

## SELF-NORMALIZED LARGE DEVIATIONS

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Let  $\{X, X_n, n \geq 1\}$  be a sequence of independent and identically distributed random variables. The classical Cramér–Chernoff large deviation states that  $\lim_{n \rightarrow \infty} n^{-1} \ln P(\sum_{i=1}^n X_i)/n \geq x) = \ln \rho(x)$  if and only if the moment generating function of  $X$  is finite in a right neighborhood of zero. This paper uses  $n^{(p-1)/p} V_{n,p} = n^{(p-1)/p} (\sum_{i=1}^n |X_i|^p)^{1/p}$  ( $p > 1$ ) as the normalizing constant to establish a self-normalized large deviation without any moment conditions. A self-normalized moderate deviation, that is, the asymptotic probability of  $P(S_n/V_{n,p} \geq x_n)$  for  $x_n = o(n^{1/(p-1)})$ , is also found for any  $X$  in the domain of attraction of a normal or stable law. As a consequence, a precise constant in the self-normalized law of the iterated logarithm of Griffin and Kuelbs is obtained. Applications to the limit distribution of self-normalized sums, the asymptotic probability of the  $t$ -statistic as well as to the Erdős–Rényi–Shepp law of large numbers are also discussed.

1. Introduction. Throughout this paper, let  $(\Omega, \Sigma, P)$  denote a probability space, and let  $\{X, X_n, n \geq 1\}$  be a sequence of independent and identically distributed (i.i.d.) nondegenerate real-valued random variables on the probability space. Put

$$S_n = \sum_{i=1}^n X_i, \quad V_n^2 = \sum_{i=1}^n X_i^2, \quad n = 1, 2, \dots$$

The classical Cramér–Chernoff large deviation [Chernoff (1952)] states that if

$$(A) \quad E e^{t_0 X} < \infty \text{ for some } t_0 > 0,$$

then for every  $x > EX$ ,

$$\lim_{n \rightarrow \infty} n^{-1} \ln P\left(\frac{S_n}{n} \geq x\right) = \ln \rho(x),$$

or equivalently,

$$(1.1) \quad \lim_{n \rightarrow \infty} P\left(\frac{S_n}{n} \geq x\right)^{1/n} = \rho(x),$$

where  $\rho(x) = \inf_{t \geq 0} e^{-tx} E e^{tX}$ .

Roughly speaking, this type of large deviation shows that the convergence rate in the law of large numbers is exponential if the moment generating

Received April 1995; revised June 1996.

<sup>†</sup>Research partially supported by a National University of Singapore Research Project.

AAS 1991 subject classifications. Primary 60F10, 60F15; secondary 60G50, 62E20.

*Key words and phrases.* Self-normalized partial sums, large deviation, moderate deviation, law of the iterated logarithm, the Erdős–Rényi–Shepp law of large numbers, limit distribution,  $t$ -statistic.

# Chapter 3 Self Normalized Large Deviations

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## **Table of Contents Chapter 3 Self Normalized Large Deviations**

1. Understanding the eBook Chapter 3 Self Normalized Large Deviations
  - The Rise of Digital Reading Chapter 3 Self Normalized Large Deviations
  - Advantages of eBooks Over Traditional Books
2. Identifying Chapter 3 Self Normalized Large Deviations
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Chapter 3 Self Normalized Large Deviations
  - User-Friendly Interface
4. Exploring eBook Recommendations from Chapter 3 Self Normalized Large Deviations
  - Personalized Recommendations
  - Chapter 3 Self Normalized Large Deviations User Reviews and Ratings
  - Chapter 3 Self Normalized Large Deviations and Bestseller Lists
5. Accessing Chapter 3 Self Normalized Large Deviations Free and Paid eBooks
  - Chapter 3 Self Normalized Large Deviations Public Domain eBooks
  - Chapter 3 Self Normalized Large Deviations eBook Subscription Services
  - Chapter 3 Self Normalized Large Deviations Budget-Friendly Options

6. Navigating Chapter 3 Self Normalized Large Deviations eBook Formats
  - ePub, PDF, MOBI, and More
  - Chapter 3 Self Normalized Large Deviations Compatibility with Devices
  - Chapter 3 Self Normalized Large Deviations Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Chapter 3 Self Normalized Large Deviations
  - Highlighting and Note-Taking Chapter 3 Self Normalized Large Deviations
  - Interactive Elements Chapter 3 Self Normalized Large Deviations
8. Staying Engaged with Chapter 3 Self Normalized Large Deviations
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Chapter 3 Self Normalized Large Deviations
9. Balancing eBooks and Physical Books Chapter 3 Self Normalized Large Deviations
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Chapter 3 Self Normalized Large Deviations
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Chapter 3 Self Normalized Large Deviations
  - Setting Reading Goals Chapter 3 Self Normalized Large Deviations
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Chapter 3 Self Normalized Large Deviations
  - Fact-Checking eBook Content of Chapter 3 Self Normalized Large Deviations
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements

- Interactive and Gamified eBooks

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