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New fuzzy insurance pricing method for giga-investment project insurance

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ABSTRACT

Large industrial investments, also called giga-investments, are a risky business and to attract financing they often require project insurance to mitigate risks. Giga-investments have long economic lives and can often steer their markets: information available is non-stochastic, normative, and often imprecise. The type of uncertainty that faces giga-investments is parametric and structural. We use possibility theory as a mathematical framework for modeling giga-investment profitability and based on the profitability models derive a new and intuitive four-step procedure for pricing giga-investment project insurance that is based on creating a pay-out distribution for the giga-investment project insurance contract. We present a set of numerical illustrations of insurance pricing with the new method.

1. Introduction

Large industrial real investments, also called giga-investments, often have long construction times, long economic lives, and a high degree of irreversibility (Collan, 2004, 2011b). These investments often lock the capital invested to a location, to the chosen technology, to the chosen quality level, and also lock the capacity of the investment. The investment size of giga-investments is in the "100+ million € class" and examples of giga-investments include, e.g., power plants, mines, oilfields, steel mills, and paper and pulp mills.

The long construction time and the long economic life of giga-investments make the accurate estimation of the project cost- and revenue cash-flows difficult. Uncertainty and estimation inaccuracy come from a number of separate sources and combinations of sources, see e.g. Miller (1992) and Verbeeten (2001). Furthermore, "as the time span increases, it is more likely that large changes will occur in the environment" (Armstrong and Crohman, 1972), and the likelihood of large unexpected changes, "black swans" (Taleb, 2007), work to increase the difficulty of ex-ante analysis of giga-investments. The type of uncertainty that managers analyzing giga-investments have to deal with is parametric, or even structural, see e.g., Arrow (1974), Knight (1921), Kyläheiko (1995, 1998) and Langlois (1984).

Sometimes giga-investments have the ability to steer their markets, this ability opens the door for actively increasing the value of these investments, and makes non-stochastic information available for decision-making, see, e.g., Harris (1978) and Keppo and Lu (2003). This kind of managerial flexibility is often referred to as real options (Amram and Kulatilaka, 1999) and the value and valuation of real options becomes relevant in the giga-investment context (Collan, 2011b). In the presence of parametric and structural uncertainty all (real option) valuation methods may not be suitable, because the available information is non-stochastic and often includes normative judgment of managers, or groups of managers. Fortunately, valuation methods that fit these types of uncertainty and imprecise normative information exist, e.g., see Collan (2012), Collan et al. (2009), Collan and Haahtela (2013), Collan et al. (forthcoming), Mathews et al. (2007) and Mathews and Salmon (2007) for examples of suitable (real option) valuation methods.

Here we posit that possibility theory and fuzzy numbers offer a good fit in terms of mathematical background for modeling giga-investments, as they are compatible with the use of normative imprecise information (Kuchta, 2000) and are usable under parametric and even structural uncertainty. In this paper we use the principles laid out by the pay-off method (Collan et al., 2009) in modeling the profitability of giga-investments that acts as the starting point for further analyses.

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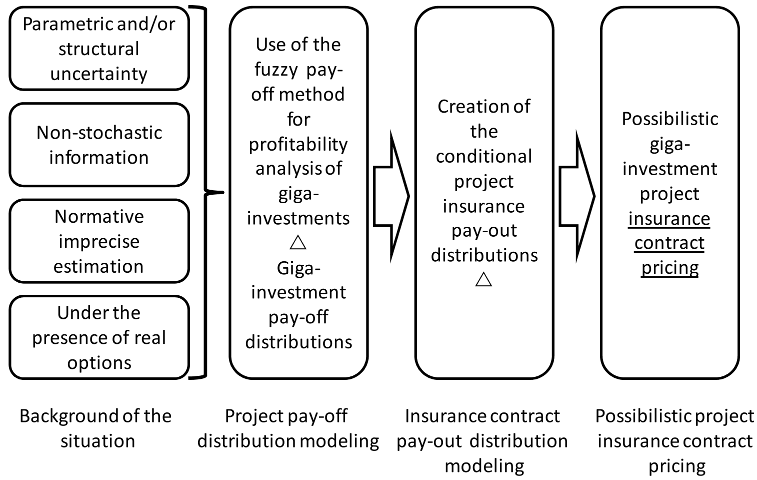

Fig. 1. The logic of the new method for possibilistic project insurance pricing.

Giga-investments are often made with the support of external financing and often as separate project companies (Finnerty, 1996), and financiers are understandably keen to ensure that any risks facing the project do not affect them negatively. It is a well-known fact that large industrial investments face a number of risks (Nielsen, 2006) and are known to cause cost-overruns (Flyvbjerg et al., 2003). Consequently, investors will frequently insist, as a condition to financing that the project transfers risk to the insurance markets in the form of project insurance (Liu et al., 2007; Orman, 2002). Financiers and their advisors may also take an interest in supplementary insurance coverage, whether compulsory or not, as a matter of wider professional due diligence.

Project insurance is a topic that seems not to have received very much attention, a search with the term "project insurance" on the EBSCO database returned 190 hits and a search on the ScienceDirect database returned 51 hits. Of these a total of about ten, academic and magazine articles, were relevant to this discussion, with articles discussing construction project insurance (Gaafar and Perry, 1999; Ndekugri et al., 2013; Perry, 2013), insurance of projects into risky markets (country risk insurance) (James, 2012; Wilson and Begley, 1997), large industrial investments (Nielsen, 2006), public investments (Mendelsohn and Strang, 1984), and space and satellite projects insurance (Schöffski and Wegener, 1999). Of the above articles only (Mendelsohn and Strang, 1984) specifically discuss the pricing of project insurance.

As the available information in the planning and analysis stage of giga-investments is most often imprecise and we have selected to use possibility theory and fuzzy numbers to mathematically model and treat the profitability of giga-investment projects, it follows naturally that our approach to model giga-investment project insurance is also based on possibility theory. Application of possibility theory and fuzzy logic to risk and insurance modeling has been previously discussed, e.g., in Anzilli (2012), De Wit (1982), Georgescu (2009, 2011, 2012) and Shapiro (2004, 2013).

In this vein, the focus area and the new scientific contribution of this paper are to present the new idea of giga-investment project insurance pricing that is based on project insurance pay-out distributions derived from project pay-off distributions, and to present a new method for possibilistic project insurance pricing. Furthermore, the new project insurance pricing method is illustrated numerically with a set of examples. Fig. 1 presents the logic of the new method presented in the paper.

This paper continues by presenting how (real) option valuation logic can be used for insurance pricing, then the possibilistic mathematical background of the paper is shortly presented, followed by the introduction of the new possibilistic project insurance pricing approach, and a set of numerical illustrations of insurance pricing with the method. The paper closes with a discussion and some conclusions.

2. Using (real) option valuation logic for insurance pricing

The logic of (real) option valuation put simply, is to calculate the expected value (in a probabilistic setting), or a central measure such as the possibilistic mean or the center of gravity (in a possibilistic setting) of a future pay-off distribution for a real option, and discounting it to a present value. The future pay-off distribution for a real option is obtained from a distribution of possible future outcomes of an investment by mapping the negative values to the value zero, while "keeping their weight", for details see Collan (2011a). The logic remains the same, irrespective of the way in which the investment future value distribution is created that is, all the best known methods used in real option valuation, such as the classical financial option pricing models, Black–Scholes option pricing method (Black and Scholes, 1973) and the binomial option valuation method (Cox et al., 1979) adhere to this logic. A net present value (NPV) version of the pay-off distribution can also be used for the valuation purpose and a single real option value can be calculated by using the NPV version of a pay-off distribution (Mathews et al., 2007) that is, unlike in the classical option valuation models the "extraction" of the single option value is not made from the net future value distribution of the real option, but from an NPV pay-off distribution. A difference in the order in which the "algorithm" used is executed.

What the valuation logic means is that calculation of the real option value (ROV) can be simplified into the following form (Collan et al., 2009):

$$ROV = \frac{\int_0^\infty A(x)\,dx}{\int_{-\infty}^\infty A(x)\,dx} \times E(A_+)$$

where the likelihood (in the probabilistic case), or the possibility in terms of the area under the possibility distribution, of the investment outcome being on the positive side of the NPV distribution is multiplied by the expected value, or the central measure, of the positive side of the estimated investment NPV distribution. In the above "pay-off method for real option valuation" formula (Collan et al., 2009) the term $E(A_+)$ denotes the possibilistic mean (Fuller and Majlender, 2003) of the positive area of the pay-off distribution.

In this research we have chosen to use the pay-off distribution in terms of NPV and the center of gravity (COG) is selected to be used as the central measure in extracting a single value in the