The Maximum Durability Problem for Investing in Gold Market

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Abstract: - In this paper, we propose the model for applying in durability of investment in gold market. The rate of return is considered for this study. The gold price from January 1990 to June 2014 is transformed to be rate of return. The Laplace distribution is chosen for calculating the capital at day of n because of the least statistic value of goodness of fit tests for the rate of return with the parameters $b = 0.0063613232$ and $\mu = 0.00010572$. We simulate the situation for calculating the capital and the number of days. The number of situations is 1,000. We are interested in the longest number of days with acceptation the loss at α in order to consider the distribution associated with them. They are randomized by Laplace distribution. The distribution according with the longest number of days is used for calculating the maximum durability of investment in gold market. For the results, we found that the longest number of days is associated with the distribution of Inverse Gaussian (3P). Moreover, at confidence level 0.1 and risk level 0.9 the maximum durability of investment in gold market is 15,383 days.

Key-Words: - Gold price, Rate of return, Laplace distribution, Inverse Gaussian distribution (3P), Maximum likelihood method, Goodness of fit test

1 Introduction

Gold is the most valuable and popular metal for investment. Investors hold gold to prevent economic and political uncertainty or currency crisis. However, the price of gold is fluctuations daily or monthly. For instance, gold prices are sharply increased in 2012, while they are dramatically decreased in 2013. The interest which is main point of an investor is the forecast the price of gold to decide whether to invest in the gold market. Gold price can be measured and predicted for decisions in the future although it cannot be controlled. Forecasting models based on time series data are very popular, because there are fewer errors in forecasting.

Reference [6] proposed combination of Markov chain and GM(1,1) model, which is called MCGM(1,1), to forecast the gold price in London. The transition probabilities of Markov chain are constructed by the error of GM(1,1) and original data from January 1990 to December 2011. They compare the accuracy of the prediction using the testing data from January 2012 to June 2014.

Reference [5] carried out a study on global gold market and gold price forecasting. They analyzed the world gold market from January 1968 to December 2008. They applied a modified econometric version of the long-term trend reverting jump and dip diffusion model for forecasting natural resource commodity prices. Reference [3] developed a forecasting model for predicting gold price using Multiple Linear Regression (MLR). They obtained four different models based on several economic factors. Moreover, reference [4] forecasted Thai gold price, using Multiple Regression and Auto-Regression Integrated Moving Average (ARIMA) model.

There are many papers which study and develop the model corresponding to the gold. Reference [2] developed and tested the model relating the inflation rate of the gold price to expected consumer and wholesale prices and to expected interest rates through substitution effects. Reference [1] explored factors that can explicate variation in gold price over time. Reference [7] investigated macroeconomic influences on gold using the asymmetric power GARCH model.

In this study, the rate of return is considered for measuring durability of investment in gold market. The gold price from January 1990 to June 2014 is transformed to be rate of return. The Laplace distribution provides the less statistic value of the goodness of fit tests for rate of return. The Laplace distribution associated with rate of return is formed its inverse of Cumulative Distribution Function (CDF) for calculating the capital at day of n. We are interested in the longest number of days to survive when we accept an α percent of loss. Then the distribution is considered for less statistic value of goodness of fit tests which is associated with the longest number of days. The distributions of Frechet, Inverse Gaussian (3P), Log-Pearson 3, Frechet (3P), Pearson 6 (4P), Pearson 5, Lognormal (3P), Log-Gamma, and Burr are studied for this research. Finally, we find the maximum of days at the risk level 0.9 and the confident level 0.1 with the distributions providing the least statistic value of goodness of fit tests.

Our work is organized as follows: The research methodology is provided in section 2. Rate of return, Laplace distribution, parameter estimation the goodness of fit tests, and the simulation are described in this section. Research results and discussions are provided in section 3. A comparison of the results is also given in this section. The conclusion is in section 4.

2 Research Methodology

In this section, we separate into 4 parts which are mainly represented by rate of return, Laplace distribution, parameter estimation, the goodness of fit tests, and the simulation. The Laplace distribution is formed its inverse. The parameter estimation method for the distributions which obtain from the less statistic value of the goodness of fit test are composed of Least squares method (LSM), Maximum likelihood method (MLM) and Method of moments (MOM). The goodness of fit tests for our work is Kolmogorov-Smirnov Test, Anderson-Darling Test, and Chi-Squared Test.

2.1 Rate of Return

The gold price from January 1990 to June 2014 is transformed to be rate of return. The rate of return R_n is calculated from the formula as follow:

$$R_n = \frac{S_n - S_{n-1}}{S_{n-1}},$$

where S_n is the price of gold at day of n and S_{n-1} is the price of gold at day of $n-1$.

2.2 Laplace Distribution

The Laplace distribution is a continuous probability distribution. It is occasionally called the double exponential distribution, because it can be thought of as two exponential distributions with an additional location parameter. The parameters of Laplace distribution are composed of 2 parameters as follows:

b is a continuous inverse scale parameter $(b > 0)$.

μ is a continuous location parameter.

Probability Density Function (PDF) is

$$f(x; b, \mu) = \frac{\lambda}{2}\exp(-b|x-\mu|), \qquad x \in R.$$

Cumulative Distribution Function (CDF) is

$$F(x; b, \mu) = \begin{cases} \frac{1}{2}\exp\big(-b(\mu - x)\big), & x \le \mu \\ 1 - \frac{1}{2}\exp\big(-b(x-\mu)\big), & x > \mu. \end{cases}$$

The method of moments is parameter estimation method for Laplace distribution.

Let $u = F(x)$, then the inverse of $F(x)$ is

$$x = F^{-1}(u) = \begin{cases} b\ln 2u + \mu, & u \le 0.5 \\ -\mu - b\ln 2(1-u), & u > 0.5. \end{cases} \tag{1}$$

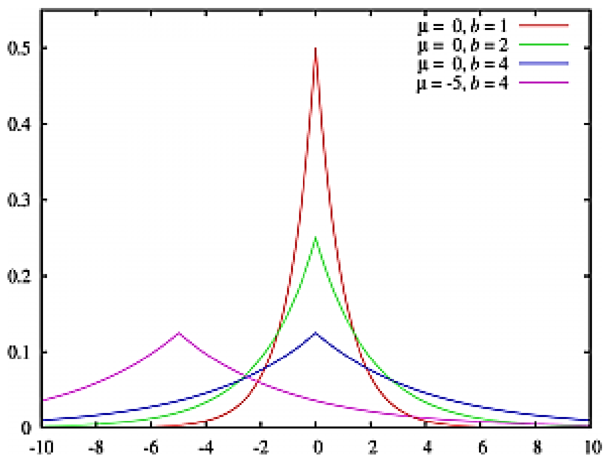

Fig. 1 Plot of PDF of Laplace distribution

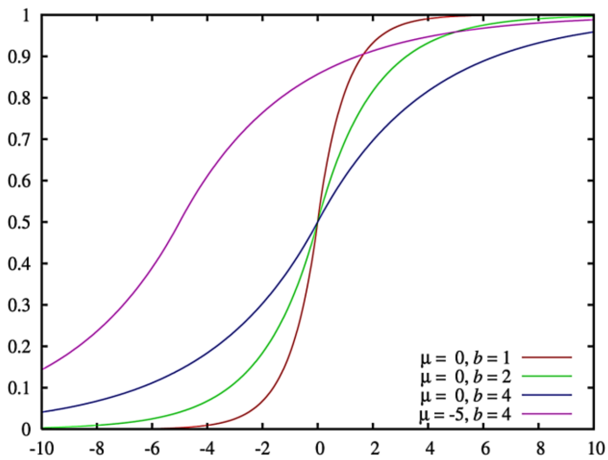

Fig. 2 Plot of CDF of Laplace distribution

2.3 Parameter Estimation

We use least squares method (LSM), maximum likelihood method (MLM) and method of moments (MOM) for estimating the parameter of the distributions. The distributions for this study are Frechet, Inverse Gaussian (3P), Log-Pearson 3, Frechet (3P), Pearson 6 (4P), Pearson 5, Lognormal (3P), Log-Gamma, and Burr distribution. The parameters estimation methods for each distribution are shown in table 1.

Table 1 The parameters estimation methods for each distribution

Distribution	Parameter Estimation Method
Frechet	LSM
Inverse Gaussian (3P)	MLM
Log-Pearson 3	MOM
Frechet (3P)	MLM
Pearson 6 (4P)	MLM
Pearson 5	MLM
Lognormal (3P)	MLM
Log-Gamma	MOM
Burr	MLM

2.4 Goodness of Fit Test

The goodness of fit test of a statistical model describes how well it fits a set of observations. The goodness of fit is typically measured and summarized the dislocation between observed values and the values expected under the model. In this study, we consider the goodness of fit test as following items.

2.4.1 Kolmogorov-Smirnov Test

This test is used to decide if a sample comes from a hypothesized continuous distribution. It is based on the empirical cumulative distribution function (ECDF). Assume that we have a random sample $x_1, x_2, \dots, x_n$ from some distribution with CDF $F(x)$. The empirical CDF is denoted by

$$F_n(x) = \frac{1}{n}[\text{Number of observations} \leq x]$$

The Kolmogorov-Smirnov statistic (D) is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function:

$$D = \max_{1 \leq i \leq n}\left(F(x_i) - \frac{i-1}{n}, \frac{i}{n} - F(x_i)\right).$$

2.4.2 Anderson-Darling Test

The Anderson-Darling procedure is a general test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test.

The Anderson-Darling statistic (A^2) is defined as

$$A^2 = -n - \frac{1}{n}\sum_{i=1}^{n}(2i-1)\left[\ln F(x_i) + \ln\left(1 - F(x_{n-i+1})\right)\right].$$

2.4.3 Chi-Squared Test

The Chi-Squared test is used to determine if a sample comes from a population with a specific distribution. Although there is no optimal choice for the number of bins (k), there are several formulas which can be used to calculate this number based on the sample size (N). For example, EasyFit employs the following empirical formula:

$$k = 1 + \log_2 N.$$

The Chi-Squared statistic is defined as

$$\chi^2 = \sum_{i=1}^{k}\frac{(O_i - E_i)^2}{E_i},$$

where O_i is the observed frequency for bin i, and E_i is the expected frequency for bin i calculated by

$$E_i = F(x_2) - F(x_i),$$

where F is the CDF of the probability distribution being tested, and x_1, x_2 are the limits for bin i.

2.5 The Simulation

In this study, we simulate the situation for calculating the capital and the number of days. The number of situations is 1,000.

By considering the rate of return, we found that it is corresponding to the Laplace distribution with the parameters $b = 0.0063613232$ and $\mu = 0.00010572$, because of the less statistical value of goodness of fit tests. Then we consider the inverse of CDF of Laplace distribution as following equation (1) to calculate the capital as the following form:

$$I_n = I_0 \prod_{i=1}^{n}\left(1 + F_i^{-1}(u)\right),$$

where I_0 is the initial capital and I_n is the capital at day of n.

We simulate the situation to find the longest number of days. We are interested in the longest number of days with acceptation the loss at α . The formula for calculating the longest number of days is provided as follow:

$$T_{\alpha} = \min\{n | I_n \geq (1-\alpha)I_0 \text{ and } I_{n+1} < (1-\alpha)I_0, n = 1,2,3,\ldots\}.$$

Next, the distributions of Frechet, Inverse Gaussian (3P), Log-Pearson 3, Frechet (3P), Pearson 6 (4P), Pearson 5, Lognormal (3P), Log-Gamma, and Burr are compared the statistical value of the goodness of fit tests with each the loss at α.

The distribution providing the least statistical value of the goodness of fit tests is considered for calculating the longest number of days. We accept the durability of the longest number of days, m, at the confidence level β and risk level α which can calculate by following formula:

$$MaD(\alpha,\beta) = max\,\{m | Pr(T_{\alpha} > m) \geq \beta\}. \qquad (2)$$

Where T_{α} is the distribution associated with the longest number of days.

3 Research Results and Discussions

The rate of return is calculated from the gold price from January 1990 to June 2014. We found that it is associated with the Laplace distribution owing to the less statistic value of goodness of fit test.

We simulate the 1,000 situations to find the longest number of days with acceptation the loss at α.

Table 2 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.1$.

For Kolmogorov-Smirnov test, the statistic value of Frechet distribution is the least, following Inverse Gaussian (3P) distribution, and Log-Pearson 3 distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Frechet (3P) distribution, and Pearson 6 (4P) distribution, respectively. For Chi-Squared test, the statistic value of Log-Pearson 3 distribution is the least, following Frechet (3P) distribution, and Pearson 6 (4P) distribution, respectively.

Table 3 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.2$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Frechet (3P) distribution, and Log-Pearson 3 distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Frechet (3P) distribution, and Log-Pearson 3 distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Frechet (3P) distribution, and Pearson 5 (3P) distribution, respectively.

Table 4 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.3$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Pearson 6 (4P) distribution, and Lognormal (3P) distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Log-Pearson 3 distribution, and Pearson 6 (4P) distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Log-Pearson 3 distribution, and Frechet (3P) distribution, respectively.

Table 5 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.4$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Log-Pearson 3 distribution, and Lognormal (3P) distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Log-Pearson 3 distribution, and Log-Gamma distribution, respectively.

Table 6 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.5$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Gamma distribution, respectively.

Table 7 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.6$.

For Kolmogorov-Smirnov test, the statistic value of Log-Pearson 3 distribution is the least, following Lognormal (3P) distribution, and Inverse Gaussian (3P) distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Log-Pearson 3 distribution, and Lognormal (3P) distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Frechet (3P) distribution, and Pearson 5 (3P) distribution, respectively.

Table 8 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.7$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively. For Chi-Squared test, the statistic value of Lognormal (3P) distribution is the least, following Inverse Gaussian (3P) distribution, and Log-Gamma distribution, respectively.

Table 9 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.8$.

For Kolmogorov-Smirnov test, the statistic value of Lognormal (3P) distribution is the least, following Inverse Gaussian (3P) distribution, and Log-Gamma distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Gamma distribution, respectively. For Chi-Squared test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Pearson 3 distribution, respectively.

Table 10 shows the statistic value of the goodness of fit test for each distribution with $\alpha = 0.9$.

For Kolmogorov-Smirnov test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Gamma distribution, respectively. For Anderson-Darling test, the statistic value of Inverse Gaussian (3P) distribution is the least, following Lognormal (3P) distribution, and Log-Gamma distribution, respectively. For Chi-Squared test, the statistic value of Lognormal (3P) distribution is the least, following Log-Pearson 3 distribution, and Log-Gamma distribution, respectively.

Fig. 3-5 shows the plot the statistis value and value of α for Kolmogorov Smirnov test, Anderson-Darling test, and Chi-Squared test, respectively.

We found that Inverse Gaussian (3P) distribution provides almost the less statistic value for the goodness of fit test for all acceptations the loss at α. Therefore, the number of days is associated with the distribution of inverse Gaussian (3P). The PDF and CDF of inverse Gaussian distribution are provided as follows:

The PDF of Inverse Gaussian distribution (3P) is

$$f(x;\lambda,\mu,\gamma) = \sqrt{\frac{\lambda}{(2\pi)(x-\gamma)^3}}\ \exp\left(-\frac{\lambda(x-\gamma-\mu)^2}{2\mu^2(x-\gamma)}\right).$$

The CDF of Inverse Gaussian (3P) distribution is

$$F(x;\lambda,\mu,\gamma) = \Phi\left(\sqrt{\frac{\lambda}{x-\gamma}}\left(\frac{x-\gamma}{\mu}-1\right)\right) + \Phi\left(-\sqrt{\frac{\lambda}{x-\gamma}}\left(\frac{x-\gamma}{\mu}+1\right)\right)\exp\left(\frac{2\lambda}{\mu}\right)$$

where Φ is the Laplace Integral.

$$\Phi(x) = \frac{1}{\sqrt{2\pi}}\int_0^x e^{-\frac{t^2}{2}}\,dt.$$

At the risk level 0.9, the parameters $\lambda, \mu,$ and γ of Inverse Gaussian (3P) distribution are 70873, 54974, and -13.349, respectively.

We calculate the maximum durability of the number of days at the confidence level 0.1 and loss level 0.9 from equation (2) with the CDF of Inverse Gaussian (3P). The result is found that at the confidence level 0.1 and risk level 0.9 the maximum durability of investment in gold market is 15,383 days.

Not until is the proposed model applied for the durability of investment in gold market, but it is also applied in insurance and others which can apply for further research.

The distributions which are used in this study may be inadequate; therefore we can choose more distributions for further research.

Table 2 The statistic value of the goodness of fit test for $\alpha = 0.1$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.02146	0.93931	12.68600
Inv.Gaussian (3P)	0.02353	0.39438	9.11990
Log-Pearson 3	0.02358	1.18660	4.73550
Frechet (3P)	0.02491	0.52809	8.01840
Pearson 6 (4P)	0.02600	0.76092	8.46830
Pearson 5	0.04251	1.43280	10.12900
Lognormal (3P)	0.05729	6.82850	39.99600
Log-Gamma	0.03383	2.79500	13.80200
Burr	0.04472	2.11770	14.04800

Table 3 The statistic value of the goodness of fit test for $\alpha = 0.2$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.04537	3.30020	24.25700
Inv.Gaussian (3P)	0.02171	0.53709	12.75200
Log-Pearson 3	0.04380	1.98070	27.43700
Frechet (3P)	0.03495	1.66730	19.87500
Pearson 6 (4P)	0.04407	2.24550	24.22500
Pearson 5	0.04906	3.20280	25.42400
Lognormal (3P)	0.04753	2.73920	34.44200
Log-Gamma	0.04987	2.71650	27.49900
Burr	0.05228	3.59910	36.26000

Table 4 The statistic value of the goodness of fit test for $\alpha = 0.3$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.04913	4.36590	24.03300
Inv.Gaussian (3P)	0.01415	0.13420	4.57150
Log-Pearson 3	0.03214	1.03200	8.79180
Frechet (3P)	0.03578	1.58850	9.85410
Pearson 6 (4P)	0.03058	1.16470	10.98000
Pearson 5	0.04792	3.41990	17.46900
Lognormal (3P)	0.03101	1.34220	14.79800
Log-Gamma	0.03485	1.50960	11.37700
Burr	0.04344	2.86270	17.14300

Table 5 The statistic value of the goodness of fit test for $\alpha = 0.4$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.04777	5.48740	29.68300
Inv.Gaussian (3P)	0.01398	0.13403	4.27500
Log-Pearson 3	0.02332	1.15680	7.55740
Frechet (3P)	0.03183	1.81810	10.36800
Pearson 6 (4P)	0.03469	2.02530	11.15300
Pearson 5	0.04318	3.77820	19.77200
Lognormal (3P)	0.02641	1.06530	13.14800
Log-Gamma	0.02686	1.46070	8.40990
Burr	0.03774	2.85330	13.56300

Table 6 The statistic value of the goodness of fit test for $\alpha = 0.5$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.06195	7.25120	45.30800
Inv.Gaussian (3P)	0.01885	0.29272	8.26280
Log-Pearson 3	0.03566	1.29390	15.52100
Frechet (3P)	0.04203	2.37700	16.13400
Pearson 6 (4P)	0.04275	2.45440	16.67100
Pearson 5	0.05584	4.55100	32.48300
Lognormal (3P)	0.03019	0.69304	11.69900
Log-Gamma	0.03727	1.38600	15.19200
Burr	0.03914	3.17250	21.67400

Table 7 The statistic value of the goodness of fit test for $\alpha = 0.6$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.04992	5.39960	24.35400
Inv.Gaussian (3P)	0.02234	0.30966	4.95360
Log-Pearson 3	0.02004	0.70459	8.28880
Frechet (3P)	0.02796	1.23150	7.15190
Pearson 6 (4P)	0.02601	1.15380	7.93290
Pearson 5	0.04432	2.77050	12.16300
Lognormal (3P)	0.0208	0.77792	9.51660
Log-Gamma	0.02588	1.27460	12.52500
Burr	0.02837	2.03090	14.06000

Table 8 The statistic value of the goodness of fit test for $\alpha = 0.7$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.06583	11.43300	56.36100
Inv.Gaussian (3P)	0.01758	0.32485	5.99880
Log-Pearson 3	0.02165	0.68229	8.21790
Frechet (3P)	0.03117	2.21770	15.70500
Pearson 6 (4P)	0.02909	1.85530	15.18400
Pearson 5	0.05837	5.74690	41.55200
Lognormal (3P)	0.01817	0.49288	5.91400
Log-Gamma	0.02188	0.68890	8.64560
Burr	0.03134	2.11140	13.66300

Table 9 The statistic value of the goodness of fit test for $\alpha = 0.8$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.06280	10.61200	53.26200
Inv.Gaussian (3P)	0.01304	0.167830	2.15770
Log-Pearson 3	0.01715	0.35104	4.10090
Frechet (3P)	0.03030	1.44850	8.18290
Pearson 6 (4P)	0.02726	1.10850	6.21780
Pearson 5	0.04877	4.86110	28.07000
Lognormal (3P)	0.01280	0.18331	3.48360
Log-Gamma	0.01680	0.34107	4.90080
Burr	0.03002	1.67980	13.17600

Table 10 The statistic value of the goodness of fit test for $\alpha = 0.9$

Distribution	Statistic		
	Kolmogorov Smirnov	Anderson Darling	Chi-Squared
Frechet	0.07912	11.31300	62.76900
Inv.Gaussian (3P)	0.02077	0.23656	10.27200
Log-Pearson 3	0.02847	0.63104	9.31690
Frechet (3P)	0.03497	1.82630	14.48500
Pearson 6 (4P)	0.06684	6.90750	43.01700
Pearson 5	0.05886	4.12510	30.67800
Lognormal (3P)	0.02214	0.39326	8.41690
Log-Gamma	0.02802	0.62773	9.61790
Burr	-	-	-

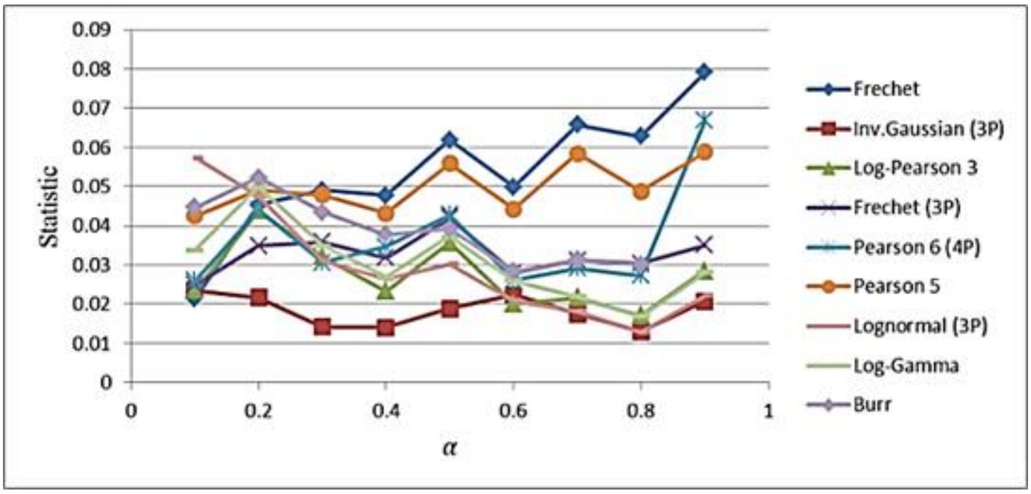

Fig. 3 Kolmogorov Smirnov

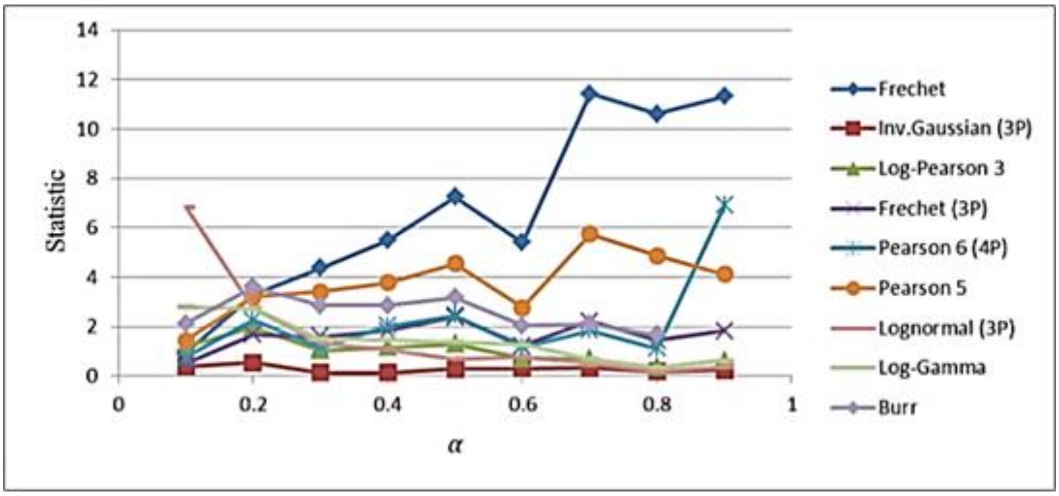

Fig. 4 Anderson-Darling

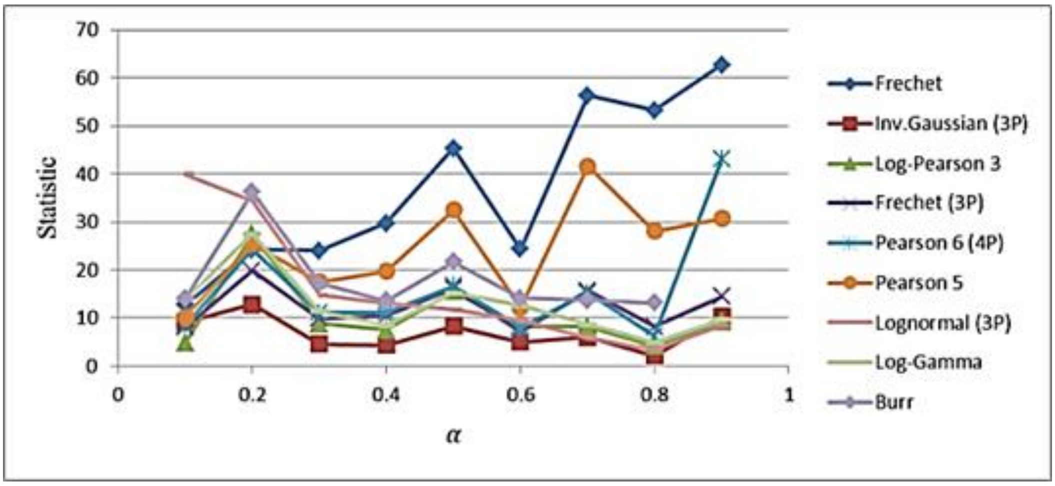

Fig. 5 Chi-Squared

4 Conclusion

The Laplace distribution is chosen for calculating the capital at day of n. The distribution according with the longest number of days with each risk level and the goodness of fit test is Inverse Gaussian (3P). At confidence level 0.1 and risk level 0.9 the maximum durability of investment in gold market is 15,383 days. The model applied for the durability of investment in gold market can be applied in insurance for further research.

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