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# Improved Estimation of the Exponential Mean under an Order Restriction

Steven T. Garren
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**ABSTRACT** Suppose two independent observations are drawn from two-parameter exponential distributions with unknown but equal scale parameters and an order restriction on the unknown location parameters. An isotonic regression estimator of the smaller location parameter stochastically dominates a preferred marginal estimator. The results expressed herein advance the theory of order restricted inference.

***Keywords*** Geometric distribution; Isotonic regression estimator; Order restriction; Two-parameter exponential distribution; Stochastic and universal domination.

## 1. Introduction

Suppose one is interested in estimating a parameter $\lambda$ under some order restriction on parameters from two different distributions. In some situations an *isotonic regression estimator* of $\lambda$ based on independent samples from the two distributions may dominate an estimator of $\lambda$ based on just the marginal sample, in terms of mean squared error (MSE).

Domination in terms of MSE is a special case of universal domination, defined below. An estimator $\hat{\lambda}$ is said to universally dominate another estimator $\lambda^*$ if for all $\lambda$ and all nondecreasing loss functions $L(\cdot)$, $E_\lambda L(|\hat{\lambda}-\lambda|) \le E_\lambda L(|\lambda^*-\lambda|)$, with a strict inequality for some $\lambda$ and some nondecreasing loss function $L(\cdot)$.

Hwang [3] showed that universal domination is equivalent to stochastic domination, defined below. When estimating a parameter $\lambda$, an estimator $\hat{\lambda}$ is said to stochastically dominate another estimator $\lambda^*$ if

$$P_\lambda(|\hat{\lambda}-\lambda| \le t) \ge P_\lambda(|\lambda^*-\lambda| \le t) \tag{1.1}$$

for all $t \ge 0$ and all $\lambda$, with a strict inequality for some $t \ge 0$ and some $\lambda$.

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# Point and Interval Estimation for a Simple Step-Stress Model with Random Stress-Change Time

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**ABSTRACT** In accelerated testing, the units are tested at varying stress levels. A special class of accelerated tests is step-stress test, that allows the experimenter to change the stress levels at pre-specified times during the experiment. It is observed that in the conventional step-stress testing, the parameters are not always estimable and even when the life time distributions are exponential; the exact confidence intervals are quite complicated. In this paper, we consider a simple step-stress model with a random stress-change time. In this set up the stress level changes at the time when a pre-specified number of failures take place. We derive the maximum likelihood estimators when the life time distributions are exponential and under the assumption of a cumulative exposure model. The joint distribution of the parameters is obtained. We provide the confidence intervals using the exact distribution and by two bootstrap methods. Bayes estimates and the corresponding credible intervals are also obtained. Monte Carlo simulations are performed to compare the performances of the different methods.

***Keywords*** Accelerated testing; Step-stress test; Cumulative exposure model; Maximum likelihood estimator; Uniformly minimum variance unbiased estimator; Bootstrap confidence intervals; Credible intervals.

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# Recurrence Relations for Single and Double Moments of GOS from the Inverted Linear Exponential Distribution and Any Continuous Function

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**ABSTRACT** In generalized order statistics, some representations of marginal density and distribution functions are developed. These results are applied to obtain several relations, such as recurrence relations for the single and product moments, conditional expectation and variance for inverted linear exponential (ILE) distribution. Furthermore, recurrence relations are obtained for the expectation for any continuous function and for some special cases such as moment generating function.

***Keywords*** Ordinary order statistics; Generalized order statistics; Moment generating functions; Recurrence relation; Inverted linear exponential distribution.

## 1. Introduction

Marmoud and Mohie El-Din [7] have obtained some parameters such as the mean, variance, mode and median, for the ILE distribution. Mohie El-Din [8] has established some recurrence relations for single and product moments for ordinary order statistics (OOS) for the ILE distribution. Also they derived characterization for this distribution based on the conditional expectation from OOS.

Generalized order statistics based on the standard uniform distribution for the random variables $X(1,n,\overline{m},k),\cdots,X(n,n,\overline{m},k)$ are denoted by $U(r,n,\overline{m},k)$. Let $X$ be an investigated random variable with the absolutely continuous distribution function $F(x)\equiv F(x\,|\,\theta)$ and density function $f(x)\equiv f(x\,|\,\theta)$, where the parameter $\theta\in\Theta$ may be a real vector. Corresponding

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# Characterization of Bivariate Distributions Using Residual Measure of Uncertainty

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**ABSTRACT** In this paper we propose a new measure of bivariate residual entropy which is applicable to a two component parallel system. Properties of this residual entropy are considered. The paper also includes entropy characterizations in terms of bivariate lack of memory property and bivariate mean residual life function.

***Keywords*** Bivariate residual entropy function; Characterization; Cox failure rate; Bivariate mean residual life function.

## 1. Introduction

Let $X$ be a non-negative random variable representing component failure time with distribution function $F(x) = P[X \le x]$ and survival function $\overline{F}(x) = 1 - F(x)$. Assuming $X$ to be absolutely continuous, let $f(x)$ denote the density function of $X$. Some of the commonly used measures to characterize or to compare the ageing process of the units are the failure rate and mean residual life function. The various characteristic properties of these functions are abundant in literature. But highly uncertain components or systems are inherently not reliable. One measure of this uncertainty is the Shannon information measure (Shannon [15], Wiener [16]). For a distribution function $F$, it is defined as

$$H(f) = -\int_0^\infty f(x)\log f(x)dx = -E[\log f(X)].$$

Low entropy distributions are more concentrated and hence more informative than high entropy distributions. This measure was modified to take age into account and a measure of uncertainty

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# Introduction of Shape/Skewness Parameter(s) in a Probability Distribution

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**ABSTRACT** In this paper we discuss six different methods to introduce a shape/ skewness parameter in a probability distribution. It should be noted that all these methods may not be new, but we provide new interpretations to them and that might help the practitioner to choose the correct model. It is observed that if we apply any one of these methods to any probability distribution, it may produce an extra shape/skewness parameter to that distribution. Structural properties of these skewed distributions are discussed. For illustrative purposes, we apply these methods when the base distribution is exponential, which resulted in five different generalizations of the exponential distribution. It is also observed that if we combine two or more than two methods successively, then it may produce more than one shape/skewness parameters. Several known distributions can be obtained by these methods and various new distributions with more than one shape parameters may be generated. Some of these new distributions have several interesting properties.

***Keywords*** Hazard function; Reversed hazard function; Cumulative distribution function; Odds ratio; Cumulant generating function.

## 1. Introduction

Recently there has been quite a bit of interests to define skewed distributions in various manners. Azzalini [1, 2] first introduced the skew-normal distribution and then a series of papers appeared on skewed distribution both in the univariate and multivariate set up. Arnold

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# A Marshall-Olkin Beta Distribution and Its Applications

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**ABSTRACT** In this paper a new distributions called Marshall-Olkinbeta distribution is introduced. It can be considered as a four parameter extension of a beta distribution. The properties of the distribution are studied in detail. The maximum likelihood estimators are derived. Expressions for the moments are obtained. A minification process with Marshall-Olkin distribution is constructed and its properties are considered. The first order autocovariance function is derived. Some applications of the new distribution in the modelling of two real data sets on permeability values and daily ozone measurements are considered. The R program to compute the moments is given as appendix.

***Keywords*** Four parameter beta distribution; Marshall-Olkin beta distribution; Maximum likelihood estimation; Minification process.

## 1. Introduction

The majority of continuous distributions are defined on infinite intervals. But beta distribution is a continuous distribution defined on a bounded interval and its probability density function exhibits a wide range of shapes. This flexibility encourages its empirical use in a large variety of applications. For many years the use of beta distribution has been as "prior" distribution for binomial proportions. In recent years beta distributions have been used in modelling distributions of hydrological variables, in operations research, in risk analysis etc. (see Nadarajah [13] for some references).

Recently many authors have obtained generalizations of beta distribution using various techniques. McDonald and Xu [12] introduced a five-parameter beta distribution. Various properties of a family of generalized beta distribution including beta-normal, beta-exponential,

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# A Note on Kernel Quantile Estimators

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**ABSTRACT** Kernal quantile estimator is popular in nonparametric statistical inferences. However, closed form formula of kernel quantile estimator is not known yet. In this paper, we give a closed form formula for the kernel quantile estimator with a truncated hyperbolic cosine kernel function. We also provide a quick proof for the central limit theorem of kernel quantile estimator.

***Keywords*** Kernel quantile estimator.

## 1. Introduction

The quantile $F^{-1}(p) = \inf\{x : F(x) \geq p\}$, $0 < p < 1$, of a distribution $F(x)$ is an important concept in probability. In statistics, both the distribution function $F(x)$ and $F^{-1}(p)$ are unknown and have to be inferred from samples. In nonparametric statistics, the estimation of population quantile is of great interest, especially when the underlying distribution is skewed (Sheather and Marron [7]). Kernel quantile estimators are by far the most popular estimators in literatures (see Nadaraya [5], Azzalini [1], Yang [8], Jones [4] and Cheng and Sun [3] and references therein for details). Functions of quantiles can also be estimated by kernel quantile estimators (Chen and Hsu [2]).

Kernel quantile estimator of $F^{-1}(p)$ is described below. Let $\{h_n\}$ be a sequence of positive numbers converging to 0 and $K(s)$ be a known probability density function or kernel function. For convenience, we will suppress the index $n$ of $h_n$. Given a sample $X_1, \cdots, X_n$ obtained from a population with distribution function $F(x)$ and probability density function $f(x)$, define

$$\hat{F}(x) = \int_{-\infty}^{x} \hat{f}(t)dt$$

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# Performance Analysis of a Finite-Buffer Batch Service Queue with General Input and Exponential Multiple Vacations

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**ABSTRACT** This paper considers a finite-buffer single server queue with general independent inter-arrival and exponential service time. The service is performed in batches according to general batch service rule ($a$, $b$). At the end of a busy period, if the server finds less than "$a$" waiting customers, he takes an exponentially distributed vacation. On return from a vacation if the server finds more than "$a$" customers in the queue, then he serves the customers as per batch service rule. Otherwise he again proceeds for another vacation and continues in this manner till he finds at least "$a$" waiting customers. We obtain the steady-state distributions of the number of customers in the queue at pre-arrival and arbitrary epochs along with some useful performance measures. Some tables and graphs showing the effect of model parameters on key performance measures are presented.

***Keywords*** Batch service; Finite-buffer; *GI*/*M*/1 queue; Multiple vacations.

## 1. Introduction

Queueing systems with server's vacations have attracted much attention from numerous researchers due to their wide application in several areas including computer-communication and manufacturing systems. In the past, most of the queueing systems with vacations have been analyzed assuming Poisson arrival process, but in several practical applications it is seen that the

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# A Retrial Queueing System with Choice of a Service under Bernoulli Vacation Schedule

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**ABSTRACT** This paper deals with a single server retrial queueing system providing two kinds of general heterogeneous service and Bernoulli vacation schedule which operates under the so called linear retrial policy. Just before his service starts, a customer may choose one kind of services and as soon as a service (of any kind) gets completed, the server may take a vacation or may continue staying in the system. The server vacations are based on Bernoulli schedules under a single vacation policy. This model extends both the classical *M*/*G*/1 retrial queue with linear retrial policy as well as the *M*/*G*/1 queue with two kinds of general heterogeneous service and Bernoulli vacation model. We carry out an extensive analysis of this model.

***Keywords*** Retrial queues; Bernoulli vacation schedule; Two kinds of heterogeneous service; Linear retrial policy, Stochastic decomposition.

## 1. Introduction

During last two decades there has been considerable attention paid to the analysis of queueing systems with repeated attempts (or retrial queues) (see, for example, the surveys by Yang and Templeton [34], Falin [16], Kulkarni and Liang [26] and the book by Falin and Templeton [17]). For more recent references see bibliographical overviews in [3,4,21]. Retrial queueing system are characterized by the feature that arriving customer who finds all servers and waiting positions occupied is obliged to leave the service area and join a group of un-satisfied customers (called *retrial group* or *orbit*) to try again for their service after a random period of time called *retrial time*. This type of situation arises in telephony, where an arriving

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# Batch Arrival Bernoulli Schedule Vacation Queue with Two Types of General Heterogeneous Service and Random System Breakdowns

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**ABSTRACT** This paper deals with the steady state behavior of a Bernoulli vacation batch arrivals queue with two types of service and random system breakdowns. Such a model may find applications in many real life queueing situations. We assume that just before a service starts, a customer has the option to choose one of the two types of services. Further we assume that after a service completion, the server is allowed to take a single vacation under Bernoulli schedule. On the other hand, the system might suddenly break down while a customer is being served in any type of service, and hence it enters a repair process immediately. Service times, vacation time and repair time are all assumed to have general distributions. Some important performance measures of the queueing system we obtained.

***Keywords*** $M^X/G/1$ queue; Batch arrival; Vacation time; Bernoulli schedule; Random breakdown.

## 1. Introduction

Simple queueing model is not always applicable to queueing models found in real life situations. There may be some situations where the server may shut down the service facility (may be engaged in other work or may just go away), or the server may well be subject to un-

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# Future Supply Uncertainty Model for Deteriorating Items under Inflation and Permissible Delay in Payment

Deepa H. Kandpal and Khimya S. Tinani
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**ABSTRACT** This paper develops a model to determine an optimal ordering policy for deteriorating items under inflation, permissible delay of payment and allowable shortage for future supply uncertainty. We consider order quantity/reorder-point inventory models where the availability of supply is subject to random fluctuations. We use concepts from renewal reward processes to develop average cost objective function. In many inventory situations, purchasers are allowed a period to pay back for the goods bought without paying any interest. Depending on the length of that payment period, the purchaser can earn interest on the sales of the inventory. The effect of inflation and time value of money was investigated under given sets of inflation and discount rates.

***Keywords*** Future supply uncertainty; Inflation; Permissible delay in payment; Discount rate.

## 1. Introduction

Inventory can be considered as an accumulation of physical commodity that can be used to satisfy some future demand for that commodity. The main and foremost reason for maintaining inventory level is to shorten the gap between demand and supply for the commodity under consideration. Any inventory system consists of an input process and output process. The input process refers to supply either by means of production or purchase while the output process refers to demand due to which depletion of inventory occurs. Thus, supply is a replenishment process, whereas demand is a depletion process.

Deterioration is defined as decay, damage, spoilage, obsolescent, pilferage, loss of utility or loss of marginal value of a commodity that results in decrease of usefulness from the original one. The decrease or loss of utility due to decay is usually a function of the on hand inventory.

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# Appendix

1. **Acknowledgements**
2. ***JPSS* Subscription Forms**

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