, the percentage of private sector contribution to the reported project, and the income group of the project's country.

Government cash supports, infrastructure types, and project contract periods. A new variable, contract period, is added to Model (1) above to explore whether the explanatory power of the model will be enhanced if the variable is introduced. The new model is as shown below:

$$Cash\_Support = \beta_{0,2} + \beta_{1,2}Infra\_Type + \beta_{2,2}Contract\_Per + \varepsilon_{0,2} \tag{2}$$

In Model (2) above, *Contract_Per* is the project contract period variable, $\beta_{1,2}$ and $\beta_{2,2}$ are the coefficients of infrastructure types and project contract periods respectively while $\beta_{0,2}$ and $\varepsilon_{0,2}$ are the model's constant and error term respectively. The model shows how the relationship between government cash support and project type is affected when the project contract period is introduced.

Government cash support, infrastructure types, and private sector contribution to the projects. Another variable that will be explored for its effect on the relationship between government cash support and project type is percentage of private sector contribution to the project. The new model will show whether and how private sector contribution combines with the project type to affect the level of government support to infrastructure projects. Models (3a) and (3b) show the new relationship. While Model (3a) includes project type and private sector contribution variables in the relationship, Model (3b) includes the three variables: project type, contract period, and private sector contribution:

$$Cash\_Support = \beta_{0,3a} + \beta_{1,3a} Infra\_Type + \beta_{2,3a} Pct\_Private + \varepsilon_{0,3a} \tag{3a}$$

$$Cash\_Support = \beta_{0,3b} + \beta_{1,3b} Infra\_Type + \beta_{2,3b} Contract\_Per + \beta_{3,3b} Pct\_Private + \varepsilon_{0,3b} \tag{3b}$$

The *βs* and *εs* are as explained earlier while *Pct_Private* is the variable for the percentage of private sector partners' contribution to the project.

Government cash support, infrastructure types, and income group of the project's country. The last set of models investigates the effect of income group of the project's country on the relationship between government cash support and the infrastructure project type. It explores the significance or otherwise of the variable on the relationship. There are two reported income groups in the infrastructure projects' database: the upper middle income group and lower middle income group. The models are presented below:

$$Cash\_Support = \beta_{0,4a} + \beta_{1,4a} Infra\_Type + \beta_{2,4a} Income\_Grp + \varepsilon_{0,4a} \tag{4a}$$

$$\begin{aligned} Cash\_Support = \beta_{0,4b} + \beta_{1,4b} Infra\_Type + \beta_{2,4b} Contract\_Per + \\ \beta_{3,4b} Pct\_Private + \beta_{4,4b} Income\_Grp + \varepsilon_{0,4b} \end{aligned} \tag{4b}$$

where *Income_Grp* is the income group of the infrastructure project's country, $\beta_{0,4a}$ and $\beta_{0,4b}$ are the constants of the models, $\beta_{1,4a}$, $\beta_{2,4a}$, $\beta_{1,4b}$, $\beta_{2,4b}$, $\beta_{3,4b}$, and $\beta_{4,4b}$ are the coefficients of the models and $\varepsilon_{0,4a}$ and $\varepsilon_{0,4b}$ are the error terms.

Model (4a) shows whether the income group of the country where the project is developed affects the level of government cash support to the project and hence the viability of the project. Model (4b) examines the combined effects of the project type and the three other variables considered in this study (contract period, private sector contribution, and income group of the project country) on the level of government cash supports to the studied infrastructure projects.

Other Forms of Government Support and Their Analyses

Fixed government payments, mostly government cash supports, constitute about half of the government supports to the infrastructure project data used in this study. The other forms of government supports including payment guarantee, revenue guarantee, variable government payments, debt guarantee, interest rate guarantee, construction cost guarantee, exchange rate guarantee, and a combination of two or more government support types constitute the other half. The analysis of the relationships between the infrastructure project types and the non-fixed government supports or real options reported for the projects is done using statistical tables/charts. While 233 of the reported infrastructure projects have fixed government supports in form of government cash supports, the other 248 projects have other forms of government supports given to them. The distribution of the non-fixed government supports among the infrastructure types is as shown in Table 4.

Table 4

Distribution of Non-fixed Government Supports Among the Infrastructure Project Types

Infrastructure project type	Number of projects
Energy	147
Telecom	0
Transport	47
Water & sewerage	54

Results and Discussion

Real Options, Project Types, and Government Cash Supports

Models (1a)-(1d) were implemented in Stata using the infrastructure project data from World Bank's PPI database. An initial analysis of the data shows that no energy infrastructure project received government cash support. This finding suggests that energy-related projects appear to be more viable than the other project types reported in the database used in this study. This also lends support to the earlier arguments that the more the common real options in a PPP infrastructure project, the more viable the project. The Stata output of the regression of the other three project types, transport, telecom, and water & sewerage, against government cash support, is as shown in Table 5.

Table 5

Regression Output of Real Options-Embedded Project Types and Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	3	0.4437629	0.0474	3.231822	0.0427
Cash_Support	Coef.	Std. err.	*t*	$P > \|t\|$	[95% conf. interval]	
Transport	-0.1660303	0.0924842	-1.80	0.075	-0.3489993	0.0169387
Telecom	-0.533	0.2362109	-2.26	0.026	-1.000315	-0.0656851
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
_cons	0.533	0.0810197	6.58	0.000	0.3727123	0.6932877

As shown in the table, the regression of the government cash support with infrastructure project types is significant at 95% confidence interval with real options-embedded infrastructure project types explaining about 5% of the changes in government cash supports to the reported projects.

Government cash supports and transport infrastructure projects. Model (1a), the sub-model for transport, is not significant at 95%. It is however significant at 90%. From the regression results, it implies that:

$$Cash\_Support = \beta_0 + \beta_{Transport} + \varepsilon_1 = 0.533 - 0.1660303 + \varepsilon_1 = 0.3669697 + \varepsilon_1$$

The model shows that transport project type will have a positive 0.3669697 effect on the level of government cash support. The reported data suggest that at 90% confidence interval, transport projects are not likely to be financially viable without government cash supports. Although formal incorporations and valuations of common real options are not reported in the PPI database, it is assumed that as a minimum that risk management measures in forms of real options are embedded in the projects. The results thus suggest that transport infrastructure projects will still require government cash supports to be viable even with the current intuitive or formal incorporations of real options.

Government cash supports and telecom infrastructure projects. The sub-model for telecom is significant at 95% confidence interval and is stated below:

$$Cash\_Support = \beta_0 + \beta_{Telecom}(1) + \varepsilon_2 = 0.533 - 0.533 + \varepsilon_2 = 0 + \varepsilon_2$$

The regression output shows that telecom infrastructure projects do not require any level of government cash support. The results show that the reported telecom infrastructure projects are viable as implemented with embedded forms of flexibilities or real options. This thus suggests that just like energy infrastructure projects that have no reported case of government cash support, empirical analysis of telecom projects also shows that they do not require government cash support. The reported data thus support the paper's earlier arguments that based on alignments of common real options with project types, the levels of government cash supports to energy and telecom projects will be less than the level to transport projects.

Government cash supports and water and sewerage infrastructure projects. Since there is no reported valid case of government cash support for energy infrastructure projects, the earlier four sub-models (1a)-(1d) are reduced to three and the model for water and sewerage now becomes:

$$Cash\_Support = \beta_0 + \beta_{Water\_Sewage}(0) + \varepsilon_3 = \beta_0 + \varepsilon_3 = 0.533 + \varepsilon_3$$

The water and sewerage model is significant and from the model, there is evidence that water and sewerage projects will require high level of government cash support, higher than the level for transport support. Results from the reported project data thus suggest that water and sewerage projects are the least viable of the four projects types. The projects require the highest level of government cash support even with the common real options assumed to be either intuitively or formally incorporated into them. The findings support the arguments that common real options-embedded projects types will affect the levels of government support in the ways suggested earlier in Tables 1 and 2.

Effects of Other Project-Related Factors on Government Cash Supports

The paper examines how the reported PPI project-related factors, contract period, percentage of private sector participation and income group of the project country; combine with project types to affect the levels of government cash supports to the reported projects.

Effects of project types and contract period on government cash support. Table 6 shows the regression output for Model (2), the effects of project types and contract period on the level of government cash support to infrastructure projects. The model is significant and including the contract period variable increases the explanatory powers of the independent variables to about 13% of the changes in government cash support. The coefficient of transport project type, however, becomes less significant while other coefficients are significant.

Table 6

Regression Output of Project Types and Contract Period on Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	4	0.4264507	0.1270	6.256101	0.0005
Cash_Support	Coef.	Std. err.	*t*	*P* > |*t*|	[95% conf. interval]	
Transport	-0.1254576	0.0896596	-1.40	0.164	-0.3028514	0.0519361
Telecom	-0.5343918	0.2269961	-2.35	0.020	-0.9835091	-0.0852744
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Contract_Per	-0.0208768	0.0060854	-3.43	0.001	-0.0329169	-0.0088367
_cons	0.9519278	0.1448235	6.57	0.000	0.665391	1.238465

The results show that contract period has a negative effect on the level of government cash support to the reported projects. The higher the project contract period, the lower the government cash support to the project. A possible explanation for this is that uncertainties are resolved with increasing years of project contract. Longer years of contract therefore make projects to be more viable and thus require less government cash supports. The inclusion of contract period variable does not however affect the order of the levels of government cash supports to the infrastructure project types.

Effects of project types and percentage of private sector participation on government cash support. Tables 7 and 8 show the regression results for Models (3a) and (3b) respectively. The two models are significant. The percentage of private sector participation combines with project type to explain 15% of the changes in government cash support. It combines with project type and contract period variables to explain more than 23% of the changes in government cash support.

Table 7

Regression Output of Project Types and Percentage of Private Sector Participation on Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	4	0.4206523	0.1506	7.623401	0.0001
Cash_Support	Coef.	Std. err.	*t*	*P* > |*t*|	[95% conf. interval]	
Transport	-0.113781	0.0886554	-1.28	0.202	-0.2891878	0.0616259
Telecom	-0.4531287	0.2248161	-2.02	0.046	-0.8979329	-0.0083244
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Pct_Private	-0.0135375	0.0034191	-3.96	0.000	-0.0203023	-0.0067728
_cons	1.80688	0.3307753	5.46	0.000	1.152433	2.461327

Table 8

Regression Output of Project Types, Contract Period, and Percentage of Private Sector Participation on Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	5	0.4005711	0.2357	9.869697	0.0000
Cash_Support	Coef.	Std. err.	*t*	*P* > |*t*|	[95% conf. interval]	
Transport	-0.0704219	0.0852005	-0.83	0.410	-0.2390056	0.0981618
Telecom	-0.4524374	0.2140839	-2.11	0.037	-0.876039	-0.0288359
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Contract_Per	-0.0215933	0.0057186	-3.78	0.000	-0.0329085	-0.0102781
Pct_Private	-0.0138987	0.0032573	-4.27	0.000	-0.0203437	-0.0074536
_cons	2.27417	0.338423	6.72	0.000	1.604542	2.943797

The regression output shows that the higher the percentage of private sector participation in the PPI projects, the lower the level of government cash support to the project. A possible explanation is that private investors tend to look for other areas to make infrastructure projects more viable. These areas include charging user fees and inclusion of other types of government support in forms of guarantees, rather than fixed government cash assistance, in the project contracts. The findings also show that the combinations of the variable with project types and with project types and contract periods do not affect the order of government cash support to the infrastructure project types.

Effects of project types and income group on government cash support. Models (4a) and (4b) examine the effects the reported income group of the project's country will have on government cash support to the PPI project when combined with projects types and other factors respectively. The results of the multivariate regressions are as shown in Tables 9 and 10. Although Model (4a) is significant at 90% confidence interval as shown in Table 9, the coefficient of income group variable is not significant. The variable does not explain any significant changes in the government support to the PPI projects. The results therefore show that the income group of the country of implementation of the infrastructure project does not affect the level of government support to the infrastructure project and hence the viabilities of the projects.

Table 9

Regression Output of Project Types and Income Group on Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	4	0.4452816	0.0482	2.178134	0.0937
Cash_Support	Coef.	Std. err.	*t*	*P* > |*t*|	[95% conf. interval]	
Transport	-0.1902509	0.1171464	-1.62	0.107	-0.422028	0.0415261
Telecom	-0.5282845	0.2374276	-2.23	0.028	-0.9980407	-0.0585282
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Income_Grp	-0.0353664	0.104393	-0.34	0.735	-0.2419105	0.1711777
_cons	0.5636509	0.1216336	4.63	0.000	0.3229959	0.8043059

Table 10

Regression Output of Project Types, Contract Period, Percentage of Private Sector Participation and Income Group on Government Cash Support

Equation	Obs.	Parms	RMSE	*R*-sq.	*F*	*P*
Cash_Support	133	6	0.4009295	0.2403	8.035899	0.0000
Cash_Support	Coef.	Std. err.	*t*	*P* > |*t*|	[95% conf. interval]	
Transport	-0.009038	0.1102617	-0.08	0.935	-0.2272259	0.2091499
Telecom	-0.4614192	0.2145194	-2.15	0.033	-0.8859143	-0.036924
Water_Sewage	0	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
Contract_Per	-0.0225297	0.0058222	-3.87	0.000	-0.0340507	-0.0110087
Pct_Private	-0.0143012	0.0032922	-4.34	0.000	-0.0208159	-0.0077864
Income_Grp	0.0847057	0.0964525	0.88	0.381	-0.1061563	0.2755678
_cons	2.257424	0.3392621	6.65	0.000	1.586086	2.928762

The incremental explanatory power is also not significant when income group variable combines with project types and other factors in Model (4b). Although the model is significant, the coefficients of transport project type and income group are not significant. However, the order of the remaining project types in terms of government cash support provided to them still remains the same.

Results and Discussion of Other Types of Government Supports

Of the 481 reported PPI project data, 248 of them have other forms of government supports reported for them which are not fixed government support in form of government cash supports. These include construction cost guarantee, interest/exchange rate guarantees, payment/revenue guarantees, debt guarantee, variable government payments, and multiple government support. As shown in Table 4, 147 or 59% of the reported PPI projects with these forms of government supports are energy projects, 54 or 22% are water and sewerage projects, 47 or 19% of the projects are transport-related projects while telecom project has no reported case of non-fixed government support. Since these forms of guarantees constitute other forms of real options, the results suggest that energy projects have the most forms of these real options incorporated into them. These guarantees, just like the common real options, protect investors from downside risks and improve the projects' upside potentials. These findings when combined with the earlier findings that energy projects have nil government cash support given to them suggest that incorporating real options into energy projects improves the viabilities of the projects. The results therefore support the findings from extant literature that real options expand the values of investment projects.

The distribution of non-fixed government support between transport and water & sewerage projects types is relatively close. Further examinations of the distribution however show that 100% of the construction cost and interest rate guarantees are given to transport-related infrastructure types. The distribution of the remaining forms of government support is as shown in Figures 3-8.

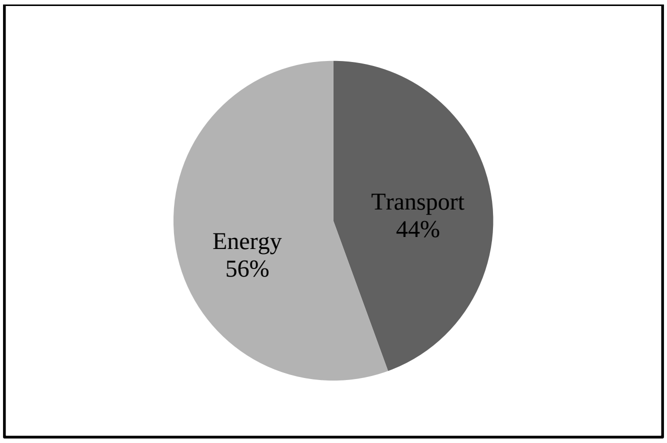

Figure 3. Debt guarantee.

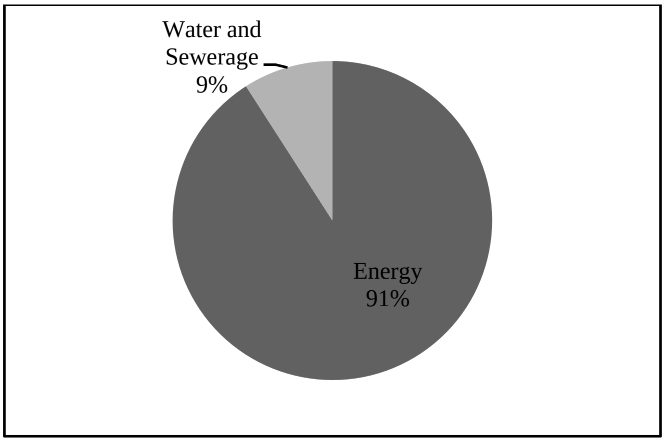

Figure 4. Exchange rate guarantee.

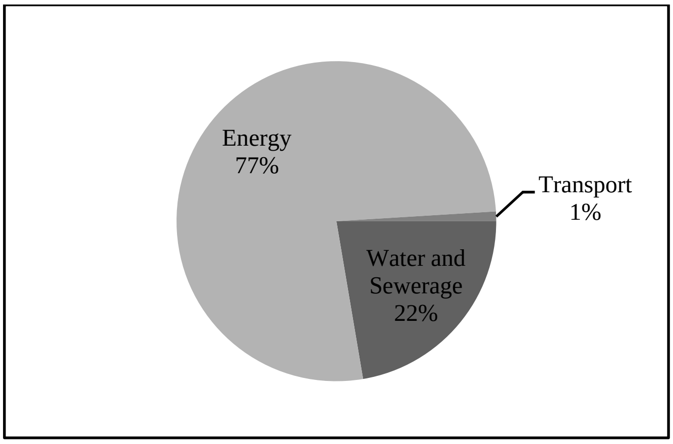

Figure 5. Payment guarantee.

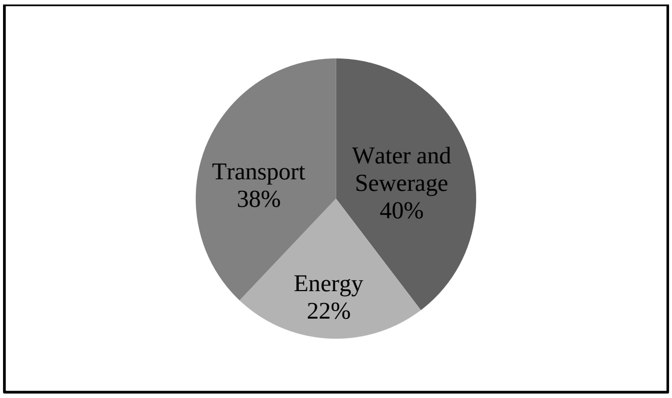

Figure 6. Revenue guarantee.

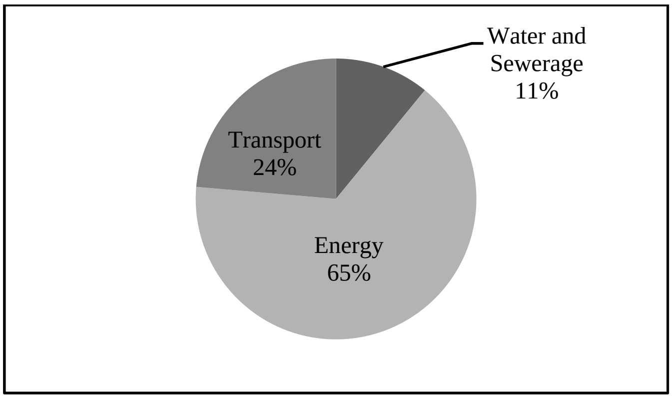

Figure 7. Variable government payments.

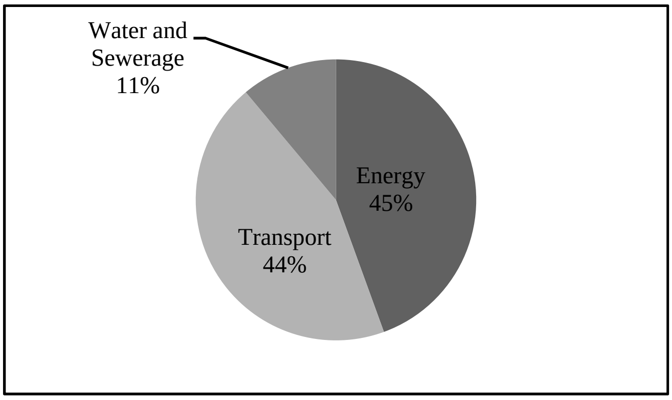

Figure 8. Multiple government support.

The distribution of the eight non-fixed government supports shows that transport project types have more of these other forms of government supports or real options than water and sewerage projects in five (construction cost guarantee, interest rate guarantee, debt guarantee, variable government payment, and multiple government support) of the government supports. Comparing these results with the results of models (1a)-(1c) further shows that real options affect the level of government cash supports to PPP infrastructure projects and hence the viabilities of these projects. Further empirical evidence is however required to further show which of the transport and water & sewerage projects have more real options and therefore expected to be more financially viable.

Limitations of the Study

The paper uses the reported PPI project data to explore the relationship between real options and financial viabilities of infrastructure projects. Although there are no formal reports of the incorporations of common real options in the project data used in this study, intuitive incorporations of real options are now evident in infrastructure projects. Lack of formal reported data on common real options is however a limitation to this study. To address this shortcoming, future study can collect primary data from surveys of PPP infrastructure projects. Responses to direct survey questions on incorporations of common real options will provide the needed data to further explore the relationship between real options and financial viabilities of infrastructure projects. Another limitation of this study is that the effects of real options are limited to the levels of government cash supports to infrastructure projects. Although the amount of government cash support to an infrastructure project is a good indicator of the financial viability of an infrastructure project, the availability of data on net present value and/or return on investment of the PPP projects would provide more direct evidence of the relationship between real options and profitability of an infrastructure project. Future studies can explore this area.

Conclusion

This study explores the effects of real options on the levels of government supports to infrastructure projects. Governments across the world have had to partner with private investors in the delivery of critical infrastructures to the people. Socio-political considerations however restrict chargeable user fees and hence revenues from the infrastructure projects. As this negatively affects the viabilities of these projects, governments now offer various forms of supports to improve the viabilities of these projects. This paper examines these different types of government supports and also explores the various types of infrastructure projects to see if there is a link between the project type and the level of government support. The paper argues that PPP infrastructure projects, by their nature, have a number of risk management measures or real options embedded into them to improve their viabilities. Aligning the common real options in the literature with infrastructure project types, the paper sets out to find out how the levels of government support vary with real options-embedded PPP project types. The global infrastructure project data from the World Bank's PPI database are used to perform the empirical analysis.

The models developed in this study use the PPI data and explore the effects of the various project types on government supports to the project. The analysis starts with models that examine the effects of project types with different degrees of common real options on the level of government cash supports to the projects. The results show that energy infrastructure projects require the least government cash support followed by telecom projects while transport and water & sewerage projects require the highest levels of government supports. These findings suggest that energy PPP projects are likely to be more viable than transport and water & sewerage PPP project types. The paper has earlier argued that energy projects have more real options embedded into them than telecom, transport and water & sewerage infrastructure projects. The results thus support the findings from extant real options literature that real options expand the values of investment projects. The paper also extends the analysis to other forms of government supports. These supports are usually in forms of government guarantees and constitute other forms of real options. The analysis of these forms of government supports or real options shows that majority of the guarantees go to energy PPP projects followed by transport and water & sewerage projects. This further shows that the presence of common and other forms of real options in investment projects has positive effects on the values of the projects. Further evidence from the analysis of actual real options and infrastructure projects' profitability data will however be necessary to strengthen the findings of this study.

References

Adams, M. (2004). Real options and customer management in the financial services sector. *Journal of Strategic Marketing, 12*(1), 3-11.

Ahmed, Z., Elharidy, A., Fu, K., & Northcott, D. (2011). Capturing the value of flexibility in public sector capital investment projects: Evidence from New Zealand local government organisations. *New Zealand Journal of Applied Business Research, 9*(2).

Algarni, A. M., Arditi, D., & Polat, G. (2007). Build-operate-transfer in infrastructure projects in the United States. *Journal of Construction Engineering and Management, 133*(10).

Amram, M., & Kulatilaka, N. (1999). *Real options: Managing strategic investment in an uncertain world*. Boston, MA: Harvard Business School Press.

Arya, A., & Glover, J. (2003). Abandonment options and information system design. *Review of Accounting Studies, 8*(1), 29-45.

Benaroch, M., & Kauffman, R. J. (1999). A case for using real options pricing analysis to evaluate information technology project investments. *Information Systems Research, 10*(1), 70-86.

Benaroch, M., & Kauffman, R. J. (2000). Justifying electronic banking network expansion using real options analysis. *MIS Quarterly, 24*(2), 197-225.

Benninga, S., & Tolkowsky, E. (2002). Real options – An introduction and an application to R&D valuation. *The Engineering Economist, 47*(2), 151-168.

Block, S. (2007). Are “real options” actually used in the real world? *The Engineering Economist, 52*(3), 255-267.

Brandao, L. E. T., & Saraiva, E. (2008). The option value of government guarantees in infrastructure projects. *Construction Management and Economics, 26*(11), 1171-1180.

Brennan, M., & Schwartz, E. (1985). Evaluating natural resource investments. *Journal of Business, 58*(2), 137-157.

Cardin, M. A., & de Neufville, R. (2009). A direct interaction approach to identify real options “in” large-scale infrastructure systems. Proceedings of *the Real Options Conference 2009*.

Caselli, S., Gatti, S., & Marciante, A. (2009). Pricing final indemnification payments to private sponsors in project-financed public-private partnerships: An application of real options valuations. *Journal of Applied Corporate Finance, 21*(3), 95-106.

Cheah, C. Y., & Liu, J. (2006). Valuing governmental support in infrastructure projects as real options using Monte Carlo simulation*. Construction Management and Economics, 24*(5), 545-554.

Davis, G. A. (1998). Estimating volatility and dividend yield when valuing real options to invest or abandon. *Quarterly Review of Economics and Finance, 38*(3), 725-754.

Denison, C. A., Farrell, A. M., & Jackson, K. E. (2012). Managers’ incorporation of the value of real options into their long-term investment decisions: An experimental investigation. *Contemporary Accounting Research, 29*(2), 590-620.

Doan, P., & Menyah, K. (2013). Impact of irreversibility and uncertainty on the timing of infrastructure projects. *Journal of Construction Engineering and Management, 139*(3).

Doan, P., & Pate, K. (2010). Investment with government subsidies and cost contingency: The case of build-operate-transfer (BOT) toll road. Working Paper: 14th International Conference on Real Options.

Huang, Y., & Chou, S. (2006). Valuation of the minimum revenue guarantee and the option to abandon in BOT infrastructure projects. *Construction Management and Economics, 24*(4), 379-389.

Kulatilaka, N. (1993). The value of flexibility: The case of a dual-fuel industrial steam boiler. *Financial Management, 22*(3), 271-280.

Luehrman, T. A. (1998). Strategy as a portfolio of real options. *Harvard Business Review*.

McGrath, R. G. (1997). A real options logic for initiating technology positioning investments. *Academy of Management Review, 22*(4), 974-996.

Ottoo, R. E. (1998). Valuation of internal growth opportunities: The case of a biotechnology company. *The Quarterly Review of Economics and Finance, 38*(3), 615-633.

Paddock, J. L., Siegel, D. R., & Smith, J. L. (1988). Option valuation of claims on real assets: The case of offshore petroleum leases. *Quarterly Journal of Economics, 103*(3), 479-508.

Panayi, S., & Trigeorgis, L. (1998). Multi-stage real options: The cases of information technology infrastructure and international bank expansion. *The Quarterly Review of Economics and Finance, 38*(3), 675-692.

Rose, S. (1998). Valuation of interacting real options in a Tollroad infrastructure project. *Quarterly Review of Economics and Finance, 38*(3), 711-723.

Schwartz, E. S., & Zozaya-Gorostiza, C. (2000). Valuation of information technology investments as real options. Working Paper: Anderson Graduate School of Management, University of California, Los Angeles, CA.

Smit, H. T., & Trigeorgis, L. (2009). Valuing infrastructure investment: An option games approach. *California Management Review, 5*(2), 79-100.

Titman, S. (1985). Urban land prices under uncertainty. *American Economic Review, 75*(3), 505-514.

Tong, T. W., Reuer, J. J., & Peng, M. W. (2008). International joint ventures and the value of growth options. *Academy of Management Journal, 51*(5), 1014-1029.

Triantis, A. (2005). Realizing the potential of real options: Does theory meet practice? *Journal of Applied Corporate Finance, 17*(2), 8-16.

Trigeorgis, L. (1993a). Real options and interactions with financial flexibility. *Financial Management, 22*(3), 202-224.

Trigeorgis, L. (1993b). The nature of option interactions and the valuation of investments with multiple real options. *Journal of Financial and Quantitative Analysis, 28*(1), 1-20.

Wibowo, A. (2006). CAPM-based valuation of financial government supports to infeasible and risky private infrastructure projects. *Journal of Construction Engineering and Management, 132*(3).

Ye, S., & Tiong, R. K. (2007). Government support and risk-return trade-off in China's BOT power projects. *Engineering, Construction and Architectural Management, 7*(4), 412-422.