Project Evaluation with Large Uncertainties and Disasters

Natasa Bilkic and Thomas Gries*)

Abstract

During the last 30 years the number of disaster has significantly increased. Hence, disaster risk is a growing threat for development and infrastructure projects. Disasters are large events with a high uncertainty concerning the frequency of occurrence and size of effect. Since such events can have a major impact on effected people or the success of a infrastructure or development project these events need to be studied more intensively. Cost Benefit Analysis (CBA) has been developed as an instrument for project evaluation of public projects. While cost benefit analysis under certainty is well established, the evaluation of disasters or large uncertain events on long term projects has not jet been developed. Therefore, this paper provides a theoretical concept to evaluate disastrous uncertainties in project planning. With a stochastic Ito-Levi Jump process we model large uncertainties, both in terms of the occurrence of events and the size of impact, and include these events in the framework of costs benefit project evaluation. As a result we can determine how the frequency or the size of disasters affects the value of a project.

JEL classifications: D61, D72, D81, C60
Keywords: non-systematic risk of investment, cost-benefit analysis disaster

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During the last 30 years the number of disaster has significantly increased. Hence, disaster risk is a growing threat for development and infrastructure projects. Disasters are large events with a high uncertainty concerning the frequency of occurrence and size of effect. Since such events can have a major impact on effected people or the success of a infrastructure or development project these events need to be studied more intensively. Cost Benefit Analysis (CBA) has been developed as an instrument for project evaluation of public projects. While cost benefit analysis under certainty is well established, the evaluation of disasters or large uncertain events on long term projects has not jet been developed. Therefore, this paper provides a theoretical concept to evaluate disastrous uncertainties in project planning. With a stochastic Ito-Levi Jump process we model large uncertainties, both in terms of the occurrence of events and the size of impact, and include these events in the framework of costs benefit project evaluation. As a result we can determine how the frequency or the size of disasters affects the value of a project.

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1 Introduction

The observed increase in disasters and disaster risk is becoming a focus of professional interest in economic modelling. The socially and economically large impacts associated with disasters have caused significant attention of decision-makers faced with risky investment projects. Despite the recent sudden discussion on the role of disasters, little progress has been made once the stochastic nature of disasters is accounted for in infrastructure and development projects.

Cost Benefit Analysis (CBA) was developed as a standard tool for project evaluation of public projects. In particular infrastructure and development projects were evaluated by applying the tool box of CBA methodology. While CBA under certainty is well developed, we find only few articles discussing the effects of uncertainty[1] or even more of uncertain disasters on the value of long term projects.

For practical purposes the problem of accounting for disaster risks is well identified. According to the Natural Resource Council (1985) extreme events are more frequent than expected by a normal distribution. Morimoto and Hope (2004) attempt to incorporate this when proposing a valuation method based on a CBA framework of the world's largest hydro project: the Three Gorges Project (TGP) in China. For evaluating disaster risk, their approach would require obtaining probability distributions on disaster events to generate probabilistic distributions of the project outcomes. Instead Morimoto and Hope (2004) rely on Monte Carlo simulations for computing the probability distributions.

There are also major concerns that CBA is not able to adequately evaluate large uncertain events and disaster risk. In the context of climate change Jäger et al. (1998) believe CBA to be inferior to other risk management strategies due to the difficulties linked with the quantification of external costs of climate change. For a special class of disaster risk, coined mega-catastrophes, Van der Bergh (2004) question the appropriateness of cost-benefit analysis. Lave and Apt (2006) defend the implementation of CBA by including disaster risk in a CBA framework to examine the risks and management of natural disasters. Despite their specific question of flooding risk, their study can be seen as a benchmark for the inclusion of disaster risk into CBA-based frameworks and leaves further suggestions up for discussion. In the qualitative assessment of

[1] See cf Graham (1981) for including risk in CBA. The conceptual distinction between "risk" and "uncertainty" dates back to the early contribution of Knight (1921) and Keynes (1921). Vercelli (1991) defines "risk" as a weak-form of uncertainty where probabilistic distribution of the possible states-of-nature exists as opposed to "uncertainty" where a lack of reliable classification of criteria prevents the assignment of probabilities to the different states.

disaster risk mitigation of Kousky et al. (2010), the implementation of CBA for catastrophe risk is likewise supported. Despite acknowledging the challenges with using traditional CBA based frameworks for mega-catastrophes they argue other rational choice methods to be inferior to CBA. Since the qualitative assessment in Kousky et al. (2010) provides no formal model it promotes further investigation into the modelling of disaster risk with CBA.

Apart from CBA few other approaches try to include disasters into their framework. Haurie and Moresino (2006) approach the task of modelling the occurrence of an environmental catastrophe by framing the problem of resource allocation under uncertainty in a macroeconomic model. Whereby it should be noted that the incorporation of expected costs of their model into a global welfare optimization scheme follows the general philosophy of CBA.[2]

The diffusion of disaster risk evaluation has largely taken place in another strand of literature which approaches the task of modelling disaster effects with the evaluation of catastrophe-linked financial instruments for insurance issuance purposes. The motivation for this strand of literature hinges upon the large fluctuations in the price and availability of reinsurance and catastrophe-linked hedging instruments that arise from catastrophic events. Hence there is the grown interest in disaster risk modeling in the insurance field with contributions such as Kunreuther, H. (1996) and Kleindorfer and Kunreuther (1999). Crucial for the evaluation of financial instruments is to model the dynamics of yields. Cox, Fairchild and Pederson (2004) follow the classical approach[3] to derive a pricing formula for a catastrophe equity put options (CatEPuts[4]) by assuming that share prices follow a geometric Brownian motion. To model discontinuities in the share price upon which the put option is written on, Cox, Fairchild and Peterson (2004) include downward jumps modelled by a multiple Poisson processes in the event of a catastrophe, though the uncertain size of the catastrophe on the effect of the instrument price is not modelled. Jaimungal and Wang (2006) extend their model and

[2] The aim of the paper is to determine the optimal capital accumulation path in the event of an uncontrolled environmental catastrophe the occurrence of which is described by a Poisson process with a given intensity. Besides the limitations of a Poisson process to model the size of the catastrophe, no unique solution is provided to the theoretical model. Instead numerical experiments are used to explore the model responses. The above cited literature highlights the limited applicability of investment decision-rules based on classical cost-benefit analysis for the modelling of investment projects under risk and especially under disaster risk.

[3] This approach was most prominently started by Black and Scholes (1973) .

[4] CatEputs give the owner the right to sell a specified amount of risk of its stock at the strike price if CAT losses surpass a specified trigger.

use a compound Poisson process which models random jumps in both directions of a random size, as a generator of losses to analyze the pricing and hedging of CatEPuts under stochastic interest rates. Their use of a jump-diffusion process similar to the compound Poisson process models the underlying asset prices, however the effects of the stochastic interest rates and variances on the price of the CatEPut are conducted numerically. Chang, Lin and Yu (2006) empirically show smaller pricing errors for a specific class of CatEPuts whose catastrophe process are assumed to follow a Markov Modulated Poisson process (MMPP)[5] with changing intensities as opposed to a compound Poisson process. The advantage of a MMPP over classical Poisson processes is claimed to be the departure from a constant (average) intensity rate of the process. The above cited literature shows the diffusion of a variety of Jump processes for the modelling of catastrophe dynamics. Bertoin (1998); Sato (1999); Duffie et al. (2000); Barndorff-Nielsen et al. (2001); Carr et al. (2003); Cont and Tankov (2004) and Kou and Wang (2004) are among other papers that contribute to this list with the use of Lévy processes and jump diffusion processes to model market fluctuations in finance. The applicability of Lévy processes in other fields such as insurance with both constant and stochastic interest rates can be found in Jang, J., (2007) and Yang, H. and Zhang, L. (2005).

However, although there is a vast discussion of disasters and their effects there is still no formal evaluation method that allows for a cost benefit examination of investment projects including the risk of disasters and their effect. Therefore, this paper provides a theoretical concept to evaluate disastrous uncertainties in project planning. In the first part we discuss the importance of disasters and justify that they should be taken into account. In the second part we propose several stochastic processes that may help to model disasters with special characteristics. After a discussion of the advantages and drawbacks of each process we extend the modelling that finally ends up in an Ito-Lévy jump diffusion which allows for the most general analysis of non-systematic risk. In the third part we show how to include Ito-Lévy jump diffusion into the CBA or more precisely the net present value method. Finally we analyze the effects of disasters on investments in public projects.

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[5] The MMPP stands for a doubly stochastic Poisson process where the underlying state is governed by a homogeneous Markov chain (see Last and Brandt, 1995). For the application of MMPPs in different fields see Stern and Coe (1984), Ramesch (1998), Davidson and Ramesch (1996), Oliver and Walrand (1994)

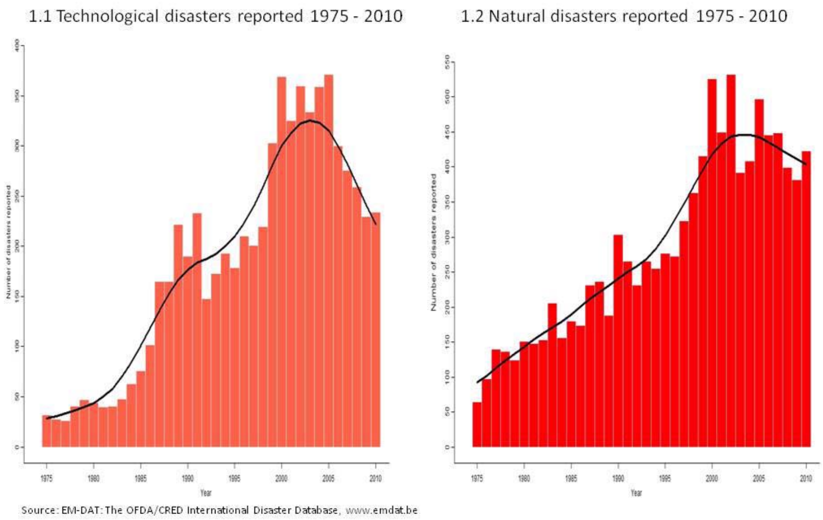

Figure 1: Technological and natural disasters reported 1975 - 2010

2 Exposure to Disasters and Disaster Risk

When evaluating development projects and infrastructure projects, why are we interested in evaluating disasters? Figure 1 suggests that at a global scale the number of natural disasters and technical disasters has increased since the 1970s. After a period of about 30 years it can be seen that the number of technical disasters is nearly five times higher and for natural disasters even 9 times higher.

However, for the current discussion more important seems the fact that not just the number of disasters increased but also the number of effected people. A reported in 2 this relationship can especially be seen for natural disasters. However, the decreasing number of affected people due to technological disasters cannot be found. Increasing security norms and technical improvement lead to a decrease instead.

Another way of looking at the effects of such disasters is the caused damage. Figure 3 present data. The trend line in these figures indicate that we have to observe an increase in these damages. Although the evolution of caused damage due to natural disasters is obvious the increasing structure for technological disasters is surprising when remembering their decreasing number. However, we can see that less technological cause more damage so that their role should not be undervalued.

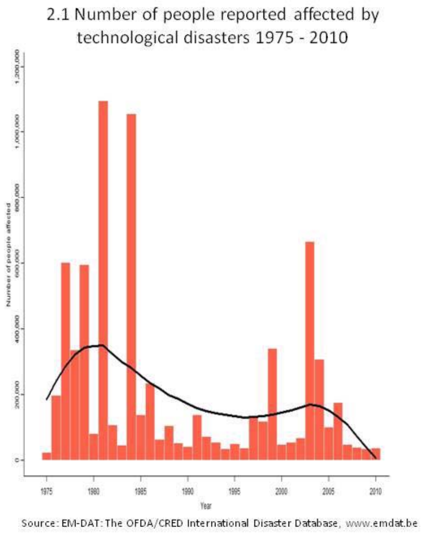

Figure 2: Number of people reported affected by technological and natural disasters 1975 - 2010

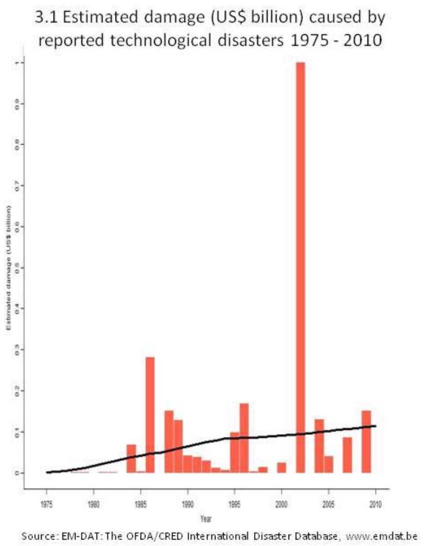

Figure 3: Estimated damage (US$ billion) caused by reported technological and natural disasters 1975 - 2010

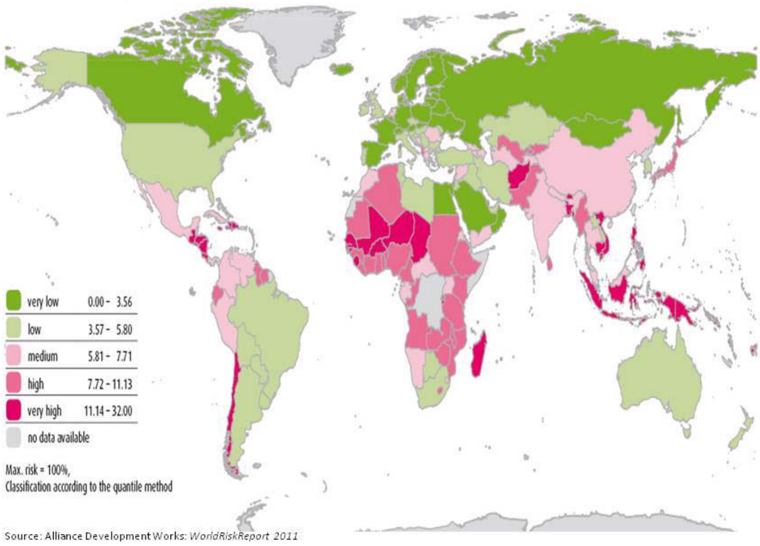

Figure 4: WorldRiskIndex as the result of exposure and vulnerability

A first attempt to measure and indicate the overall disaster risk has been made by the UNU EHS World Risk Report 2011. Even if the concept suggested in this report is not perfect, the report gives a start for thinking about the exposure and effects of large disasters on human conditions. The over picture of "being effected by disastrous risk" is given in figure 4.

3 Project Evaluation using Stochastic Processes

Natural and technological disasters and other major uncertain events are an increasingly important component of economic activities in particular in the context of development and infrastructure projects. These non-systematic risks are so important so that an adequate instrument for evaluation is needed. In investment theory systematic risk, in the course of time, is introduced by dynamic stochastic processes, most often by Brownian motions. However, in the current context, non-systematic risk and uncertain large events like disasters need to be accounted for. Therefore, we extend this existing literature by introducing Ito-Lévy Jump diffusion processes to set a framework for evaluating the effects of such uncertain disasters and their potential damage in the context of development and infrastructure project evaluation. To do this we first discuss a stochastic process like a Brownian motion as benchmark and show that this benchmark is close to the existing well studied approaches. Second, we introduce Ito-Lévy Jump diffusion processes to suggest a consistent theoretical framework to take care of uncertain large events which seem to become increasingly important in particular in developing countries.

3.1 Geometric Brownian Motion

The geometric Brownian motion is one of the most famous stochastic processes for modeling prices or values of derivatives. In CBA the evolution of benefits Y of a project can be characterized by the following stochastic differential equation

$$dY = \alpha Y dt + \sigma Y dW \text{ with } Y(0) = Y_0$$

where α and σ are non-negative constants and dW describes the increment of the standard Wiener Process. The differential equation defines a stochastic process with continuous trajectories. According to definition of the geometric Brownian motion it is possible to describe movements of values, e.g. prices, that have a trend but also a stochastic and small fluctuation.

An example of such a path is plotted in figure (5)

Figure 5: Path of the geometric Brownian motion

For a positive α the curve is increasing in average and its expectation value is an increasing function

$$EY(t) = EY(0)e^{\alpha t},$$

plotted as the black curve in figure (5). Furthermore, the higher the constant σ, also referred as the volatility of a stochastic process, the more the process fluctuates around its expected value $EY(t)$. With $\sigma = 0$ the stochastic differential equation simplifies to an ordinary differential equation

$$dY = \alpha Y dt \text{ with } Y(0) = Y_0$$

with the following solution

$$Y(t) = Y(0)e^{\alpha t}.$$

The geometric Brownian motion became very famous in the option valuation approach by Black and Scholes (1973). In their model they assume stochastic prices for underlying financial assets, which follow for the geometric Brownian motion. Hence, this form is leading to a log-normal distribution of the rates of the return. As a key result of their paper, they are able to derive the optimal price of the corresponding call and put options.

Although their approach was a benchmark in the valuation framework it has some disadvantages. Merton (1975) criticizes their model due to the continuity of the price movement. According to his argumentation stock prices can never be represented by continuous stochastic processes because incoming important news can lead to an immediate non-marginal upward or downward movement of the prices. In addition, he emphasized that trade in continuous time is not possible. However, in the traditional Mean-Variance-Approach risk was identified by a measure for the square deviation from the mean, hence the variance. For this reason, the direction of the deviation was not valued. Stochastic processes usually allow risk to be measured by volatility and the higher it is the more the process fluctuates around its mean. For the geometric Brownian motion this fluctuation takes place continuously so that only marginal differences from one point of time to another are included. Furthermore, as the coefficient sigma is known, this stochastic process is only able to encompass a systematic risk.

The expected present value (PV) of such a pass of benefits for a risk neutral evaluator is

$$PV = E\left(\int_T^\infty Y e^{-r(t-T)} dt\right) = \frac{Y}{r-\alpha}; \quad r > \alpha,$$

with r being the risk free interest rate.

We clearly see that CBA with the Brownian motion is just able to model marginal and hence the so-called systematic risk. This process does not describe sudden major events like a major disaster. Hence, to model large extraordinary impacts of a disaster on the value of a project other processes need to be used in a dynamic CBA framework.

3.2 Jump Processes

To model disasters, incorporating jump processes to a Brownian motion for modeling discontinuities in the process is necessary. In this subsection we introduce two types of jump processes and go on to define the discontinuous counterpart of the geometric Brownian motion. As we will see, both jump process differ in the step height and in the shape of the continuous path. As a result both will deliver important properties for the modeling of jump diffusions in our CBA framework.

3.2.1 Compensated Poisson Process

The compensated Poisson process is provided by the following definition.

Let $N(t)$ be a Poisson process. The stochastic process

$$\tilde{N}(t) = N(t) - \lambda t = N(t, U) - v(U)t \tag{1}$$

is called a compensated Poisson process with the Lévy measure $\lambda = v(U)$. U is a family of Borel sets in $\mathbb{R}$ and its closure U does not contain 0. As we can see in figure (6) the process jumps upwards by one and declines like a linear function up to the next jump. The compensated

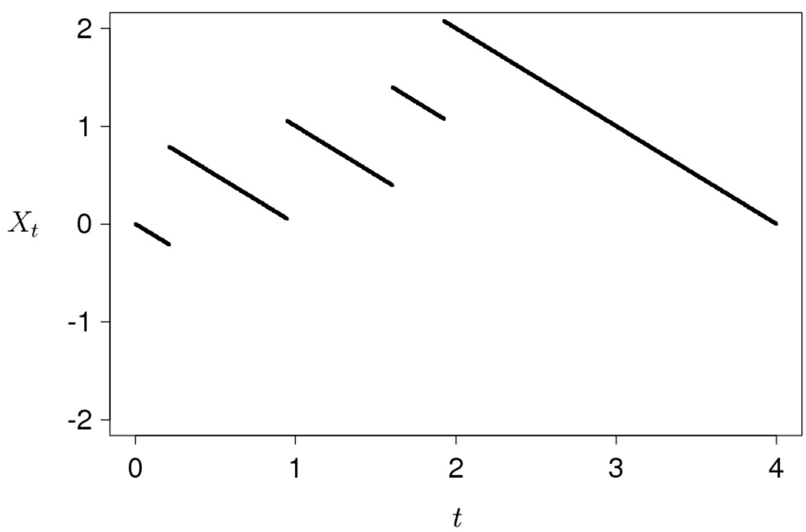

Figure 6: Path of the compensated Poisson process

Poisson process is also referred as the martingale and the centered version of the Poisson process because it counts the number of jumps with the heights from U up to t and reduces it by t times the mean number of jumps. Therefore the compensated Poisson process does not take any integer values and its expectation value is 0. Also note that the compensated Poisson process is not a counting process anymore.

However, using the compensated Poisson process means that only jumps with a magnitude of 1 can be accounted for. Concerning the evaluation of investment projects the use of this process is therefore quite limited. We go a step further and introduce a more general process.

3.2.2 Compound Poisson Process

The second jump process considered is the compound Poisson process with uncertain step heights. Let F_i be a set of iid random variables with distribution f and $N(t)$ a regular Poisson process with intensity λ, which is independent of the random variables Y_i. The stochastic process

$$X(t) = \sum_{i=1}^{N(t)} F_i = \int_U zN(t, dz)$$

is called a compound Poisson process with intensity λ.

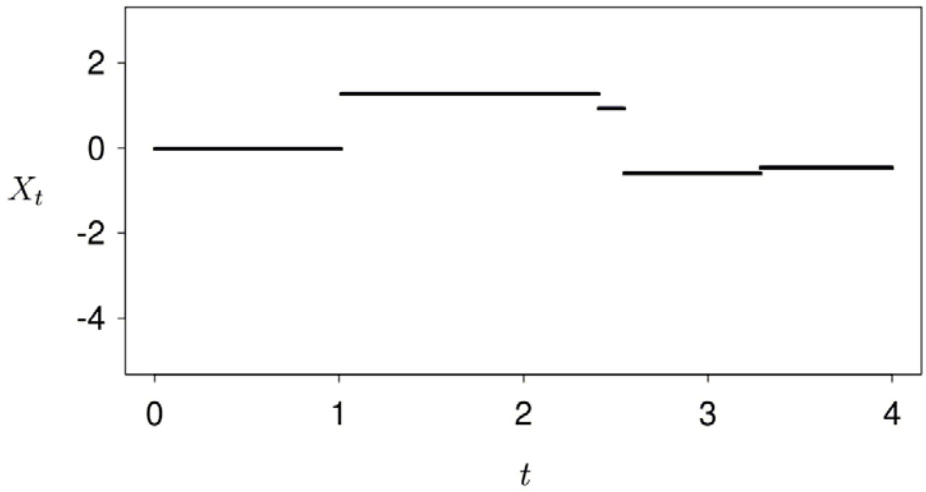

Figure 7: Path of a compound Poisson process

Figure (7) presents an example of a path of a compound Poisson process in which the varied step heights become apparent. Hence, at random times the process jumps by a random amount. These random times are the same as for the underlying Poisson process $N(t)$, which can also be obtained as a special case with $Y_i \equiv 1$ for all $i = 1...N(t)$. In contrast to the Poisson process, the inclusion of the compensated Poisson process in our methodology covers both positive and negative jumps so that both directions are included. Hence, with this type of process we are able to evaluate major events or especially disasters that occur at an uncertain point in time and has a random effect.

3.2.3 Ito-Lévy Jump Diffusions

Following the approach of Jang, J., (2007) and Yang, H. and Zhang, L. (2005), we combine both jump processes with the geometric Brownian motion to model discontinuities of the value of the project and also to account for the size and direction of these.

The combination of jump processes with Lévy processes has been extendedly diffused in the field of finance among others by Bertoin (1998), Sato (1999), Duffie et al. (2000), Barndorff-Nielsen et al. (2001), Carr et al. (2003), Cont and Tankov (2004), and Kou and Wang (2004) for modeling discontinuities in the price process of financial derivatives. The resulting so-called geometric Ito-Lévy jump diffusion process is defined by the following stochastic differential equation

$$dY = Y\alpha dt + Y\sigma dW + Y\int_U z\tilde{N}(t, dz), \quad Y(0) = y_0 \tag{2}$$

with α, $\sigma > 0$ and constant. Again dW denotes the increment of the Wiener process and the condition $Yz > -1$ is also important to guarantee only positive values of the process. Furthermore, $\tilde{N}$ stands for the compensated Poisson process with intensity $\upsilon(dz)dt$. The stochastic differential equation describes a process which predominantly evolves like a geometric Brownian motion and at random points in time it jumps upwards or downwards. Figure (8) shows an example of a path of a geometric Ito-Lévy jump diffusion process.

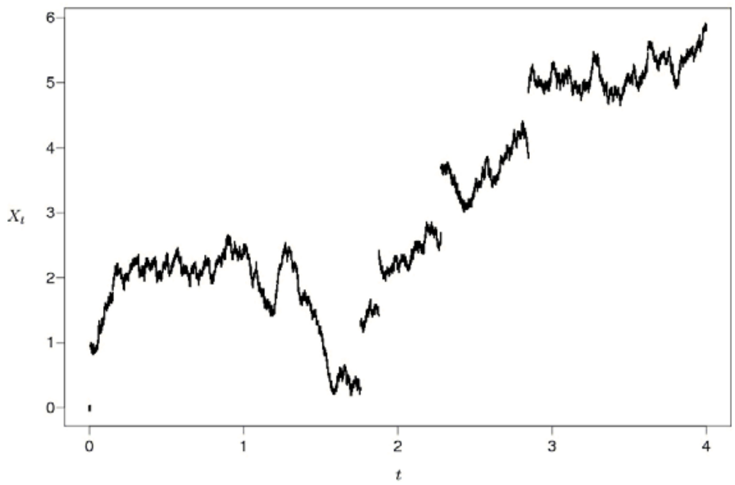

Figure 8: Path of a geometric Ito-Lévy process

The last term $\int_U z\tilde{N}(t, dz)$ accumulates all jumps that are caused by exogenous shocks. They are a positive or a negative reaction of a price due to offered opportunities or risk. The direction and amount of one jump is represented by the step height $\triangle Y(t) = Y(t) - Y(t^-) \in U$ with U defined as for (1). Without the last term the geometric Brownian motion will be obtained again.

As we have seen, the geometric Brownian motion is only able to model a systematic risk due to an exogenous volatility σ. With a combination of this continuous part with a jump process we are able to describe a totally random situation. Since the time at which the process jumps and its magnitude are random, the geometric Ito-Lévy process therefore also covers the non-systematic risk with non-marginal changes.

Furthermore, there exists another important difference between the geometric Brownian motion and the Ito-Lévy jump diffusion process. For a positive α the expectation value of the geometric Brownian motion is an increasing exponential function

$$EY(t) = EY(0)e^{\alpha t}.$$

Although the stochastic differential equation for Y contains a volatility, it has no influence on the expectation value. Accordingly, the risk determining component is not involved in the expectation value and only deterministic components play a role.

In contrast, the Ito-Lévy jump diffusion process has two risk determinants, σ for the systematic risk and $\int_U z\tilde{N}(t, dz)$ for the non-systematic risk and the "non-continuous uncertainty". With the condition $\int_U e^{uz} \upsilon(dz) < \infty$, which guarantees finite exponential moments, the moments of the stochastic process in (2) are also finite and the corresponding expectation value is determined by

$$EY(t) = EY(0) \exp \left[t \left(\alpha + \int_{f^{-1}(U)} z\upsilon(dz) + \int_U z\upsilon(dz) \right) \right]$$

and is not automatically an increasing function for a positive α. The shape of the expectation function also depends on $\int_{f^{-1}(U)} z\upsilon(dz) + \int_U z\upsilon(dz)$ and therefore on the intensity and height of the jumps. Is for example $\alpha + \int_{f^{-1}(U)} z\upsilon(dz) + \int_U z\upsilon(dz) < 0$, so that predominantly negative jumps occur, then the expectation value is a decreasing function. This fact means that the investor is faced with more negative shocks than positive opportunities. Otherwise the expectation value increases again.

The expectation of jump diffusions allows for the valuation of both uncertainty and their direction. In our chosen CBA framework the decision-maker is faced with uncertainty, which is represented by the volatility and negative jumps, but there also exist opportunities which can lead to an increased expectation value and therefore to a compensation of risk.

3.3 Discontinuous Net Present Value Method

The purpose of this paper is to determine decision rules for the evaluation of an investment project taking into account the occurrence and the magnitude of a disaster. The framework of our analysis is based on a CBA, for which the net present value approach is one of the most famous and applied decision rules. The net present value approach underlies mutually exclusive investment opportunities and the one which is leading to the largest net present value is seen as the best choice.

If the returns of an investment opportunity are defined as continuous payments z_t, the net present value (NPV) is determined by

$$NPV = -I_0 + \int_T^\infty z_t e^{-rt} dt$$

where I_0 denotes the costs of investment and r is the risk-free interest rate. All payments are discounted to $t = 0$ and accumulated over time.

The net present value method becomes more interesting when the payments and therefore the returns of investment are uncertain, as in investment projects with disaster risk. In this case, for every t the payments z_t are random variables (denoted as Z_t), which can be best described by stochastic processes. Due to the randomness of z_t a function of a random variable is also a random variable, so that the net present value is uncertain. However, in order to make a valuation possible, we can consider the expected net present value

$$ENPV = -I_0 + E\int_T^\infty Z_t e^{-rt} dt$$

and then the investment opportunity with the highest expected net present value is seen as optimal.

If the returns are determined by a stochastic differential equation of the form

$$dZ = Z\alpha dt + Z\sigma dW + Z\int_U z\tilde{N}(t, dz), \; Z(0) = z_0,$$

which is the previously described Ito-Lévy jump diffusion, the expected net present value is given by

$$
\begin{aligned}
ENPV &= -I_0 + E\int_T^{\infty} e^{-r(t-T)} Z(t)dt \\
&= -I_0 + \frac{Z(T)}{\left(r - \int\limits_{f^{-1}(U)} zv(dz) - \int\limits_U zv(dz) - \alpha\right)} \\
&= -I_0 + \frac{Z(T)}{\left(r - \lambda \int\limits_{f^{-1}(U)} zh(dz) - \lambda\int\limits_U zh(dz) - \alpha\right)}
\end{aligned}
$$

for $r > \int\limits_{f^{-1}(U)} zv(dz) + \int\limits_U zv(dz) + \alpha$. Note that h denotes the distribution of step heights of the jump process. As we can see, through the expectation value of Z the expected net present value is affected by the intensity and the height of the jumps.

3.4 Effects of Disasters on the Net Present Value

As suggested, the number of natural and technological disasters has increased during the last 30 years. Even more important, however, is their increasing effect on both the number of people affected and the caused damage. In this section we analyze whether they also have an effect on investments in public projects.

By using the CBA approach which allows for a discontinuous project value described by Ito-Lévy jump diffusions we are able to determine the effect of an increasing number of disasters on the net present value. Hence, the derivative of the expected net present value according to the jump intensity λ is:

$$
\begin{aligned}
\frac{\partial ENPV}{\partial \lambda} &= \left(-I_0 + \frac{Z(T)}{\left(r - \lambda \int\limits_{f^{-1}(U)} zh(dz) - \lambda\int\limits_U zh(dz) - \alpha\right)} \right)' \\
&= -\frac{\left(\int\limits_{f^{-1}(U)} zh(dz) + \int\limits_U zh(dz)\right) Z(T)}{\left(r - \lambda \int\limits_{f^{-1}(U)} zh(dz) - \lambda\int\limits_U zh(dz) - \alpha\right)^2} \lesseqgtr 0.
\end{aligned}
$$

In general, the effect of an increased frequency of jumps is ambiguous or depends on the average directions of jumps. Hence, an increasing number of disasters leads to a negative numerator making the derivative of the expected net present value positive. This means, more disasters increase the expected value so that the investment in public projects becomes more profitable. In other word, the damage caused by natural, technological or other disasters is so devastating that a project should be carried out earlier.

In a next step we also examine the effect of an increasing damage of disasters. Hence, the derivative of the expected net present value according to the jump size Z is:

$$\frac{\partial ENPV}{\partial z} = \left(-I_0 + \frac{Z(T)}{\left(r - \int\limits_{f^{-1}(U)} zv(dz) - \int\limits_{U} zv(dz) - \alpha \right)} \right)'$$

$$= -\frac{\left(\int\limits_{f^{-1}(U)} 1v(dz) + \int\limits_{U} 1v(dz) \right) Z(T)}{\left(r - \lambda \int\limits_{f^{-1}(U)} zh(dz) - \lambda \int\limits_{U} zh(dz) - \alpha \right)^2} \lesseqgtr 0.$$

The derivative of the expected net present value according to magnitude of jumps is generally ambigious. However, increasing z means that disasters are less severe leading to a decreased damage. Less devastating disasters therefore lead to a decreased project value.

3.5 Conclusion

This paper addresses the impact of disasters on the value of development or infrastructure projects. Since the number of disaster has significantly increased during the last decades disaster risk is a growing threat for long term investment projects. Disasters are large events with high uncertainty with respect to the frequency and size of effect. Cost Benefit Analysis (CBA) has been developed as an instrument for project evaluation of public projects. However, there is no framework for the evaluation of disaster risk within the cost benefit framework. Therefore, this paper provides a theoretical concept to evaluate disastrous uncertainties in project planning. Using a stochastic Ito-Levi Jump process we model large uncertainties, both with respect to the occurrence and size of impact. These large uncertain events are implemented into the framework of costs benefit project evaluation. As a result we can determine how the frequency and the size of disasters events affects the value of a project.

References

[1] Barndorff-Nielsen, O.E.; Mikosch, T.; Resnick, S.I. (2001): Lévy Processes: Theory and Applications. Birkhäuser, Boston. MA.

[2] Bertoin, J., (1998): Levy Processes. Cambridge University Press, UK.

[3] Carlson, D.; Haurie, A.; Leizarowitz, A. (1994): Infinite Horizon Optimal Control: Deterministic and Stochastic Systems. Berlin: Springer.

[4] Carr, P.; Geman, H.; Madam, D.B.; Yor, M., (2003): Stochastic Volatility for Lévy processes. Mathematical Finance 13, pp. 345-382.

[5] Chang, C.; Chang, J; Yu, M.-T. (1996): Pricing Catastrophe Insurance Future Call Spreads: A Randomized Operational Time Approach. Journal of Risk and Insurance 63, pp. 599-617.

[6] Cont, R.; Tankov, P. (2004): Financial Modelling with Jump Processes. Champan & Hall, Boca Raton, FL.

[7] Cox, H.; Fairchild, J.; Pedersen, H. (2004): Valuation of Structured Risk Management Products. Insurance: Mathematics and Economics, 34, pp. 259-272.

[8] Davidson, A.C.; Ramesh, N.I. (1996): Some Models for Discretized Series to a A Markov-Modulated Poisson Process, Journal of Applied Probability, Vol.32 , pp. 1103-1111.

[9] Graham, D. (1981): Cost-Benefit Analysis under Uncertainty. The American Economic Review, pp. 715-725.

[10] Duffie, D., Pan, J., Singleton, K. (2000): Transform Analysis and Asset Pricing for Affine Jump-Diffusions. Econometrica 68, pp. 1343-1376.

[11] Haurie, A. (2005): A Multigenerational Game to Analyse Sustainable Development. Annals of Operations Research, 137, pp. 369-386.

[12] Haurie, A.; Moresino, F. (2006): A Stochastic Control Model of Economic Growth with Environmental Disaster Prevention. Automatica 42, pp.1417-1428

[13] Jaimungal, S.; Wang, T. (2006): Catastrophe Options With Stochastic Interest Rates and Coumpound Poisson Losses. Insurance: Mathematics and Economics 38, pp. 469-483.

[14] Jang, J. (2007): Jump Diffusion Processes and their Applications in Insurance and Fnance. Insurance: Mathematics and Economics 41, pp. 62-70.

[15] Jäger, C.; Renn, O.; Rosa, E.; and Webbter, T. (1998): Decision Analysis and Rational Action. In: Rayner S and Malone EL(eds): Human Choice and Climate Change, Vol. 3: The Tools for Policy Analysis. Battelle Press, Columbus, pp. 141-215.

[16] Keynes, J.M. (1921): A Treatise on Probability. Reprint as Vol.8 of the Collected Writing of J.M. Keynes, 1971. Macmillan, London.
[17] Kleindorfer, R.; and Kunreuter, H. (1999). The Complementary Roles of Mitigation and Insurance in Managing Catastrophic Risks. Risk Analysis 19, pp. 727-738.
[18] Knight, F.H. (1921): Risk, Uncertainty and Profit. Houghton and Mifflin, Boston. MA.
[19] Kou, S.G., Wang, H. (2004). Option Pricing under a Double Exponential Jump Diffusion Model. Management Science 50(9), pp. 1178-1192
[20] Kousky, C.; Rostapshova, O.; Toman, M.; and Zeckhauser, R. (2010). Responding to Climate Change Mega-Catastrophes. The World Bank Policy Research Working Paper 5127.
[21] Kunreuter, H. (1996). Mitigating Disaster Losses Through Insurance. Journal of Risk and Uncertainty 12, pp.171-187
[22] Last, G: Brandt (1995): Marked Point Processes on the Real Line: The Dynamic Approach. New York: Springer.
[23] Lave, L.B.; Apt, J. (2006): Planning for Natural Disasters in a Stochastic World. Journal of Risk and Uncertainty 33, pp. 117-130.
[24] Morimoto, R.; Hope, C. (2004): Applying a Cost-Benefit Analysis Model to the Three Georges Project in China. Impact Assessment and Project Appraisal, Vol. 22, pp. 205-220.
[25] Oliver, C.; Walrand, J. (1994): On the existence of Finite-Dimensional Filters for Markov-Modulated Traffic. Journal of Applied Probability, 31, pp. 515-525.
[26] Phelps, E.S.; Polak, R. (1968): On the Second-Best National Saving and Game-Equilibrium Growth. Review of Economic Studies Vol. 35 (2), pp. 185-199.
[27] Ramesch, N.I. (1998): Temporal Modelling of Short-Term Rainfall using Cox Processes. Environmetrics, Vol. 9, pp. 629-643.
[28] Sato, K. (1999). Lévy Processes and Infinitely Divisible Distributions. Cambridge University Press, UK.
[29] Stern R.D.; Coe, R. (1984): A Model Fitting Analysis of Daily Rainfall Data. Journal of the Royal Statistical Society A (147), pp. 1-34.
[30] Van der Bergh, J.C.J.M. (2004): Optimal Climate Policy Is a Utopia: From Quantitative to Qualitative Cost-Benefit Analysis. Ecological Economics 48, pp. 385-393.
[31] Vercelli, A. (1991): Methodological Foundations of Macroeconomics: Keynes and Lucas. Cambridge University Press, Cambridge.
[32] Yang, H.; Zhang, L. (2005). Optimal Investment for Insurer with

Jump-Diffusion Risk Process. Insurance: Mathematics and Economics 37, 615-634.