



## Article

# Backward Stochastic Differential Equations Driven by a Jump Markov Process with Continuous and Non-Necessary Continuous Generators

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**Abstract:** We deal with backward stochastic differential equations driven by a pure jump Markov process and an independent Brownian motion (BSDEs for short). We start by proving the existence and uniqueness of the solutions for this type of equation and present a comparison of the solutions in the case of Lipschitz conditions in the generator. With these tools in hand, we study the existence of a (minimal) solution for BSDE where the coefficient is continuous and satisfies the linear growth condition. An existence result for BSDE with a left-continuous, increasing and bounded generator is also discussed. Finally, the general result is applied to solve one kind of quadratic BSDE].

**Keywords:** backward stochastic differential equations; jump Markov process; comparison principle; quadratic BSDE with jumps



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## 1. Introduction

In this work, we are interested in the following backward stochastic differential equations driven by both Wiener and Markov jump processes.

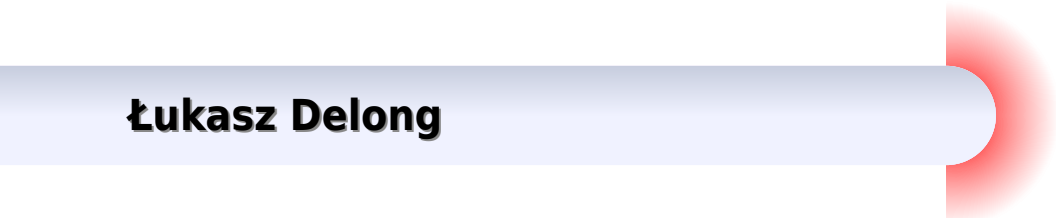
$$\begin{aligned} Y_t = & h(X_T) + \int_t^T f(r, X_r, Y_r, Z_r, K_r(\cdot))dr \\ & - \int_t^T Z_r dB_r - \int_t^T \int_E K_r(r)q(dr, de), \end{aligned} \quad (1)$$

where  $X$  is a  $\Gamma$ -valued (to be defined later) jump Markov process defined on a complete filtered probability space  $(\Omega, \mathcal{F}, (\mathcal{F}_t)_{t \in [0, T]}, \mathbb{P})$ ,  $\{B_t : t \in [0, T]\}$  is a standard  $\mathbb{R}$ -valued Wiener process,  $f$  is the generator,  $h(X_T)$  is the terminal condition and  $q(dr, de)$  stands for a random measure associated with the jump Markov process  $X$ .

It is well known that BSDEs driven by continuous Brownian motion without the jump part have been studied extensively in the literature and they comprise an important tool in the real world concerning applications such as control theory, finance, stochastic games, partial differential equations and homogenization. After the seminal work of Pardoux and Peng [1], where they proved the first results for the existence and uniqueness concerning BSDEs, many efforts have been made to relax the assumptions concerning the terminal data and the generator with respect to the state variables. More precisely, Hamadène [2] studied a BSDE whose generator  $f$  is locally Lipschitz and satisfies a reasonably growing condition. Thereafter, Lepeltier and San Martin [3] studied a one-dimensional BSDE with a bounded terminal condition and an only continuous generator, which satisfies the linear growth conditions. Bahlali [4] studied the existence and uniqueness of solutions for a multidimensional BSDE with a local Lipschitz coefficient and square-integrable terminal data. More recently, Abdelhadi and Khelfallah [5] extended the former results to the case

# Backward Stochastic Differential Equations

**Łukasz Delong**



## **Backward Stochastic Differential Equations:**

*Backward Stochastic Differential Equations* N El Karoui, Laurent Mazliak, 1997-01-17 This book presents the texts of seminars presented during the years 1995 and 1996 at the Universit Paris VI and is the first attempt to present a survey on this subject Starting from the classical conditions for existence and unicity of a solution in the most simple case which requires more than basic stochartic calculus several refinements on the hypotheses are introduced to obtain more general results

**Forward-Backward Stochastic Differential Equations and Their Applications** Jin Ma, Jiongmin Yong, 1999-06-21 This volume is a survey monograph on the recently developed theory of forward backward stochastic differential equations FBSDEs Basic techniques such as the method of optimal control the Four Step Scheme and the method of continuation are presented in full Related topics such as backward stochastic PDEs and many applications of FBSDEs are also discussed in detail The volume is suitable for readers with basic knowledge of stochastic differential equations and some exposure to the stochastic control theory and PDEs It can be used for researchers and or senior graduate students in the areas of probability control theory mathematical finance and other related fields

Backward Stochastic Differential Equations with Jumps and Their Actuarial and Financial Applications Łukasz Delong, 2013-06-12 Backward stochastic differential equations with jumps can be used to solve problems in both finance and insurance Part I of this book presents the theory of BSDEs with Lipschitz generators driven by a Brownian motion and a compensated random measure with an emphasis on those generated by step processes and Lvy processes It discusses key results and techniques including numerical algorithms for BSDEs with jumps and studies filtration consistent nonlinear expectations and g expectations Part I also focuses on the mathematical tools and proofs which are crucial for understanding the theory Part II investigates actuarial and financial applications of BSDEs with jumps It considers a general financial and insurance model and deals with pricing and hedging of insurance equity linked claims and asset liability management problems It additionally investigates perfect hedging superhedging quadratic optimization utility maximization indifference pricing ambiguity risk minimization no good deal pricing and dynamic risk measures Part III presents some other useful classes of BSDEs and their applications This book will make BSDEs more accessible to those who are interested in applying these equations to actuarial and financial problems It will be beneficial to students and researchers in mathematical finance risk measures portfolio optimization as well as actuarial practitioners

**On Backward Stochastic Differential Equations (BSDEs) with jumps of infinite activity** Martin Büttner, 2016-06-03 Diploma Thesis from the year 2011 in the subject Mathematics Stochastics grade 1.0 Humboldt University of Berlin Mathematik language English abstract This diploma thesis is concerned with backward stochastic differential equations BSDEs with jumps which are driven by a Brownian Motion and a random measure We derive existence and uniqueness results for bounded solutions to such BSDEs when the generator possesses a certain monotonicity property instead of the usual global Lipschitz condition Starting with results in the case of finite activity considering

generators of difference type and showing a comparison theorem allows us to advance to the case of infinite activity

Backward Stochastic Differential Equations with Jumps and Applications Rong Situ, 2000      **Some Results on**

**Backward Stochastic Differential Equations** Yimin Yang (Mathematician), 2019      **Backward Stochastic Differential**

**Equations** Jianfeng Zhang, 2017-08-22 This book provides a systematic and accessible approach to stochastic differential equations backward stochastic differential equations and their connection with partial differential equations as well as the recent development of the fully nonlinear theory including nonlinear expectation second order backward stochastic differential equations and path dependent partial differential equations Their main applications and numerical algorithms as well as many exercises are included The book focuses on ideas and clarity with most results having been solved from scratch and most theories being motivated from applications It can be considered a starting point for junior researchers in the field and can serve as a textbook for a two semester graduate course in probability theory and stochastic analysis It is also accessible for graduate students majoring in financial engineering      **Stochastic Differential Equations, Backward**

**SDEs, Partial Differential Equations** Etienne Pardoux, Aurel Răşcanu, 2014-06-24 This research monograph presents results to researchers in stochastic calculus forward and backward stochastic differential equations connections between diffusion processes and second order partial differential equations PDEs and financial mathematics It pays special attention to the relations between SDEs BSDEs and second order PDEs under minimal regularity assumptions and also extends those results to equations with multivalued coefficients The authors present in particular the theory of reflected SDEs in the above mentioned framework and include exercises at the end of each chapter Stochastic calculus and stochastic differential equations SDEs were first introduced by K Itô in the 1940s in order to construct the path of diffusion processes which are continuous time Markov processes with continuous trajectories taking their values in a finite dimensional vector space or manifold which had been studied from a more analytic point of view by Kolmogorov in the 1930s Since then this topic has become an important subject of Mathematics and Applied Mathematics because of its mathematical richness and its importance for applications in many areas of Physics Biology Economics and Finance where random processes play an increasingly important role One important aspect is the connection between diffusion processes and linear partial differential equations of second order which is in particular the basis for Monte Carlo numerical methods for linear PDEs Since the pioneering work of Peng and Pardoux in the early 1990s a new type of SDEs called backward stochastic differential equations BSDEs has emerged The two main reasons why this new class of equations is important are the connection between BSDEs and semilinear PDEs and the fact that BSDEs constitute a natural generalization of the famous Black and Scholes model from Mathematical Finance and thus offer a natural mathematical framework for the formulation of many new models in Finance

*Topics on Backward Stochastic Differential Equations* Arnaud Lionnet, 2013      *Optimal Stochastic Control, Stochastic*

*Target Problems, and Backward SDE* Nizar Touzi, 2012-09-25 This book collects some recent developments in stochastic

control theory with applications to financial mathematics We first address standard stochastic control problems from the viewpoint of the recently developed weak dynamic programming principle A special emphasis is put on the regularity issues and in particular on the behavior of the value function near the boundary We then provide a quick review of the main tools from viscosity solutions which allow to overcome all regularity problems We next address the class of stochastic target problems which extends in a nontrivial way the standard stochastic control problems Here the theory of viscosity solutions plays a crucial role in the derivation of the dynamic programming equation as the infinitesimal counterpart of the corresponding geometric dynamic programming equation The various developments of this theory have been stimulated by applications in finance and by relevant connections with geometric flows Namely the second order extension was motivated by illiquidity modeling and the controlled loss version was introduced following the problem of quantile hedging The third part specializes to an overview of Backward stochastic differential equations and their extensions to the quadratic case

**Financial Modeling** Stephane Crepey, 2013-06-13 Backward stochastic differential equations BSDEs provide a general mathematical framework for solving pricing and risk management questions of financial derivatives They are of growing importance for nonlinear pricing problems such as CVA computations that have been developed since the crisis Although BSDEs are well known to academics they are less familiar to practitioners in the financial industry In order to fill this gap this book revisits financial modeling and computational finance from a BSDE perspective presenting a unified view of the pricing and hedging theory across all asset classes It also contains a review of quantitative finance tools including Fourier techniques Monte Carlo methods finite differences and model calibration schemes With a view to use in graduate courses in computational finance and financial modeling corrected problem sets and Matlab sheets have been provided St phane Cr pey s book starts with a few chapters on classical stochastic processes material and then fasten your seatbelt the author starts traveling backwards in time through backward stochastic differential equations BSDEs This does not mean that one has to read the book backwards like a manga Rather the possibility to move backwards in time even if from a variety of final scenarios following a probability law opens a multitude of possibilities for all those pricing problems whose solution is not a straightforward expectation For example this allows for framing problems like pricing with credit and funding costs in a rigorous mathematical setup This is as far as I know the first book written for several levels of audiences with applications to financial modeling and using BSDEs as one of the main tools and as the song says it s never as good as the first time Damiano Brigo Chair of Mathematical Finance Imperial College London While the classical theory of arbitrage free pricing has matured and is now well understood and used by the finance industry the theory of BSDEs continues to enjoy a rapid growth and remains a domain restricted to academic researchers and a handful of practitioners Cr pey s book presents this novel approach to a wider community of researchers involved in mathematical modeling in finance It is clearly an essential reference for anyone interested in the latest developments in financial mathematics Marek Musiela Deputy Director of the

Oxford Man Institute of Quantitative Finance      Backward Stochastic Differential Equations with Jumps are Stable  
 Alexandros Saplaouras,2017      Backward Stochastic Differential Equations in the Plane N. Lanjri Zaïdi,D. Nualart,1999  
**Backward Stochastic Differential Equations with Unbounded Coefficients and Their Applications** Jiajie Li,2014  
*Linear Forward-backward Stochastic Differential Equations* University of Minnesota. Institute for Mathematics and Its  
 Applications,Jiongmin Yong,1996      Numerical Methods for Backward Stochastic Differential Equations with Applications to  
Stochastic Optimal Control Bo Gong,2017 The concept of backward stochastic differential equation BSDE was initially  
 brought up by Bismut when studying the stochastic optimal control problem And it has been applied to describe various  
 problems particularly to those in finance After the fundamental work by Pardoux and Peng who proved the well posedness of  
 the nonlinear BSDE the BSDE has been investigated intensively for both theoretical and practical purposes In this thesis we  
 are concerned with a class of numerical methods for solving BSDEs especially the one proposed by Zhao et al For this  
 method the convergence theory of the semi discrete scheme the scheme that discretizes the equation only in time was  
 already established we shall further provide the analysis for the fully discrete scheme the scheme that discretizes in both  
 time and space Moreover using the BSDE as the adjoint equation we shall construct the numerical method for solving the  
 stochastic optimal control problem We will discuss the situation when the control is deterministic as well as when the control  
 is feedback      **Numerical Methods for Backward Stochastic Differential Equations** ,2014      **Backward Stochastic**  
**Differential Equations with Applications to Stochastic Control Problems and Generalized Stochastic Differential**  
**Utility** Felix Stenau,2009      *Contributions to Quadratic Backward Stochastic Differential Equations with Jumps and*  
*Applications* Rym Salhi,2019 This thesis focuses on backward stochastic differential equation with jumps and their  
 applications In the first chapter we study a backward stochastic differential equation BSDE for short driven jointly by a  
 Brownian motion and an integer valued random measure that may have infinite activity with compensator being possibly time  
 inhomogeneous In particular we are concerned with the case where the driver has quadratic growth and unbounded terminal  
 condition The existence and uniqueness of the solution are proven by combining a monotone approximation technics and a  
 forward approach Chapter 2 is devoted to the well posedness of generalized doubly reflected BSDEs GDRBSDE for short with  
 jumps under weaker assumptions on the data In particular we study the existence of a solution for a one dimensional  
 GDRBSDE with jumps when the terminal condition is only measurable with respect to the related filtration and when the  
 coefficient has general stochastic quadratic growth We also show in a suitable framework the connection between our class  
 of backward stochastic differential equations and risk sensitive zero sum game In chapter 3 we investigate a general class of  
 fully coupled mean field forward backward under weak monotonicity conditions without assuming any non degeneracy  
 assumption on the forward equation We derive existence and uniqueness results under two different sets of conditions based  
 on proximation schema weither on the forward or the backward equation Later we give an application for storage in smart

grids     *Backward Stochastic Differential Equations with Weak Integrability* Imen Hassairi, 2017-08-09

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