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Kou 的跳躍擴散模型擴展：將雙伽瑪分佈的跳躍大小納入。

An Extension of Kou’s Jump-Diffusion Model to Incorporate Double-Gamma Distributed Jump Sizes

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本論文係胡祖望君（R10723059）在國立臺灣大學財務金融學系暨研究所完成之碩士學位論文，於民國 112 年 6 月 1 日承下列考試委員審查通過及口試及格，特此證明

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Abstract

This paper aims to extend Kou's Double Exponential Jump Diffusion model to the Double Gamma Jump Diffusion model. We employ the Fast Fourier Transform method to obtain option prices for both models and use finite difference methods to calculate the Greeks. The Greeks are then utilized for hedging investment portfolios. We know that exponential distribution is a special case of the Gamma distribution. The results show that extending the model to the Double Gamma not only reproduces the results of Kou's model but also provides enhanced flexibility in simulating market behavior, allowing for fine-tuning of the model.

Keywords: Jump diffusion model, Exponential distribution, Gamma distribution, option value, Greeks, hedging

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摘要

本論文主要在研究在將 Kou 的雙指數跳躍擴展成雙伽瑪跳躍擴散模型。我們採用快速傅立葉轉換方法來獲取兩個模型的選擇權價格，並使用有限差分法計算希臘字。這些希臘字被應用於對投資組合進行避險。我們知道指數分佈是伽瑪分佈的一個特例。結果顯示，將模型擴展為雙伽瑪模型不僅能夠再現 Kou 模型的結果，還能擁有在模擬市場上的微調能力，使模型更靈活。

關鍵字：跳躍擴散模型、指數分佈、伽馬分佈、選擇權定價、希臘字、避險

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Denotation

SDE	stochastic differential equation
FFT	Fast Fourier Transform
CF	characteristic function
PDF	probability density function
CDF	cumulative distribution function
MGF	moment-generating function
DE	Double exponential distribution
DG	Double Gamma distribution

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Chapter 1 Introduction

1.1 Motivation

This study is about changing Kou' s jump diffusion model's [3]double exponential distribution to double gamma distribution. When the economy is good we can increase mean , when the market is very volatile we can increase variance. But even when the economy is good there are still bad days, and there are good days in a bad economy, by increasing p we can increase the probability of jumps jumping up. We know that double exponential distributions have three parameters, p, α_1 and α_2, when fix mean, variance and p, parameters for α_1, α_2 are fixed. But double gamma distribution has five parameters, p, α_1, β_1 and α_2, β_2, with two extra parameters when fix mean, variance and p DG has the flexibility to fine-tune the parameters to fit the market, where as DE's parameters is fixed and might be in conflict with the market. We can also replicate the results of double exponential simply by setting $\beta_1 = \beta_2 = 1$. The above reasons are why we want to generalize to double gamma.

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1.2 Jump diffusion model

In this section we will be going through the basics of the jump diffusion model. [4]

1.2.1 Stochastic Differential Equation for Stock price (S_t)

In jump-diffusion model, S_t is assumed to follow the following stochastic differential equation(SDE)

$$\frac{dS_t}{S_t} = \mu dt + \sigma dW_t + dJ_t \tag{1.1}$$

where

$$\begin{aligned} J_t &= \sum_{j=1}^{N_t}(Y_t - 1) \\ W_t &\sim \text{Normal}(0, t) \\ N_t &\sim \text{Poisson}(\lambda t) \end{aligned} \tag{1.2}$$

for the jump part $dS_t = Y_t S_t - S_t$, we can write as $\frac{dS_t}{S_t} = Y_t - 1$ the SDE can be written as

$$\frac{dS_t}{S_t} = \mu dt + \sigma dW_t + (Y_t - 1)dN_t - \lambda k dt \tag{1.3}$$

where $E[(Y_t - 1)dN] = E[Y_t - 1]E[dN_t] = k \times \lambda dt$

equation (1.3) can futher be written as

$$\frac{dS_t}{S_t} = (\mu - \lambda k)dt + \sigma dW_t + \prod_{j=1}^{dN_t}(Y_j - 1) \tag{1.4}$$

by applying $It\hat{o}'s$ lemma we get

$$d\text{ln}S_t = \frac{1}{S_t}dS_t + \frac{1}{2}\frac{1}{S_t^2}dS_t^2 + \text{ln}(\prod_{j=1}^{dN_t} S_t Y_j) - \text{ln}(S_t) \tag{1.5}$$

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$$= \frac{1}{S_t}dS_t + \frac{1}{2}\frac{1}{S_t^2}dS_t^2 + \sum_{j=1}^{dN_t} \ln(Y_j) \tag{1.6}$$

and since we know what $\frac{dS_t}{S_t}$ looks like, we can insert it into equation (1.6)

$$d\ln S_t = (\mu - \lambda k - \frac{1}{2}\sigma^2)dt + \sigma dW_t + \sum_{j=1}^{dN_t} \ln(Y_j) \tag{1.7}$$

$$\begin{aligned} \ln S_t - \ln S_0 &= (\mu - \lambda k - \frac{1}{2}\sigma^2)t + \sigma(W_t - W_0) + \sum_{j=1}^{N_t - N_0} \ln(Y_j) \\ &= (\mu - \lambda k - \frac{1}{2}\sigma^2)t + \sigma W_t + \sum_{j=1}^{N_t} \ln(Y_j) \end{aligned} \tag{1.8}$$

we can rewite it in a different form to make it more elegant

$$S_t = S_0 e^{v_t + \sigma W_t + X_t} \tag{1.9}$$

where

$$\begin{aligned} v_t &= (\mu - \lambda k - \frac{1}{2}\sigma^2)t \\ X_t &= \sum_{j=1}^{N_t} \ln(Y_j) \end{aligned} \tag{1.10}$$

1.2.2 Return distribution

The return distribution the the log of the fuure stock price minus the log of the current stock price.

$$R_t = \ln(\frac{S_t}{S_0}) = v_t + \sigma W_t + X_t \tag{1.11}$$

1.2.3 Martingale condition

In risk neutral world

$$E^Q[S_t] = S_0 e^{(r-q)t} \tag{1.12}$$

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or equivalenty

$$
\begin{aligned}
&E^Q[e^{R_t}] = e^{(r-q)t} \\
&E^Q[e^{v_t+\sigma W_t+X_t}] = e^{(r-q)t} \\
&e^{(\mu-0.5\sigma^2)t} * E^Q[e^{\sigma W_t}] * E^Q[e^{X_t}] = e^{(r-q)t} \\
&\mu = r - q - \frac{\ln(E^Q[e^{X_t}])}{t} = r - q - \lambda k
\end{aligned}
\tag{1.13}
$$

here we get $\mu = r - q - \lambda k$, and therefore

$$v_t = (r - q - \lambda k - \frac{1}{2}\sigma^2)t \tag{1.14}$$

where

$$k = E^Q[e^{\ln Y}] - 1 \tag{1.15}$$

1.3 Fast Fourier Transform

1.3.1 Methodology

We will be using a numerical approach for pricing options which utilizes the characteristic function of the underlying assets' s price process. This method has been introduced by Carr and Madan(1999)[2] and is based on Fast Fourier Transform (FFT) [5] [1]. There are two reasons to use FFT. First, the algorithm offers a speed advantage. Second, the characteristic function (CF) of the log price is known and has a simple form while the density is often not known in the closed form. This method assumes that the CF of the log-price is given analytically. The basic idea of the method is to develop analytical expression for the Fourier transform of the option price and to get the price by Fourier inversion.

Fourier transform and its inversion works for square-integral functions therefore we can't directly use option price but we can with a modification of it. Let $C_T(k)$ denote the price

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of a European call option with maturity T, stock price S = exp(s) and strike K = exp(k):

$$C_T(k) = e^{-rT}E^Q[(S-K)^+] = \int_k^\infty e^{-rT}(e^s - e^k)q_T(s)ds \tag{1.16}$$

where q_T is the risk-neutral density of $s_T = \log S_T$. The function C_T is not square-integrable because $C_T(k)$ converges to S0 for $k \to -\infty$. Hence, we consider a modified function:

$$c_T(k) = \exp(\alpha k)C_T(k) \tag{1.17}$$

which is square-integrable for a suitable $\alpha > 0$. The choice of α or the damping factor, may depend on the model for S_t. The Fourier transform of c_T is defined by:

$$\begin{aligned}
\psi_T(v) &= \int_{-\infty}^{\infty} e^{ivk}c_T(k)dk \\
&= \int_{-\infty}^{\infty} e^{ivk}\int_k^\infty e^{\alpha k}e^{-rT}(e^s - e^k)q_T(s)dsdk \\
&= \int_{-\infty}^{\infty} e^{-rT}q_T(s)ds\int_{-\infty}^{s}(e^{\alpha k+s} - e^{(\alpha+1)k})e^{ivk}dk \\
&= \int_{-\infty}^{\infty} e^{-rT}q_T(s)(\frac{e^{(\alpha+1+iv)s}}{\alpha+iv} - \frac{e^{(\alpha+1+iv)s}}{\alpha+1+iv})ds \\
&= \frac{e^{-rT}\Phi_T(v-((\alpha+1)i))}{(\alpha+iv)(\alpha+1+iv)}
\end{aligned} \tag{1.18}$$

where ψ_T is the Fourier transform of q_T.

Now, we get the option price in terms of ψ_T using Fourier inversion

$$\begin{aligned}
C_T(k) &= \exp(-\alpha k) * c_T(k) \\
&= \frac{\exp(-\alpha k)}{2\pi}\int_{-\infty}^{\infty} e^{-ivk}\psi(v)dv
\end{aligned} \tag{1.19}$$

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This integral can be computed numerically by using the Trapezoidal Rules:

$$\begin{aligned} C_T(k) &\approx \frac{\exp(-\alpha k)}{\pi} \int_0^B e^{-ivk} \psi(v) dv \\ &\approx \frac{\exp(-\alpha k)}{\pi} \sum_{j=1}^{N} e^{-iv_j k} \psi(v_j) w_j \end{aligned} \tag{1.20}$$

where $v_j = \eta(j-1)$, $\eta = B/N$ and

$$w_j = \begin{cases} \eta/2 & \text{if } j = 1 \\ \eta & \text{otherwise} \end{cases}$$

1.3.2 Characteristic function

1.3.2.1 General form for jump diffusion model

The characteristic function for a function $f(x)$ is

$$\Phi_T(v) = \int_{-\infty}^{\infty} e^{ivx} f(x) dx = E[e^{ivf(x)}] \tag{1.21}$$

from sections above we know that N_t is Poisson distributed

$$P[N_t = n] = e^{-\lambda t} \frac{(\lambda t)^n}{n!} \tag{1.22}$$

Jump size is $J_t = \ln(Y_j)$ therefore jump diffusion model's f_t characteristic function is

$$\begin{aligned} \Phi_T(v) &= E[e^{ivf_t}] \\ &= e^{ivv_t t} * E[e^{iv\sigma W_t}] * E[e^{ivJ_t}] \\ &= \exp[ivv_t t - 0.5v^2\sigma^2 t + \lambda t \int [e^{iv\xi} - 1]\nu(\xi) d\xi] \\ &= \exp[ivv_t t - 0.5v^2\sigma^2 t + \lambda t(\phi_J(v) - 1)] \end{aligned} \tag{1.23}$$

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where,

$\nu(\xi)$ is the PDF of the jump size,

$\phi_J(v)$ is the characteristic function of $\nu(\xi)$

1.3.2.2 Different jump sizes

Now we will look at various jump distributions,their PDF, MGF, and derive their characteristic function.

1.3.2.3 Normal distribution

The PDF for Normal distribution is:

$$\nu(\xi) = \frac{1}{\sqrt{2\pi}\sigma_N}\text{exp}[-\frac{(\xi-\mu_N)^2}{2\sigma_N^2}] \tag{1.24}$$

The MGF for Normal distribution is:

$$E[e^{t\nu}] = \text{exp}[\mu_N t + 0.5\sigma_N^2 t^2] \tag{1.25}$$

The k in equation(1.15) is:

$$\begin{aligned} k_N &= E^Q[e^{\ln Y}] - 1 \\ &= E[e^{\nu}] - 1 \\ &= \text{exp}[\mu_N + 0.5\sigma_N^2] - 1 \end{aligned} \tag{1.26}$$

The characteristic function for Normal distribution is:

$$\phi_J(v) = \text{exp}[iv\mu_N - 0.5\sigma_N^2 v^2] \tag{1.27}$$

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Therefore the model's characteristic function is:

$$\Phi(v) = \exp[iv(r - q - \lambda k - 0.5\sigma^2)T - 0.5v^2\sigma^2 T + \lambda T(\exp[iv\mu_N - 0.5\sigma_N^2 v^2] - 1)] \tag{1.28}$$

1.3.2.4 Double exponential

The PDF for Double exponential distribution is:

$$\nu(\xi) = p\alpha_1 e^{-\alpha_1 \xi} 1_{\xi > 0} + (1 - p)\alpha_2 e^{\alpha_2 \xi} 1_{\xi \leq 0} \tag{1.29}$$

The MGF for Double exponential distribution is:

$$E[e^{t\nu}] = p(\frac{\alpha_1}{\alpha_1 - t}) + (1 - p)(\frac{\alpha_2}{\alpha_2 + t}) \tag{1.30}$$

The k in equation(1.15) is:

$$\begin{aligned} k_{exp} &= E^Q[e^{\ln Y}] - 1 = E[e^{\nu}] - 1 \\ &= p(\frac{\alpha_1}{\alpha_1 - 1}) + (1 - p)(\frac{\alpha_2}{\alpha_2 + 1}) - 1 \end{aligned} \tag{1.31}$$

The characteristic function for Double exponential distribution is:

$$\phi_J(v) = p(\frac{\alpha_1}{\alpha_1 - iv}) + (1 - p)(\frac{\alpha_2}{\alpha_2 + iv}) \tag{1.32}$$

Therefore the model's characteristic function is:

$$\Phi(v) = \exp[iv(r - q - \lambda k - 0.5\sigma^2)T - 0.5v^2\sigma^2 T + \lambda T(p(\frac{\alpha_1}{\alpha_1 - iv}) + (1 - p)(\frac{\alpha_2}{\alpha_2 + iv}) - 1)] \tag{1.33}$$

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The limitation factors for Double exponential are:

$$\alpha_1 > 1, \alpha_2 > 0 \tag{1.34}$$

1.3.2.5 Double gamma

The PDF for Double gamma distribution is:

$$\nu(\xi) = p\frac{\alpha_1^{\beta_1}}{\Gamma(\beta_1)}\xi^{\beta_1-1}e^{-\alpha_1\xi}1_{\xi>0} + (1-p)\frac{\alpha_2^{\beta_2}}{\Gamma(\beta_2)}(-\xi)^{\beta_2-1}e^{\alpha_2\xi}1_{\xi\leq 0} \tag{1.35}$$

The MGF for Double gamma distribution is:

$$E[e^{t\nu}] = p(1-\frac{t}{\alpha_1})^{-\beta_1} + (1-p)(1+\frac{t}{\alpha_2})^{-\beta_2} \tag{1.36}$$

The k in equation(1.15) is:

$$\begin{aligned} k_{gamma} &= E^Q[e^{\ln Y}] - 1 = E[e^{\nu}] - 1 \\ &= p(1-\frac{1}{\alpha_1})^{-\beta_1} + (1-p)(1+\frac{1}{\alpha_2})^{-\beta_2} - 1 \end{aligned} \tag{1.37}$$

The characteristic function for Double gamma distribution is:

$$\phi_J(v) = p(1-\frac{iv}{\alpha_1})^{-\beta_1} + (1-p)(1+\frac{iv}{\alpha_2})^{-\beta_2} \tag{1.38}$$

Therefore the model's characteristic function is:

$$\begin{aligned} \Phi(v) &= \exp[iv(r-q-\lambda k-0.5\sigma^2)T - 0.5v^2\sigma^2 T] \\ &* \exp[\lambda T(p(1-\frac{iv}{\alpha_1})^{-\beta_1} + (1-p)(1+\frac{iv}{\alpha_2})^{-\beta_2} - 1)] \end{aligned} \tag{1.39}$$

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The limitation factors for Double gamma are:

$$\begin{aligned}
&\alpha_1 > 1, \alpha_2 > 0 \\
&\beta_1 > 0, \beta_2 > 0
\end{aligned} \tag{1.40}$$

1.4 Jump size distribution moments

To be able to fix mean and variance or any other moments we must first find out the analytical formula expressed by their parameters. With the analytical formulas, fixing mean and variance are just simple system of equations to be solved, and with computers we can get our answers quick and precise

1.4.1 Double exponential distribution moments

The following function is the PDF of double exponential distribution, the parameters are p, α_1 and α_2.

$$f(\xi) = p\alpha_1 e^{-\alpha_1 \xi} 1_{\xi>0} + (1-p)\alpha_2 e^{\alpha_2 \xi} 1_{\xi\leq 0} \tag{1.41}$$

Mean's analytical form is:

$$\text{mean}(p, \alpha_1, \alpha_2) = \mu = p\frac{1}{\alpha_1} + (1-p)\frac{1}{\alpha_2} \tag{1.42}$$

We will use μ to replace mean in the following equations.

Variance's analytical form is:

$$\begin{aligned}
\text{Variance}(p, \alpha_1, \alpha_2) &= \int_{-\infty}^{\infty} [x-\mu]^2 f(x)\mathrm{d}x \\
&= p\frac{\alpha_1\mu(\alpha_1\mu - 2) + 2}{\alpha_1^2} + (1-p)\frac{\alpha_2\mu(\alpha_1\mu + 2) + 2}{\alpha_2^2}
\end{aligned} \tag{1.43}$$

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Skewness's analytical form is:

$$
\begin{aligned}
\text{Skewness}(p, \alpha_1, \alpha_2) &= \int_{-\infty}^{\infty} [x-\mu]^3 f(x) \mathrm{d}x \\
&= p\frac{6-\alpha_1\mu(\alpha_1\mu(\alpha_1\mu-3)+6)}{\alpha_1^3} + \\
&(p-1)\frac{6+\alpha_2\mu(\alpha_2\mu(\alpha_2\mu+3)+6)}{\alpha_2^3}
\end{aligned}
\tag{1.44}
$$

Kurtosis's analytical form is:

$$
\begin{aligned}
\text{Kurtosis}(p, \alpha_1, \alpha_2) &= \int_{-\infty}^{\infty} [x-\mu]^4 f(x) \mathrm{d}x \\
&= p\frac{\alpha_1\mu(\alpha_1\mu(\alpha_1\mu(\alpha_1\mu-4)+12)-24)+24}{\alpha_1^4} + \\
&(p-1)\frac{\alpha_2\mu(\alpha_2\mu(\alpha_2\mu(\alpha_2\mu+4)+12)+24)+24}{\alpha_2^4}
\end{aligned}
\tag{1.45}
$$

As we can see, all the moments of double exponential distribution is expressed by three parameters p, α_1 and α_2. If we would like to fix mean = 0 and variance = 1, once we fix p = 0.5 or any value we wish, there will only be one solution for α_1 and α_2.

1.4.2 Double gamma distribution moments

The following function is the PDF of double gamma distribution, the parameters are p, α_1, β_1, α_2 and β_2.

$$
f(\xi) = p\frac{\beta_1^{\alpha_1}}{\Gamma(\alpha_1)}\xi^{\alpha_1-1}e^{-\beta_1\xi}1_{\xi>0} + (1-p)\frac{\beta_2^{\alpha_2}}{\Gamma(\alpha_2)}(-\xi)^{\alpha_2-1}e^{\beta_2\xi}1_{\xi\leq 0}
\tag{1.46}
$$

The α in double gamma is the same as in double exponential, therefore by setting double gamma's $\beta_1 = \beta_2 = 1$, we will get double exponential.

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Mean's analytical form is:

$$\text{mean}(p, \alpha_1, \beta_1, \alpha_2, \beta_2) = \mu = p\frac{\alpha_1}{\beta_1} + (1-p)\frac{\alpha_2}{\beta_2} \tag{1.47}$$

We will use μ to replace mean in the following equations.

Variance's analytical form is:

$$\begin{aligned}\text{Variance}(p, \alpha_1, \beta_1, \alpha_2, \beta_2) &= \int_{-\infty}^{\infty} [x-\mu]^2 f(x)\mathrm{d}x \\ &= p(\frac{(\alpha_1+1)\alpha_1}{\beta_1^2} - \frac{2\mu\alpha_1}{\beta_1} + \mu^2) + \\ &(1-p)(\frac{(\alpha_2+1)\alpha_2}{\beta_2^2} + \frac{2\mu\alpha_2}{\beta_2} + \mu^2)\end{aligned} \tag{1.48}$$

Skewness's analytical form is:

$$\begin{aligned}\text{Skewness}(p, \alpha_1, \beta_1, \alpha_2, \beta_2) &= \int_{-\infty}^{\infty} [x-\mu]^3 f(x)\mathrm{d}x \\ &= p(\frac{(\alpha_1+2)(\alpha_1+1)\alpha_1}{\beta_1^3} - \frac{3\mu(\alpha_1+1)\alpha_1}{\beta_1^2} + \frac{3\mu^2\alpha_1}{\beta_1} - \mu^3) + \\ &(1-p)(\frac{-(\alpha_2+2)(\alpha_2+1)\alpha_2}{\beta_2^3} - \frac{3\mu(\alpha_2+1)\alpha_2}{\beta_2^2} - \frac{3\mu^2\alpha_2}{\beta_2} - \mu^3)\end{aligned} \tag{1.49}$$

Kurtosis's analytical form is:

$$\begin{aligned}&\text{Kurtosis}(p, \alpha_1, \beta_1, \alpha_2, \beta_2) = \int_{-\infty}^{\infty} [x-\mu]^4 f(x)\mathrm{d}x \\ &= p(\frac{(\alpha_1+3)(\alpha_1+2)(\alpha_1+1)\alpha_1}{\beta_1^4} - \frac{4\mu(\alpha_1+2)(\alpha_1+1)\alpha_1}{\beta_1^3} + \frac{6\mu^2(\alpha_1+1)\alpha_1}{\beta_1^2} - \frac{4\mu^3\alpha_1}{\beta_1} + \mu^4) + \\ &(1-p)(\frac{(\alpha_1+3)(\alpha_1+2)(\alpha_1+1)\alpha_1}{\beta_1^4} + \frac{4\mu(\alpha_1+2)(\alpha_1+1)\alpha_1}{\beta_1^3} + \frac{6\mu^2(\alpha_1+1)\alpha_1}{\beta_1^2} + \frac{4\mu^3\alpha_1}{\beta_1} + \mu^4)\end{aligned} \tag{1.50}$$

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1.5 Greeks and Greeks hedging

1.5.1 Greeks

Option Greeks are a set of risk measures used to assess the sensitivity of option prices to different factors. They help traders and investors understand the potential risks and rewards associated with options trading. Here are the main option Greeks:

1.5.1.1 Delta

Delta (Δ) is a measure of the sensitivity of an option’s price changes relative to the changes in the underlying asset’s price. In other words, if the price of the underlying asset increases by 1 dollar, the price of the option will change by Δ amount. Mathematically, the delta is found by:

$$\Delta = \frac{\partial V}{\partial S} \tag{1.51}$$

V –the option’s price (theoretical value)

S –the underlying asset’s price

Call options can have a delta from 0 to 1, while puts have a delta from -1 to 0. The closer the option’s delta to 1 or -1, the deeper in-the-money is the option.

1.5.1.2 Gamma

Gamma (Γ) is a measure of the delta’s change relative to the changes in the price of the underlying asset. If the price of the underlying asset increases by 1 dollar, the option’s delta will change by the gamma amount. The main application of gamma is the assessment

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of the option’ s delta.

$$\Gamma = \frac{\partial \Delta}{\partial S} = \frac{\partial^2 V}{\partial S^2} \tag{1.52}$$

Δ –the option’ s delta value

V –the option’ s price (theoretical value)

S –the underlying asset’ s price

Long options have a positive gamma. An option has a maximum gamma when it is at-the-money (option strike price equals the price of the underlying asset). However, gamma decreases when an option is deep-in-the-money or out-the-money.

1.5.1.3 Vega

Vega (ν) is an option Greek that measures the sensitivity of an option price relative to the volatility of the underlying asset. If the volatility of the underlying asses increases by 1 percent, the option price will change by the Vega amount.

$$\nu = \frac{\partial V}{\partial \sigma} \tag{1.53}$$

V –the option’ s price (theoretical value)

σ –the volatility of the underlying asset

The Vega is expressed as a money amount rather than as a decimal number. An increase in Vega generally corresponds to an increase in the option value (both calls and puts).

1.5.1.4 Theta

Theta (θ) is a measure of the sensitivity of the option price relative to the option’ s time to maturity. If the option’ s time to maturity decreases by one day, the option’ s price will

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change by the theta amount. The Theta option Greek is also referred to as time decay.

$$\theta = -\frac{\partial V}{\partial \tau} \tag{1.54}$$

V –the option' s price (theoretical value)

τ –the option' s time to maturity

In most cases, theta is negative for options. However, it may be positive for some European options. Theta shows the most negative amount when the option is at-the-money.

1.5.1.5 Rho

Rho (ρ) measures the sensitivity of the option price relative to interest rates. If a benchmark interest rate increases by 1 percent, the option price will change by the rho amount. The rho is considered the least significant among other option Greeks because option prices are generally less sensitive to interest rate changes than to changes in other parameters.

$$\rho = \frac{\partial V}{\partial r} \tag{1.55}$$

V –the option' s price (theoretical value)

r –interest rate

Generally, call options have a positive rho, while the rho for put options is negative.

1.5.1.6 Methodology to calculate Greeks

Calculating Greeks in Black-Scholes model is relatively easy, but when the model gets more and more complex, getting the analytic formula won't be easy, and since we can obtain option value with great speed and precision using FFT, we decide to use finite difference method to calculate Greeks.

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Finite difference method (FDM) is widely used in to solving partial differential equations. The essence of the method is that we will approximate the partial derivative representing the particular sensitivity of interest. As an example, let's assume we want to calculate the Delta of a call option. The Delta is given by $\frac{\partial C}{\partial S}(S, K, T, \sigma, r, q)$. If we calculate two call prices, one at spot and the other at spot, subtract the prices and divide by ΔS, we have a forward difference approximation to the derivative:

$$\frac{\partial C}{\partial S} \approx \frac{C(S + \Delta S, K, T, \sigma, r, q) - C(S, K, T, \sigma, r, q)}{\Delta S} \tag{1.56}$$

Each of the additional first order sensitivities (Vega, Rho and Theta) can be calculated in this manner by simply increment the correct parameter dimension. Gamma on the other hand is a second order derivative and so must be approximated in a different way. The usual approach in FDM is to use a central difference approximation to produce the following formula:

$$\frac{\partial^2 C}{\partial S^2} \approx \frac{C(S + \Delta S, K, T, \sigma, r, q) - 2 * C(S, K, T, \sigma, r, q) + C(S - \Delta S, K, T, \sigma, r, q)}{(\Delta S)^2} \tag{1.57}$$

1.5.2 Greeks hedging

To compare hedging results of Double exponential and Double gamma, we will fix mean, variance, Poisson lambda and probability. We will conduct two different hedging methods, delta hedging and delta gamma hedging. In all our portfolios (Π) we will be shorting 100 call options, and will be hedged by either delta hedging or delta gamma hedging.

Π: is portfolio

C: is call option

P: is put option

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S: is stock

$\Delta_{call/put/port}$: is delta value of a call or a put or a portfolio,

$\Gamma_{call/put/port}$: is gamma value of a call or a put or a portfolio

1. delta hedging

$$\Pi = -100 * C + 100 * \Delta_{call} * S \tag{1.58}$$

2. delta gamma hedging

$$\Pi = -100 * C + 100 * \frac{\Gamma_{call}}{\Gamma_{put}} * P + 100(-\Delta_{call} + \frac{\Gamma_{call}}{\Gamma_{put}} * \Delta_{put}) * S \tag{1.59}$$

Gamma for call and put is the same, the reason for this is because of put call parity, when differentiate by S twice we will get $\frac{\partial^2 C}{\partial S^2} = \frac{\partial^2 P}{\partial S^2}$, the numerical results by FDM, also supports that $\Gamma_{call} = \Gamma_{put}$, and therefore the portfolio can be written as :

$$\Pi = -100 * C + 100 * P + 100(-\Delta_{call} + \Delta_{put}) * S \tag{1.60}$$

Now we will be testing two things:

1. The change in portfolio value ($\Delta\Pi$):

Suppose that ΔS is the price change of an underlying asset during a small interval of time, Δt, and $\Delta\Pi$ is the corresponding price change in the portfolio.

For example at S = 100, with K = 90, call value = 2, put value = 1, call position = -100, put position = 100, stock position = 50,

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and when S increases to 110, call value = 3, put value = 0.5,

$$\begin{aligned}\Delta\Pi &= -100 * (C_{S=110} - C_{S=100}) + 100 * (P_{S=110} - P_{S=100}) + 50(S_{S=110} - S_{S=100}) \\ &= -100 * (3 - 2) + 100 * (0.5 - 1) + 50(110 - 100) \\ &= -100 - 50 + 500 = 350\end{aligned} \tag{1.61}$$

2. The difference in hedging ($\Pi_{diff}(x)$):

Because $\Delta\Pi$ for delta hedging and delta gamma hedging are weirdly shaped curves, we can't just compare them, so instead we will compare them by $\Pi_{diff}(x)$.

$$\Pi_{diff}(x) = \Delta\Pi_{100+x} - \Delta\Pi_{100-x} \tag{1.62}$$

$$\Pi_{diff}(10) = \Delta\Pi_{110} - \Delta\Pi_{90} \tag{1.63}$$

We will use this method to see if tomorrow the stock price are to change by 10 dollars but we don't know it's up or down, we want to know how big a margin it can be.

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Chapter 2 Kou's model

2.1 Sanity test

First we will compare our results with the results in Jari Toivanen(2008) [6] to make sure that our FFT method is correct. We will price European call options with the following parameters:

$K = 100, \sigma = 0.15, r = 0.05, q = 0, T = 0.25$

$\lambda = 0.1, M1 = 3.0465, M2 = 3.0775, p = 0.3445$

Stock price	Jari Toivanen results	$N = 2 * 10^{14}, \eta = 0.01, M = 0.05$	error
90	0.672677	0.672677331	3.31e-07
100	3.973479	3.973478849	1.5e-07
110	11.794583	11.79458299	9.74e-09

Table 2.1: Testing results.

We can see that the results of our FFT pricing method has the same results as in Jari Toivanen(2008)'s paper, meaning our FFT pricing method is valid and can proceed.

2.2 DE distribution

Since we are extending Kou's double exponential jump model to double gamma distributions, we need a way to compare different distributions and different parameters. First

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our method is to set fix distribution's mean and variance and compare how they effect the model. Second we will be fixing p and change M_1, M_2, and vice versa fixing M_1, M_2 and change p. Here for double exponential we have three different parameters p, M_1, M_2 and we will be comparing them with each other and with different distributions.

Table. 2.2 shows the DE distribution with fix mean and variance, with the increase in mean and variance.

Table. 2.3 shows distribution with fix p and increasing M, the increase in M decreases variance and Kurtosis.

Table. 2.4 shows the DE distribution with fix M and changing p, the increase in p increases mean and Skewness, for variance and Kurtosis they are smallest at both ends and largest at the middle ($p = 0.5$).

In these tables we only show a part of the possible distributions, for mean = 0, var = 0.5 p can be 0.35 or 0.9, but can't be 0.95. The reason for this is that Equation. 1.42 and Equation. 1.43 are equations with three variables, once we fix p it becomes simple system of equations to be solved, we can solve these equations of course, but we've also have limitation factors for our parameters. Therefore for some p might not be a suitable parameter for the model. We found that the larger the mean or variance, solutions for smaller p might not be suitable, and vice versa.

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DE Distribution fixing mean and variance				
parameters	mean	variance	Skewness	Kurtosis
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0	0.5	0.6546	2.6428
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0	0.5	0.3061	1.75
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	0.5	0	1.5
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	0	0.5	-0.3061	1.75
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	0	0.5	-0.65465	2.6428
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0	1	0.8660	7
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0	1	0.42640	6.2424
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	1	0	6
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	0	1	-0.42640	6.2424
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	0	1	-0.8660	7
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	0	1	-1.3342	8.3736
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	1.5	0	13.5
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	0	1.5	-0.7833	14.0454
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	0	1.5	-1.5909	15.75
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	0	1.5	-2.4511	18.8406
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	0	1.5	-3.4016	23.7857
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	0	1.5	-4.5	31.5
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.5	0.5	0.7685	2.4594
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.5	0.5	0.6938	2.2253
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.5	0.5	0.6022	2.0197
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.5	0.5	0.48017	1.8847
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.5	0.5	0.2928	1.9865
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	0.5	1	1.2973	7.1678
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.5	1	0.9090	6.7665
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.5	1	0.4332	7.0057
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	0.5	1	-0.2011	8.5764
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	0.5	1	-1.1742	13.7670
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	0.5	1.5	-0.4469	17.4745
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	0.5	1.5	-1.8118	24.2208
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	0.5	1.5	-3.9056	42.2950
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	0.5	1.5	-8.2424	109.4764

Table 2.2: DE Distribution fixing mean and variance

DE Distribution fixing p and increasing M				
parameters	mean	variance	Skewness	Kurtosis
p = 0.5 ,$M_{e1} = M_{e2} = 1.2$	0.0	1.3888	0.0	11.5741
p = 0.5 ,$M_{e1} = M_{e2} = 1.4$	0.0	1.0204	0.0	6.2473
p = 0.5 ,$M_{e1} = M_{e2} = 1.6$	0.0	0.7812	0.0	3.6621
p = 0.5 ,$M_{e1} = M_{e2} = 1.8$	0.0	0.6172	0.0	2.2862
p = 0.5 ,$M_{e1} = M_{e2} = 2.0$	0.0	0.5	0.0	1.5
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.0	0.4132	0.0	1.0245
p = 0.5 ,$M_{e1} = M_{e2} = 2.4$	0.0	0.3472	0.0	0.7233
p = 0.5 ,$M_{e1} = M_{e2} = 2.6$	0.0	0.2958	0.0	0.5251
p = 0.5 ,$M_{e1} = M_{e2} = 2.8$	0.0	0.2551	0.0	0.3904
p = 0.5 ,$M_{e1} = M_{e2} = 3.0$	0.0	0.2222	0.0	0.2962

Table 2.3: DE Distribution fixing p and increasing M

DE Distribution fixing M and changing p				
parameters	mean	variance	Skewness	Kurtosis
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432

Table 2.4: DE Distribution fixing M and changing p

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2.3 DE call value

In this section we will be looking at how the Double exponential model call values change with the change in parameters.

2.3.1 DE call value fixing mean and variance

From Table. 2.5 where mean = 0, var = 1, we can see that $p = 0.4$ have a Skewness of 0.8660 and $p = 0.6$ have a Skewness of -0.8660 and both have the same Kurtosis of 7, meaning that the difference in call value is due to difference in Skewness. As we can see that the smaller the Skewness the larger the call value. In Figure. 2.1 shows the distribution of these two parameters, we can see that although $p = 0.6$ has a larger positive $p(x)$ than $p = 0.4$ but $p = 0.4$ has a fatter tail in the right, meaning that extreme upward jump events are more likely to happen. And for $p = 0.6$ has a fatter tail in the left, meaning that extreme downward jump events are more likely to happen. This is the reason that the smaller the Skewness the larger the call value.

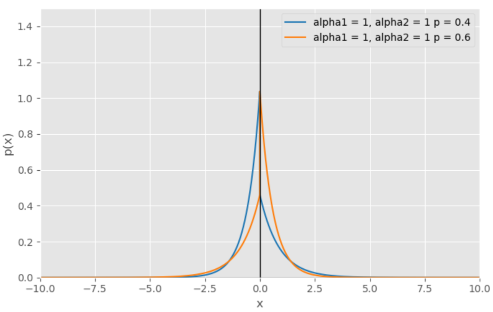

Figure 2.1: DE distribution fixing mean and variance - 1

In Figure. 2.2 legend from top to bottom is

mean = 0 var = 0.5 (Blue), mean = 0 var = 1 (Orange) , mean = 0 var = 1.5 (Green), mean = 0.5 var = 0.5 (Red), mean = 0.5 var = 1 (Purple), mean = 0.5 var = 1.5 (Brown).

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DE call value fixing mean and variance					
parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	3.8173	7.6725	13.9988
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	3.2453	7.2685	13.7794
p = 0.5, $M_{e1} = 2.0000$, $M_{e2} = 2.0000$	0	1.5	3.012	7.106	13.6924
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	2.8526	6.9907	13.6246
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	2.7137	6.8836	13.5534
mean = 0, variance = 1					
p = 0.40, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	6.5503	9.8194	15.38
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	4.87	8.5062	14.5573
p = 0.50, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	4.1806	7.9886	14.2468
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	3.786	7.6961	14.0723
p = 0.60, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	3.5162	7.4959	13.9509
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	3.3091	7.3406	13.8538
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	7.6519	10.7406	16.014
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	5.4839	8.9941	14.8769
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	4.5576	8.2816	14.4346
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	4.0183	7.8729	14.1819
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	3.6458	7.5906	14.0043
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	3.358	7.3702	13.8613
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	5.223	8.679	14.5066
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	5.0061	8.5186	14.4149
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	4.8111	8.3768	14.3375
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	4.6213	8.2382	14.261
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.2928	1.9865	4.4198	8.0881	14.1736
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	13.1296	15.633	19.5932
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	9.5464	12.3296	17.0408
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	7.6798	10.7203	15.904
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	6.4821	9.7294	15.2377
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	5.5869	9.0078	14.7646
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-0.4469	17.4745	13.9369	16.4305	20.2699
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-1.8118	24.2208	9.2284	12.0605	16.8552
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-3.9056	42.2950	6.9065	10.0779	15.4667
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-8.2424	109.4764	5.3785	8.8366	14.6434

Table 2.5: Call value of DE fixing mean and variance

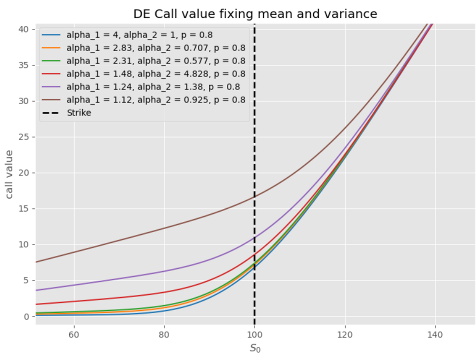

Figure 2.2: DE call value fixing mean and variance

It shows that under fix probability, that the larger the mean or variance the larger the call value, the call values converges at small S_0 and large S_0.

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In Table. 2.5 we can also see that when fixed mean and variance, with the increase in p the smaller the call value. This might sound counter-intuitive since p stands for the probability of jumps jumping upwards, shouldn't it lead to larger call value? The reason is that for DE once mean, variance and p are decided so does the distribution, and as p increases under fixed mean and variance, Skewness decrease and Kurtosis increases drastically, resulting in larger p has a fatter tail in the left and smaller p has a fatter tail in the right (shown in Figure. 2.3). Which is the reason why under fixed mean and variance, the increase in p results smaller call value.

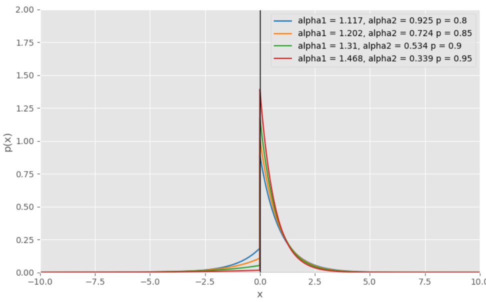

Figure 2.3: DE distribution fixing mean and variance - 2

2.3.2 DE call value fixing p and increasing M

Table. 2.6 and Figure. 2.5 shows the DE call value by fixing $p = 0.5$ and increasing M_1 and M_2 , the distributions are symmetric, with mean = 0 and Skewness = 0. In Figure. 2.4 shows the distribution of $M_1 = 1.2, 2, 3$ in Table. 2.6 , we can see that as M decreases, variance and Kurtosis increases, resulting in fatter tails and more extreme jump events are more likely to happen. This is the reason that the larger the variance and Kurtosis the larger the call value, which is shown in Figure. 2.5 .

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DE call value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	6.3758	9.6961	15.3209
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.2473	4.2521	8.0426	14.2801
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.6621	3.5612	7.5222	13.9586
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.2862	3.2179	7.2632	13.7949
p = 0.5, $M_{e1} = M_{e2} = 2.0$	0.5	1.5	3.012	7.106	13.6924
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	2.8745	6.9995	13.6206
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.7233	2.7761	6.9219	13.5668
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.5251	2.7021	6.8626	13.5245
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.3904	2.6445	6.8157	13.4902
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	2.5984	6.7776	13.4618

Table 2.6: DE call value fixing p and increasing M

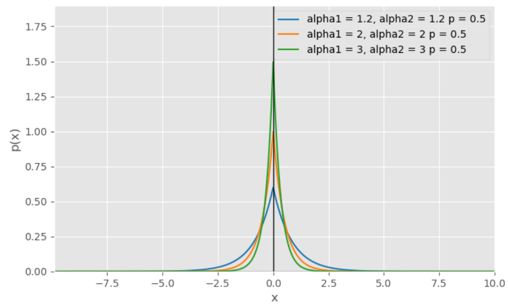

Figure 2.4: DE distribution fixing p and changing alpha

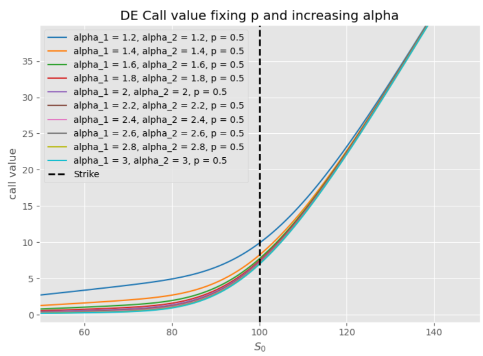

Figure 2.5: DE call value fixing p and increasing M

2.3.3 DE call value fixing M and increasing p

Table. 2.7 and Figure. 2.7 shows DE call value by fixing $M_1 = M_2$ and increasing p. In Figure. 2.6 shows the distribution of $p = 0.1, 0.5, 0.9$ in Table. 2.7 , mean and Skewness increases, while variance and Kurtosis are small at both ends and largest at p = 0.5. As p increases, positive $p(x)$ increases and creates fatter tails. This is the reason that with fixed M the larger the p the larger the call value, which is shown in Figure. 2.7 .

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DE call value for fixing M and changing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	2.5313	6.8365	13.6435
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	2.65	6.9013	13.6536
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	2.7697	6.9678	13.6651
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	2.8904	7.0361	13.678
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	3.012	7.106	13.6924
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	3.1346	7.1778	13.7083
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	3.2581	7.2512	13.7257
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	3.3824	7.3263	13.7447
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	3.5075	7.4031	13.7652

Table 2.7: DE call value for fixing M and changing p

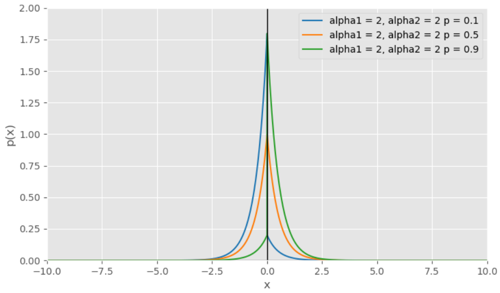

Figure 2.6: DE distribution fixing alpha and changing p

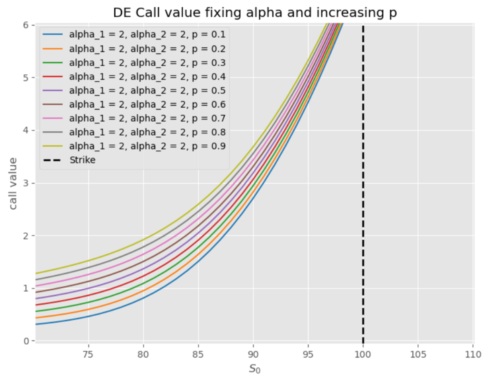

Figure 2.7: DE call value fixing M and increasing p

2.3.4 DE call value conclusion

The results on DE call values are the following. We know that the larger the mean, variance, Skewness and Kurtosis, the larger the call value. Under fixed mean and variance, the increase in p results in decrease in call value. Under fixed M, as p increases, mean,Skewness and call value increases, while variance and Kurtosis are small at both ends and largest at p = 0.5. Under fixed p, as M increases, variance, Kurtosis and call value decreases.

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2.4 DE Greeks

In this section we will be looking at how the Double exponential model Greeks values change with the change in parameters.

2.4.1 DE Greeks value fixing mean and variance

Table. 2.8, Table. 2.9, Table. 2.10, Table. 2.11, Table. 2.12 shows the DE Delta, Gamma, Vega, Theta, and Rho value by fixing mean and variance.Figure. 2.8, Figure. 2.9 , Figure. 2.10 , Figure. 2.11 , Figure. 2.12 shows the results of the data in the Tables above.

Double exponential delta value for fix mean and variance					
parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	0.2635	0.513	0.741
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	0.2763	0.5322	0.7575
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	1.5	0.2819	0.5401	0.7642
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	0.2854	0.5451	0.7684
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	0.2877	0.5488	0.7717
mean = 0, variance = 1					
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	0.226	0.4387	0.6682
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	0.2494	0.4857	0.7155
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	0.2614	0.5064	0.7347
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	0.2688	0.5184	0.7454
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	0.274	0.5265	0.7525
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	0.2779	0.5325	0.7578
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	0.2171	0.413	0.639
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	0.2417	0.4694	0.6995
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	0.256	0.4959	0.725
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	0.2653	0.5116	0.7394
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	0.2717	0.5222	0.7489
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	0.2766	0.5301	0.7559
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	0.2373	0.4634	0.6949
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	0.2413	0.4702	0.7013
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	0.2451	0.4766	0.7073
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	0.2487	0.4828	0.7131
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.2928	1.9865	0.2524	0.489	0.719
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	0.2026	0.3115	0.4885
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	0.2047	0.3659	0.5785
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	0.2155	0.4054	0.6296
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	0.2265	0.4343	0.6629
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	0.2368	0.4574	0.6875
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-0.4469	17.4745	0.2067	0.3048	0.4718
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-1.8118	24.2208	0.2073	0.3729	0.5876
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-3.9056	42.2950	0.2227	0.4236	0.6508
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-8.2424	109.4764	0.2392	0.4621	0.6924

Table 2.8: Double exponential delta value for fix mean and variance

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Double exponential gamma value for fix mean and variance

parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	0.0222	0.0255	0.0189
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	0.0234	0.0257	0.0184
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	1.5	0.0238	0.0258	0.0181
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	0.0241	0.0258	0.018
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	0.0243	0.0258	0.0179
mean = 0, variance = 1					
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	0.0172	0.0237	0.0207
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	0.0204	0.025	0.0197
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	0.0215	0.0252	0.0192
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	0.0224	0.0255	0.01887
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	0.0229	0.0256	0.0186
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	0.0232	0.0257	0.01847
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	0.0152	0.0225	0.0211
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	0.0192	0.0246	0.0201
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	0.0209	0.0252	0.0195
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	0.0219	0.0254	0.0191
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	0.0225	0.0255	0.0188
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	0.023	0.0256	0.0185
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	0.019	0.0246	0.0204
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	0.0194	0.0247	0.0202
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	0.0197	0.0248	0.02
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	0.0201	0.0249	0.0199
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.2928	1.9865	0.0205	0.025	0.0197
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	0.0069	0.0149	0.0195
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	0.0117	0.0199	0.0212
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	0.0147	0.0222	0.0212
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	0.0167	0.0234	0.0209
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	0.0183	0.0242	0.0205
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-0.4469	17.4745	0.0061	0.0137	0.0188
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-1.8118	24.2208	0.0121	0.0203	0.0212
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-3.9056	42.2950	0.0159	0.023	0.021
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-8.2424	109.4764	0.0186	0.0243	0.0204

Table 2.9: Double exponential gamma value for fix mean and variance

Double exponential Vega value for fix mean and variance

parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	6.7844	9.5913	8.601
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	7.1077	9.6463	8.337
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	1.5	7.2315	9.6596	8.2299
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	7.3101	9.67	8.1677
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	7.3757	9.684	8.126
mean = 0, variance = 1					
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	5.2578	8.9096	9.4101
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	6.2021	9.3846	8.946
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	6.5897	9.5151	8.6947
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	6.8059	9.5715	8.5406
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	6.9486	9.603	8.4351
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	7.0541	9.6243	8.3571
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	4.6591	8.4876	9.5752
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	5.8441	9.2233	9.1349
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	6.36	9.4368	8.8386
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	6.6538	9.5297	8.6452
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	6.8501	9.581	8.5084
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	6.9969	9.6151	8.4048
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	5.7621	9.2203	9.2513
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	5.8852	9.2666	9.1672
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	5.9985	9.3087	9.0895
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	6.1073	9.3499	9.0184
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.2928	1.9865	6.2189	9.3924	8.9491
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	2.1092	5.5717	8.8592
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	3.544	7.462	9.6232
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	4.4564	8.3227	9.6186
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	5.0847	8.7888	9.4659
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	5.5657	9.0809	9.2812
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-6.0378	92.1168	0.0208	0.0221	0.0233
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-11.4973	134.0377	0.0335	0.0331	0.0332
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-19.8727	236.9716	0.0868	0.4261	1.6345
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-37.2196	598.8992	1.0846	3.6236	7.1802

Table 2.10: Double exponential Vega value for fix mean and variance

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Double exponential theta value for fix mean and variance					
parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	-15.2481	-18.2497	-16.3031
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	-13.3687	-16.6802	-15.0686
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	1.5	-12.6052	-16.0587	-14.5948
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	-12.0804	-15.625	-14.2579
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	-11.6212	-15.2296	-13.9351
mean = 0, variance = 1					
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	-24.4825	-26.7232	-23.6932
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	-18.7531	-21.4624	-19.1201
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	-16.4438	-19.4292	-17.4258
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	-15.1329	-18.2955	-16.4965
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	-14.239	-17.5272	-15.8694
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	-13.5531	-16.9365	-15.3847
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	-28.2395	-30.3999	-27.1145
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	-20.7964	-23.3667	-20.8099
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	-17.6712	-20.5548	-18.4126
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	-15.8695	-18.9666	-17.0829
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	-14.6313	-17.8826	-16.1787
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	-13.6764	-17.0449	-15.4757
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	-19.7254	-22.2095	-19.5697
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	-18.9772	-21.543	-19.0113
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	-18.3102	-20.9587	-18.5308
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	-17.6648	-20.3969	-18.0723
p = 0.9, $M_{e1} = 1.6185$, $M_2 = 1.78361$	0.2928	1.9865	-16.9817	-19.7994	-17.5809
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	-46.6857	-46.8831	-47.1404
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	-34.4713	-34.6086	-33.3246
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	-28.0187	-28.1323	-27.0105
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	-23.8904	-23.9903	-23.3212
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	-20.8267	-20.9165	-20.7422
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-6.0378	92.1168	-103.9799	-106.8435	-130.4072
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-11.4973	134.0377	-118.7518	-120.5914	-148.2132
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-19.8727	236.9716	-87.6051	-88.3545	-106.9482
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-37.2196	598.8992	-57.0623	-57.3663	-61.8027

Table 2.11: Double exponential theta value for fix mean and variance

Double exponential rho value for fix mean and variance					
parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
mean = 0, variance = 0.5					
p = 0.3, $M_{e1} = 1.3093$, $M_{e2} = 3.0550$	0.6546	2.6428	4.9744	10.9066	16.877
p = 0.4, $M_{e1} = 1.6329$, $M_{e2} = 2.4494$	0.3061	1.75	5.4054	11.4879	17.3852
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	0	1.5	5.5899	11.7267	17.5913
p = 0.6, $M_{e1} = 2.4494$, $M_{e2} = 1.6329$	-0.3061	1.75	5.7078	11.8795	17.7258
p = 0.7, $M_{e1} = 3.0550$, $M_{e2} = 1.3093$	-0.65465	2.6428	5.7956	11.9981	17.8342
mean = 0, variance = 1					
p = 0.4, $M_{e1} = 1.1547$, $M_{e2} = 1.7320$	0.8660	7	3.4478	8.5132	14.5306
p = 0.45, $M_{e1} = 1.2792$, $M_{e2} = 1.5634$	0.42640	6.2424	4.393	10.015	16.0363
p = 0.5, $M_{e1} = 1.4142$, $M_{e2} = 1.4142$	0	6	4.8361	10.6626	16.6412
p = 0.55, $M_{e1} = 1.5634$, $M_{e2} = 1.2792$	-0.42640	6.2424	5.1021	11.0363	16.9805
p = 0.6, $M_{e1} = 1.7320$, $M_{e2} = 1.1547$	-0.8660	7	5.2858	11.2888	17.2068
p = 0.65, $M_{e1} = 1.9272$, $M_{e2} = 1.0377$	-1.3342	8.3736	5.4246	11.4775	17.3754
mean = 0, variance = 1.5					
p = 0.5, $M_{e1} = 1.1547$, $M_{e2} = 1.1547$	0	13.5	2.9717	7.6406	13.568
p = 0.55 ,$M_{e1} = 1.2765$, $M_{e2} = 1.0444$	-0.7833	14.0454	4.0678	9.4859	15.5175
p = 0.6 ,$M_{e1} = 1.4142$, $M_{e2} = 0.9428$	-1.5909	15.75	4.6215	10.3265	16.3288
p = 0.65 , $M_{e1} = 1.5735$, $M_{e2} = 0.8473$	-2.4511	18.8406	4.9635	10.821	16.7876
p = 0.7 ,$M_{e1} = 1.7638$, $M_{e2} = 0.7559$	-3.4016	23.7857	5.2028	11.1579	17.0942
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	-4.5	31.5	5.3849	11.4112	17.3227
mean = 0.5, variance = 0.5					
p = 0.7, $M_{e1} = 1.3671$, $M_{e2} = 24.9614$	0.7685	2.4594	4.0337	9.4149	15.4839
p = 0.75 ,$M_{e1} = 1.4202$, $M_{e2} = 8.8989$	0.6938	2.2253	4.1776	9.6261	15.6823
p = 0.8, $M_{e1} = 1.4775$, $M_{e2} = 4.82842$	0.6022	2.0197	3.9089	9.3519	15.3259
p = 0.85 ,$M_{e1} = 1.5419$, $M_{e2} = 2.9271$	0.48017	1.8847	4.4411	10.0106	16.0448
p = 0.9, $M_{e1} = 1.6185$, $M_{e2} = 1.78361$	0.2928	1.9865	4.5733	10.2035	16.2284
mean = 0.5, variance = 1					
p = 0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	1.2973	7.1678	1.2759	3.8784	8.5347
p = 0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	0.9090	6.7665	2.2192	6.0655	11.648
p = 0.85 ,$M_{e1} = 2.7487$, $M_{e2} = 0.4850$	0.4332	7.0057	2.9283	7.4542	13.3382
p = 0.9 ,$M_{e1} = 3.4641$, $M_{e2} = 0.3849$	-0.2011	8.5764	3.4756	8.4257	14.4204
p = 0.95 ,$M_{e1} = 5.0332$, $M_{e2} = 0.2649$	-1.1742	13.7670	3.931	9.1827	15.2153
mean = 0.5, variance = 1.5					
p = 0.8 ,$M_{e1} = 1.1169$, $M_{e2} = 0.9249$	-6.0378	92.1168	0.1855	0.2006	0.215
p = 0.85 ,$M_{e1} = 1.2017$, $M_{e2} = 0.7236$	-11.4973	134.0377	0.3812	0.4046	0.4256
p = 0.9 ,$M_{e1} = 1.3097$, $M_{e2} = 0.5342$	-19.8727	236.9716	0.4887	0.6354	1.2207
p = 0.95 ,$M_{e1} = 1.4676$, $M_{e2} = 0.3394$	-37.2196	598.8992	0.9544	2.488	5.9029

Table 2.12: Double exponential rho value for fix mean and variance

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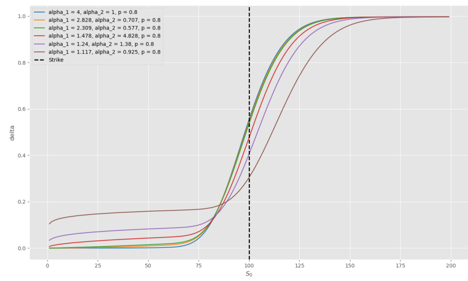

Figure 2.8: DE Delta value for fix mean and variance

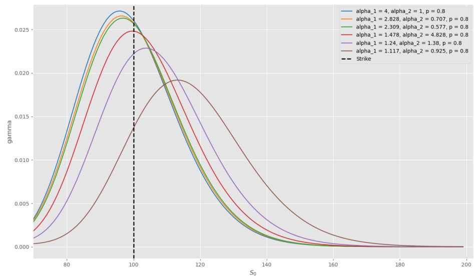

Figure 2.9: DE Gamma value for fix mean and variance

In Figure. 2.8 shows the DE delta value as we increase mean and variance. We can see that as mean and variance increases delta value curves shifts right and at far OTM delta value increases.

In Figure. 2.9 shows the DE gamma value as we increase mean and variance. We can see that as mean and variance increases gamma value curves shifts right and decreases in height.

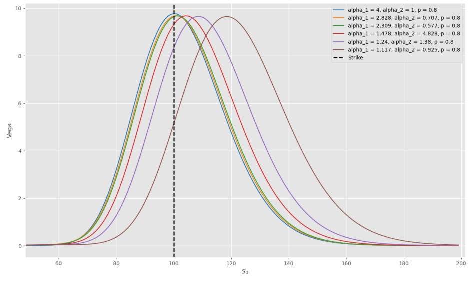

Figure 2.10: DE Vega value for fix mean and variance

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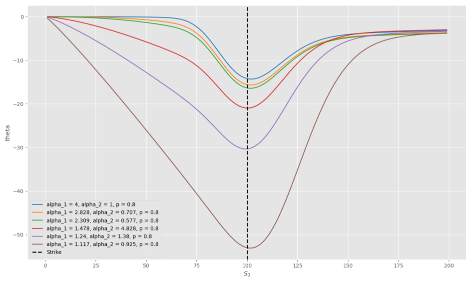

Figure 2.11: DE Theta value for fix mean and variance

In Figure. 2.10 shows the DE Vega value as we increase mean and variance. We can see that as mean and variance increases Vega value curves shifts right.

In Figure. 2.11 shows the DE theta value as we increase mean and variance. We can see that as mean and variance increases theta value curves shifts down.

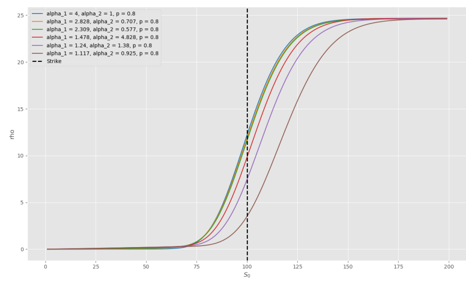

Figure 2.12: DE Rho value for fix mean and variance

In conclusion we can see that the larger the mean, variance, Skewness or Kurtosis the more right the Delta, Gamma, Vega, and Rho curves and the lower (smaller) the Theta curves are.

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2.4.2 DE Greeks value fixing p and increasing M

Table. 2.13, Table. 2.14, Table. 2.15, Table. 2.16, Table. 2.17 shows DE Delta, Gamma, Vega, Theta, and Rho value by fixing p and increasing M. Figure. 2.13, Figure. 2.14 , Figure. 2.15 , Figure. 2.16 , Figure. 2.17 shows the results of the data in the Tables above.

DE delta value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	0.2298	0.4449	0.6744
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.24739	0.2602	0.5043	0.7327
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.66210	0.2723	0.5246	0.7508
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.28623	0.2784	0.5344	0.7593
p = 0.5, $M_{e1} = M_{e2} = 2.0$	0.5	1.5	0.2819	0.5401	0.7642
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	0.2841	0.5437	0.7672
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.72337	0.2856	0.5462	0.7694
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.52519	0.2866	0.548	0.7709
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.39046	0.2873	0.5493	0.772
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	0.2878	0.5502	0.7729

Table 2.13: DE delta value fixing p and increasing M

DE gamma value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	0.0176	0.0239	0.0206
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.24739	0.0216	0.0253	0.0192
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.66210	0.0228	0.0256	0.0186
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.28623	0.0234	0.0257	0.0183
p = 0.5, $M_1 = M_{e2} = 2.0$	0.5	1.5	0.0238	0.0258	0.0181
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	0.024	0.0258	0.018
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.72337	0.0242	0.0258	0.0179
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.52519	0.0243	0.0258	0.0179
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.39046	0.0244	0.0259	0.0179
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	0.0245	0.0259	0.0178

Table 2.14: DE gamma value fixing p and increasing M

DE Vega value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	5.3515	8.9602	9.3624
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.24739	6.5494	9.5029	8.7217
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.66210	6.9354	9.6036	8.4505
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.28623	7.1221	9.6405	8.3114
p = 0.5, $M_{e1} = M_{e2} = 2.0$	0.5	1.5	7.2315	9.6596	8.2299
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	7.303	9.672	8.178
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.72337	7.3534	9.6812	8.143
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.52519	7.3909	9.6887	8.1185
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.39046	7.4198	9.6952	8.101
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	7.4429	9.701	8.0881

Table 2.15: DE Vega value fixing p and increasing M

DE theta value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	-23.8494	-26.1834	-23.2701
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.24739	-16.6809	-19.6389	-17.6022
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.66210	-14.4018	-17.6349	-15.9223
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.28623	-13.278	-16.6509	-15.0965
p = 0.5, $M_{e1} = M_{e2} = 2.0$	0.5	1.5	-12.6052	-16.0587	-14.5948
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	-12.1557	-15.6594	-14.2528
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.72337	-11.8334	-15.3704	-14.0023
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.52519	-11.5908	-15.1506	-13.8098
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.39046	-11.4016	-14.9774	-13.6566
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	-11.2499	-14.8372	-13.5316

Table 2.16: DE theta value fixing p and increasing M

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DE rho value fixing p and increasing M					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	1.3888	11.5741	3.5764	8.6983	14.7173
p = 0.5, $M_{e1} = M_{e2} = 1.4$	1.0204	6.24739	4.7908	10.5966	16.5805
p = 0.5, $M_{e1} = M_{e2} = 1.6$	0.7812	3.66210	5.2358	11.2338	17.1571
p = 0.5, $M_{e1} = M_{e2} = 1.8$	0.6172	2.28623	5.459	11.5453	17.4321
p = 0.5, $M_{e1} = M_{e2} = 2.0$	0.5	1.5	5.5899	11.7267	17.5913
p = 0.5, $M_{e1} = M_{e2} = 2.2$	0.4132	1.0245	5.6741	11.8439	17.6941
p = 0.5, $M_{e1} = M_{e2} = 2.4$	0.3472	0.72337	5.7317	11.9248	17.7657
p = 0.5, $M_{e1} = M_{e2} = 2.6$	0.2958	0.52519	5.7729	11.9835	17.8181
p = 0.5, $M_{e1} = M_{e2} = 2.8$	0.2551	0.39046	5.8032	12.0276	17.858
p = 0.5, $M_{e1} = M_{e2} = 3.0$	0.2222	0.2962	5.8262	12.0617	17.8894

Table 2.17: DE rho value fixing p and increasing M

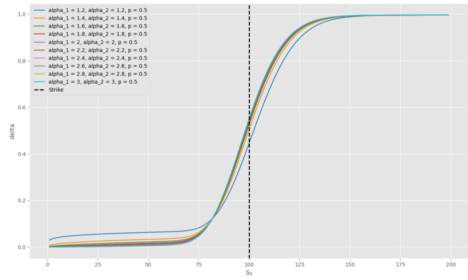

Figure 2.13: DE delta value fixing p and increasing M

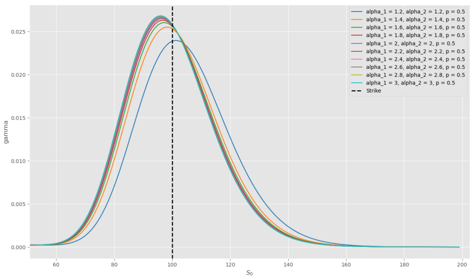

Figure 2.14: DE gamma value fixing p and increasing M

In Figure. 2.13 shows the DE delta value as we increase M. We can see that as M increases delta value curves shifts left and at far OTM delta value decreases.

In Figure. 2.14 shows the DE gamma value as we increase M. We can see that as M increases gamma value curves shifts right and decreases in height.

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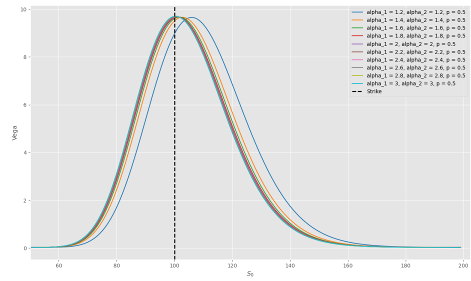

Figure 2.15: DE Vega value fixing p and increasing M

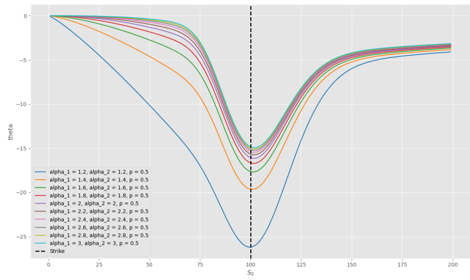

Figure 2.16: DE theta value fixing p and increasing M

In Figure. 2.15 shows the DE Vega value as we increase M. We can see that as M increases Vega value curves shifts right.

In Figure. 2.16 shows the DE theta value as we increase M. We can see that as M increases theta value curves shifts down.

In Figure. 2.17 shows the DE rho value as we increase M. We can see that as M increases

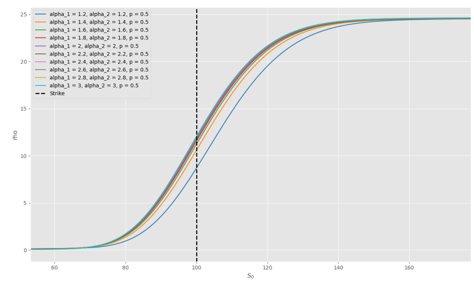

Figure 2.17: DE rho value fixing p and increasing M

rho value curves shifts right.

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In conclusion we can see that with fixed p, as M increases, the more left the Delta, Gamma, Vega, and Rho curves and the higher (larger) the Theta curves are.

2.4.3 DE Greeks value fixing M and increasing p

Table. 2.18, Table. 2.19, Table. 2.20, Table. 2.21, Table. 2.22 shows DE Delta, Gamma, Vega, Theta, and Rho value by fixing p and increasing M. Figure. 2.18, Figure. 2.19 , Figure. 2.20 , Figure. 2.21 , Figure. 2.22 shows the results of the data in the Tables above.

DE delta value fixing M and increasing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	0.2978	0.564	0.7828
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	0.2936	0.558	0.7783
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	0.2896	0.552	0.7736
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	0.2857	0.5461	0.7689
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	0.2819	0.5401	0.7642
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	0.2782	0.5342	0.7593
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	0.2747	0.5283	0.7544
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	0.2712	0.5225	0.7495
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	0.2679	0.5167	0.7445

Table 2.18: DE delta value fixing M and increasing p

DE gamma value fixing M and increasing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	0.0253	0.0258	0.0172
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	0.0249	0.0258	0.0175
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	0.0246	0.0258	0.0177
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	0.0242	0.0258	0.0179
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	0.0238	0.0258	0.0181
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	0.0234	0.0257	0.0184
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	0.023	0.0257	0.0186
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	0.0227	0.0256	0.0188
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	0.0223	0.0255	0.019

Table 2.19: DE gamma value fixing M and increasing p

DE Vega value fixing M and increasing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	7.6818	9.677	7.8187
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	7.5715	9.6791	7.9246
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	7.4596	9.6769	8.0286
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	7.3462	9.6704	8.1304
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	7.2315	9.6596	8.2299
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	7.1155	9.6445	8.3271
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	6.9986	9.625	8.4218
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	6.8807	9.6014	8.5138
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	6.762	9.5735	8.603

Table 2.20: DE Vega value fixing M and increasing p

In Figure. 2.18 shows the DE delta value as we increase p. We can see that as p increases delta value curves shifts right and at far OTM delta value increases.

In Figure. 2.19 shows the DE gamma value as we increase p. We can see that as p increases

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DE theta value fixing M and increasing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	-11.3169	-15.0973	-13.9607
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	-11.6293	-15.3248	-14.1063
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	-11.9483	-15.5609	-14.2605
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	-12.2737	-15.8056	-14.4233
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	-12.6052	-16.0587	-14.5948
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	-12.9426	-16.3202	-14.7753
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	-13.2857	-16.59	-14.9647
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	-13.6342	-16.868	-15.1632
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	-13.988	-17.1541	-15.3708

Table 2.21: DE theta value fixing M and increasing p

DE rho value fixing M and increasing p							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	-0.4	0.34	-0.128	0.9432	6.0675	12.3913	18.1165
p = 0.2 ,$M_{e1} = M_{e2} = 2$	-0.3	0.41	-0.054	1.2057	5.9446	12.225	17.9885
p = 0.3 ,$M_{e1} = M_{e2} = 2$	-0.2	0.46	-0.016	1.3752	5.824	12.0588	17.8583
p = 0.4 ,$M_{e1} = M_{e2} = 2$	-0.1	0.49	-0.002	1.4697	5.7057	11.8927	17.7258
p = 0.5 ,$M_{e1} = M_{e2} = 2$	0.0	0.5	0.0	1.5	5.5899	11.7267	17.5913
p = 0.6 ,$M_{e1} = M_{e2} = 2$	0.1	0.49	0.002	1.4697	5.4765	11.5611	17.4546
p = 0.7 ,$M_{e1} = M_{e2} = 2$	0.2	0.46	0.016	1.3752	5.3655	11.3958	17.3159
p = 0.8 ,$M_{e1} = M_{e2} = 2$	0.3	0.41	0.054	1.2057	5.2571	11.2309	17.1753
p = 0.9 ,$M_{e1} = M_{e2} = 2$	0.4	0.34	0.128	0.9432	5.1511	11.0666	17.0327

Table 2.22: DE rho value fixing M and increasing p

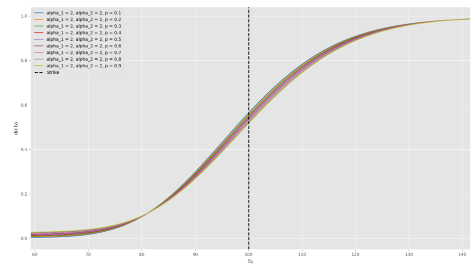

Figure 2.18: DE Delta value fixing M and increasing p

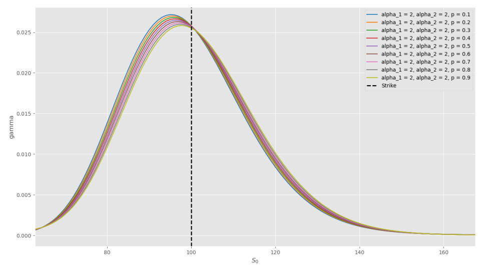

Figure 2.19: DE Gamma value fixing M and increasing p

gamma value curves shifts right and decreases in height.

In Figure. 2.20 shows the DE Vega value as we increase p. We can see that as p increases Vega value curves shifts right.

In Figure. 2.21 shows the DE theta value as we increase p. We can see that as p increases

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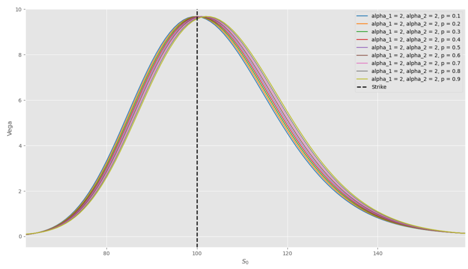

Figure 2.20: DE Vega value fixing M and increasing p

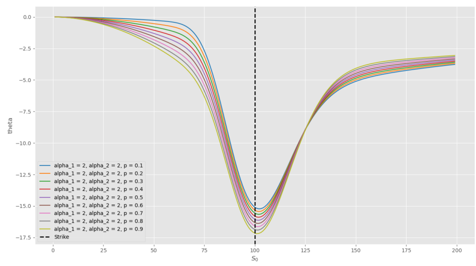

Figure 2.21: DE Theta value fixing M and increasing p

theta value curves shifts down.

In Figure. 2.22 shows the DE rho value as we increase p. We can see that as p increases

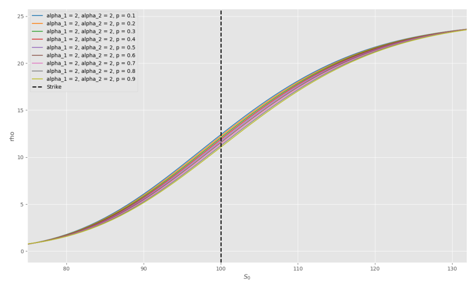

Figure 2.22: DE Rho value fixing M and increasing p

rho value curves shifts right.

In conclusion we can see that with fixed M, as p increases, the more right the Delta, Gamma, Vega, and Rho curves and the higher (larger) the Theta curves are.

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2.4.4 DE Greeks value conclusion

For DE Greeks value we can conclude the following points:

1.The larger the mean, variance, Skewness or Kurtosis the more right the Delta, Gamma, Vega, and Rho curves and the lower (smaller) the Theta curves are. And for far OTM, delta value increases.

2. As M increases, the more left the Delta, Gamma, Vega, and Rho curves and the lower (smaller) the Theta curves are. And for far OTM delta value decreases.

3. As p increases, the more right the Delta, Gamma, Vega, and Rho curves and the higher (larger) the Theta curves are. And for far OTM delta value increases.

2.5 DE Greeks hedging

In this section we will show how a Delta hedged and a Delta gamma hedged portfolio performs under DE, the details of the methods are in Section. 1.5.2.

2.5.1 DE Greeks hedging fixing mean and variance

Table. 2.23, Table. 2.24, shows DE Delta hedging and Delta gamma hedging for fixing mean and variance.Figure. 2.23, Figure. 2.24 , shows the results of the data in the Tables above.

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DE Delta hedging for fixing mean and variance				
parameters	stock position	call position	S = 90	S = 110
mean = 0, variance = 0.5				
p = 0.3, M_{e1} = 1.3093, M_{e2} = 3.0550	51.2984	-100	-127.4594	-119.6449
p = 0.4, M_{e1} = 1.6329, M_{e2} = 2.4494	53.2198	-100	-129.8797	-118.8947
p = 0.5, $M_{e1} = M_{e2} = 2.0000$	54.0127	-100	-130.7227	-118.5087
p = 0.6, M_{e1} = 2.4494, M_{e2} = 1.6329	54.5088	-100	-131.274	-118.3028
p = 0.7, M_{e1} = 3.0550, M_{e2} = 1.3093	54.8762	-100	-131.7789	-118.2215
mean = 0, variance = 1				
p = 0.4, M_{e1} = 1.1547, M_{e2} = 1.7320	43.8722	-100	-111.8169	-117.3426
p = 0.45, M_{e1} = 1.2792, M_{e2} = 1.5634	48.5663	-100	-122.042	-119.4473
p = 0.5, M_{e1} = 1.4142, M_{e2} = 1.4142	50.6388	-100	-125.5929	-119.4354
p = 0.55, M_{e1} = 1.5634, M_{e2} = 1.2792	51.8412	-100	-127.4042	-119.2128
p = 0.6, M_{e1} = 1.7320, M_{e2} = 1.1547	52.6508	-100	-128.5363	-118.9971
p = 0.65, M_{e1} = 1.9272, M_{e2} = 1.0377	53.2505	-100	-129.3542	-118.8123
mean = 0, variance = 1.5				
p = 0.5, M_{e1} = 1.1547, M_{e2} = 1.1547	41.3027	-100	-104.1505	-114.3056
p = 0.55 ,M_{e1} = 1.2765, M_{e2} = 1.0444	46.9372	-100	-118.3502	-118.8991
p = 0.6 ,M_{e1} = 1.4142, M_{e2} = 0.9428	49.5871	-100	-123.4748	-119.4239
p = 0.65 , M_{e1} = 1.5735, M_{e2} = 0.8473	51.1561	-100	-126.1002	-119.3428
p = 0.7 ,M_{e1} = 1.7638, M_{e2} = 0.7559	52.2222	-100	-127.7478	-119.1474
p = 0.75 ,$M_{e1} = 2.0$, $M_{e2} = 0.6666$	53.0151	-100	-128.9302	-118.9539
mean = 0.5, variance = 0.5				
p = 0.7, M_{e1} = 1.3671, M_{e2} = 24.9614	46.3383	-100	-117.786	-119.3765
p = 0.75 ,M_{e1} = 1.4202, M_{e2} = 8.8989	47.0225	-100	-118.9755	-119.4062
p = 0.8, M_{e1} = 1.4775, M_{e2} = 4.82842	47.6637	-100	-120.0623	-119.4313
p = 0.85 ,M_{e1} = 1.5419, M_{e2} = 2.9271	48.2803	-100	-121.1102	-119.474
p = 0.9, M_{e1} = 1.6185, M_{e2} = 1.78361	48.9019	-100	-122.183	-119.5329
mean = 0.5, variance = 1				
p=0.7, $M_{e1} = 1.110$, $M_{e2} = 2.2966$	31.1467	-100	-61.1329	-84.562
p=0.8, $M_{e1} = 1.240$, $M_{e2} = 1.3797$	36.5914	-100	-87.5881	-105.2034
p = 0.85 ,M_{e1} = 2.7487, M_{e2} = 0.4850	40.5371	-100	-101.3271	-112.9993
p = 0.9 ,M_{e1} = 3.4641, M_{e2} = 0.3849	43.432	-100	-109.5891	-116.5148
p = 0.95 ,M_{e1} = 5.0332, M_{e2} = 0.2649	45.7384	-100	-115.2862	-118.2919
mean = 0.5, variance = 1.5				
p = 0.8 ,M_{e1} = 1.1169, M_{e2} = 0.9249	30.4795	-100	-55.442	-79.1495
p = 0.85 ,M_{e1} = 1.2017, M_{e2} = 0.7236	37.2945	-100	-89.7349	-106.5244
p = 0.9 ,M_{e1} = 1.3097, M_{e2} = 0.5342	42.3595	-100	-106.4479	-115.282
p = 0.95 ,M_{e1} = 1.4676, M_{e2} = 0.3394	46.2126	-100	-116.3232	-118.5568

Table 2.23: DE Delta hedging for fixing mean and variance

In Figure. 2.23 shows the DE Delta hedging $\Delta\Pi$ curves as we increase mean and variance. We can see that Delta hedging $\Delta\Pi$ curves are like Quadratic function with opening facing down. We can also see that as mean and variance increases $\Delta\Pi$ value curves rotates clockwise. In Table. 2.23, for delta hedging, the larger the mean, variance, Skewness and Kurtosis the smaller the stock position.

In Figure. 2.24 shows the DE Delta gamma hedging $\Delta\Pi$ curves as we increase mean and

DE Delta gamma hedging for fixing mean and variance					
parameters	stock position	call position	put position	S = 90	S = 110
mean = 0, variance = 0.5					
p = 0.3, M_{e1} = 1.3093, M_{e2} = 3.0550	99.7517	-100	100.0	-0.014	0.014
p = 0.4, M_{e1} = 1.6329, M_{e2} = 2.4494	99.7496	-100	100.0	0.0073	-0.0073
p = 0.5, M_{e1} = 2.0000, M_{e2} = 2.0000	99.7493	-100	100.0	0.0105	-0.0105
p = 0.6, M_{e1} = 2.4494, M_{e2} = 1.6329	99.7503	-100	100.0	0.0	-0.0
p = 0.7, M_{e1} = 3.0550, M_{e2} = 1.3093	99.7502	-100	100.0	0.0015	-0.0015
mean = 0, variance = 1					
p = 0.4, M_{e1} = 1.1547, M_{e2} = 1.7320	99.7499	-100	100.0	0.0041	-0.0041
p = 0.45, M_{e1} = 1.2792, M_{e2} = 1.5634	99.7503	-100	100.0	-0.0003	0.0003
p = 0.5, M_{e1} = 1.4142, M_{e2} = 1.4142	99.7497	-100	100.0	0.006	-0.006
p = 0.55, M_{e1} = 1.5634, M_{e2} = 1.2792	99.7512	-100	100.0	-0.009	0.009
p = 0.6, M_{e1} = 1.7320, M_{e2} = 1.1547	99.7494	-100	100.0	0.0086	-0.0086
p = 0.65, M_{e1} = 1.9272, M_{e2} = 1.0377	99.7499	-100	100.0	0.004	-0.004
mean = 0, variance = 1.5					
p = 0.5, M_{e1} = 1.1547, M_{e2} = 1.1547	99.7498	-100	100.0	0.0052	-0.0052
p = 0.55 ,M_{e1} = 1.2765, M_{e2} = 1.0444	99.7499	-100	100.0	0.0046	-0.0046
p = 0.6 ,M_{e1} = 1.4142, M_{e2} = 0.9428	99.7477	-100	100.0	0.026	-0.026
p = 0.65 , M_{e1} = 1.5735, M_{e2} = 0.8473	99.7489	-100	100.0	0.0144	-0.0144
p = 0.7 ,M_{e1} = 1.7638, M_{e2} = 0.7559	99.7494	-100	100.0	0.0091	-0.0091
p = 0.75 ,M_{e1} = 2.0, M_{e2} = 0.6666	99.7493	-100	100.0	0.0104	-0.0104
mean = 0.5, variance = 0.5					
p = 0.7, M_{e1} = 1.3671, M_{e2} = 24.9614	99.7481	-100	100.0	0.0226	-0.0226
p = 0.75 ,M_{e1} = 1.4202, M_{e2} = 8.8989	99.7491	-100	100.0	0.0124	-0.0124
p = 0.8, M_{e1} = 1.4775, M_{e2} = 4.82842	99.7499	-100	100.0	0.0044	-0.0044
p = 0.85 ,M_{e1} = 1.5419, M_{e2} = 2.9271	99.7502	-100	100.0	0.0011	-0.0011
p = 0.9, M_{e1} = 1.6185, M_{e2} = 1.78361	99.7497	-100	100.0	0.006	-0.006
mean = 0.5, variance = 1					
p=0.7, M_{e1} = 1.110, M_{e2} = 2.2966	99.751	-100	100.0	-0.0067	0.0067
p=0.8, M_{e1} = 1.240, M_{e2} = 1.3797	99.7492	-100	100.0	0.0114	-0.0114
p = 0.85 ,M_{e1} = 2.7487, M_{e2} = 0.4850	99.7506	-100	100.0	-0.0029	0.0029
p = 0.9 ,M_{e1} = 3.4641, M_{e2} = 0.3849	99.7488	-100	100.0	0.0149	-0.0149
p = 0.95 ,M_{e1} = 5.0332, M_{e2} = 0.2649	99.7489	-100	100.0	0.0137	-0.0137
mean = 0.5, variance = 1.5					
p = 0.8 ,M_{e1} = 1.1169, M_{e2} = 0.9249	99.7513	-100	100.0	-0.0106	0.0106
p = 0.85 ,M_{e1} = 1.2017, M_{e2} = 0.7236	99.7505	-100	100.0	-0.0024	0.0024
p = 0.9 ,M_{e1} = 1.3097, M_{e2} = 0.5342	99.7513	-100	100.0	-0.0103	0.0103
p = 0.95 ,M_{e1} = 1.4676, M_{e2} = 0.3394	99.7515	-100	100.0	-0.3514	0.3514

Table 2.24: DE Delta gamma hedging for fixing mean and variance

variance. For Delta gamma hedging $\Delta\Pi$ curves are like linear functions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in mean, variance, Skewness and, Kurtosis. Gamma for call and put is the same, the reason for this is because of put call parity, when differentiate by S twice we will get $\frac{\partial^2 C}{\partial S^2} = \frac{\partial^2 P}{\partial S^2}$. So positions for call and put are the

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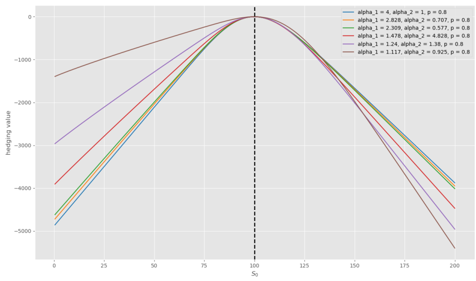

Figure 2.23: DE Delta hedging for fixing mean and variance

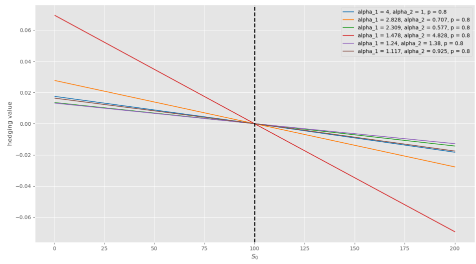

Figure 2.24: DE Delta gamma hedging for fixing mean and variance

same amount. The hedging results are quite similar for delta gamma hedging for all parameters.

2.5.2 DE Greeks hedging fixing p and increasing M

Table. 2.25, Table. 2.26, shows DE Delta hedging and Delta gamma hedging for fixing mean and variance.Figure. 2.25, Figure. 2.26 , shows the results of the data in the Tables. In Table. 2.25, we can see that under fix p the larger the M the larger the stock position.

DE Delta hedging for fixing p and increasing M				
parameters	stock position	call position	S = 90	S = 110
p = 0.5, $M_{e1} = M_{e2} = 1.2$	44.4896	-100	-112.8689	-117.5845
p = 0.5, $M_{e1} = M_{e2} = 1.4$	50.4293	-100	-125.2406	-119.4516
p = 0.5, $M_{e1} = M_{e2} = 1.6$	52.4572	-100	-128.4708	-119.0659
p = 0.5, $M_{e1} = M_{e2} = 1.8$	53.4443	-100	-129.9112	-118.7281
p = 0.5, $M_{e1} = M_{e2} = 2.0$	54.0127	-100	-130.7227	-118.5087
p = 0.5, $M_{e1} = M_{e2} = 2.2$	54.3748	-100	-131.2531	-118.3655
p = 0.5, $M_{e1} = M_{e2} = 2.4$	54.6208	-100	-131.6283	-118.2772
p = 0.5, $M_{e1} = M_{e2} = 2.6$	54.7961	-100	-131.9127	-118.2236
p = 0.5, $M_{e1} = M_{e2} = 2.8$	54.9258	-100	-132.1399	-118.1921
p = 0.5 ,$M_{e1} = M_{e2} = 3.0$	55.024	-100	-132.325	-118.1791

Table 2.25: DE Delta hedging for fixing p and increasing M

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DE Delta gamma hedging for fixing p and increasing M					
parameters	stock position	call position	put position	S = 90	S = 110
p = 0.5, $M_1 = M_2 = 1.4$	95.4852	-100	100.0	28.3816	-31.4264
p = 0.5, $M_1 = M_2 = 1.6$	99.7501	-100	100.0	8.0238	-6.1871
p = 0.5, $M_1 = M_2 = 1.8$	99.75	-100	100.0	0.9402	-0.7113
p = 0.5, $M_1 = M_2 = 2.0$	99.7502	-100	100.0	0.1745	-0.1295
p = 0.5, $M_1 = M_2 = 2.4$	99.7501	-100	100.0	0.0091	-0.0072
p = 0.5, $M_1 = M_2 = 2.6$	99.75	-100	100.0	0.0049	-0.0044
p = 0.5, $M_1 = M_2 = 2.8$	99.7501	-100	100.0	0.0022	-0.0021
p = 0.5, $M_1 = M_2 = 3.0$	99.7499	-100	100.0	0.0045	-0.0045

Table 2.26: DE Delta gamma hedging for fixing p and increasing M

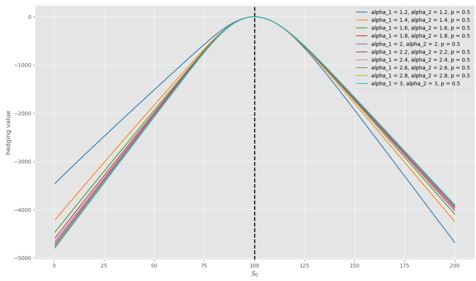

Figure 2.25: DE delta value fixing p and increasing M

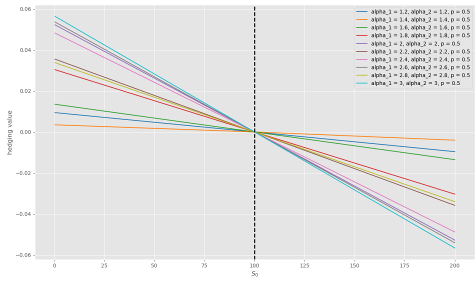

Figure 2.26: DE gamma value fixing p and increasing M

In Figure. 2.25 shows the DE Delta hedging $\Delta\Pi$ curves as we fix p and increasing M. We can see that Delta hedging $\Delta\Pi$ curves looks like Quadratic function with Opening facing down and as M increases $\Delta\Pi$ value curves rotates clockwise. In Table. 2.25, under fixed p, the larger the M the larger the stock position.

In Figure. 2.26 shows the DE Delta gamma hedging $\Delta\Pi$ curves as we fix p and increasing M. We can see that $\Delta\Pi$ value curves are like linear functions with a negative slope, that's why S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in M.

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2.5.3 DE Greeks hedging fixing M and increasing p

Table. 2.27, Table. 2.28, shows DE Delta hedging and Delta gamma hedging for fixing M and increasing p.

Figure. 2.27, Figure. 2.28 , shows the results of the data in the Tables above.

DE Delta hedging fixing M and increasing p				
parameters	stock position	call position	S = 90	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	56.4011	-100	-133.4901	-116.6955
p = 0.2 ,$M_{e1} = M_{e2} = 2$	55.801	-100	-132.8787	-117.223
p = 0.3 ,$M_{e1} = M_{e2} = 2$	55.2029	-100	-132.2153	-117.6991
p = 0.4 ,$M_{e1} = M_{e2} = 2$	54.6064	-100	-131.4937	-118.1305
p = 0.5 ,$M_{e1} = M_{e2} = 2$	54.0127	-100	-130.7227	-118.5087
p = 0.6 ,$M_{e1} = M_{e2} = 2$	53.4217	-100	-129.8992	-118.8372
p = 0.7 ,$M_{e1} = M_{e2} = 2$	52.8339	-100	-129.0247	-119.1153
p = 0.8 ,$M_{e1} = M_{e2} = 2$	52.25	-100	-128.1056	-119.3374
p = 0.9 ,$M_{e1} = M_{e2} = 2$	51.6693	-100	-127.1319	-119.5143

Table 2.27: DE Delta hedging for fixing M and increasing p

DE Delta gamma hedging for fixing M and increasing p					
parameters	stock position	call position	put position	S = 90	S = 110
p = 0.1 ,$M_{e1} = M_{e2} = 2$	99.7481	-100	100.0	0.0221	-0.0221
p = 0.2 ,$M_{e1} = M_{e2} = 2$	99.7503	-100	100.0	0.0006	-0.0006
p = 0.3 ,$M_{e1} = M_{e2} = 2$	99.7516	-100	100.0	-0.0131	0.0131
p = 0.4 ,$M_{e1} = M_{e2} = 2$	99.7499	-100	100.0	0.0038	-0.0038
p = 0.5 ,$M_{e1} = M_{e2} = 2$	99.7493	-100	100.0	0.0105	-0.0105
p = 0.6 ,$M_{e1} = M_{e2} = 2$	99.7498	-100	100.0	0.005	-0.005
p = 0.7 ,$M_{e1} = M_{e2} = 2$	99.7517	-100	100.0	-0.014	0.014
p = 0.8 ,$M_{e1} = M_{e2} = 2$	99.7503	-100	100.0	-0.0003	0.0003
p = 0.9 ,$M_{e1} = M_{e2} = 2$	99.7501	-100	100.0	0.0024	-0.0024

Table 2.28: DE Delta gamma hedging for fixing M and increasing p

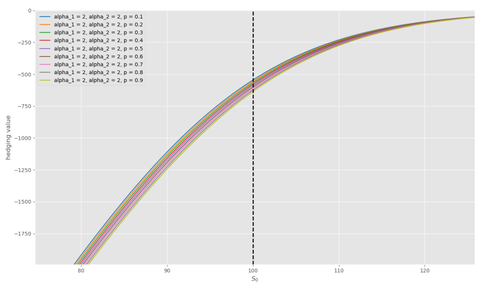

Figure 2.27: DE Delta hedging for fixing M and increasing p

In Figure. 2.27 shows the DE Delta hedging $\Delta\Pi$ curves as we fix M and increasing p. We can see that as p increases $\Delta\Pi$ value curves are like Quadratic function with Opening facing down and as we fix M and increases p $\Delta\Pi$ value curves rotates counter clockwise. In Table. 2.27, under fixed p, the larger the M the smaller the stock position.

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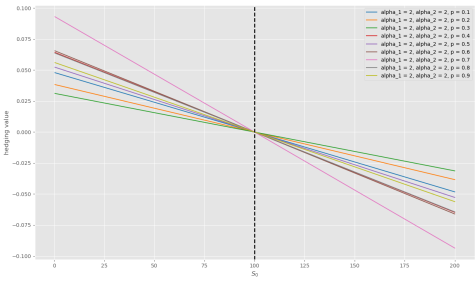

Figure 2.28: DEE Delta gamma hedging for fixing M and increasing p

In Figure. 2.28 shows the DE Delta gamma hedging $\Delta\Pi$ curves as we fix p and increasing M. We can see that $\Delta\Pi$ value curves are like linear functions with a negative slope, that's why S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in M.

2.5.4 DE Greeks hedging conclusion

For delta hedging here are the following results. Delta hedging $\Delta\Pi$ curves are like Quadratic function with Opening facing down, the larger the mean, variance, Skewness and Kurtosis the more clockwise the $\Delta\Pi$ curves rotates and the smaller the stock position. Under fixed p the larger the $M$the the more compact the $\Delta\Pi$ curves are and the more counter clockwise the $\Delta\Pi$ curves rotates. Under fixed M the larger the p the more clockwise the $\Delta\Pi$ curves rotates.

For delta gamma hedging here are the following results. Delta gamma hedging $\Delta\Pi$ curves are like linear functions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign. We can see that delta gamma hedging has better hedging effect than delta hedging. But we can see that the stock position and hedging effect doesn't really

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change in relation with the change in mean, variance, Skewness and, Kurtosis, M, β and p.

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Chapter 3 Double gamma jump diffusion model

3.1 DG distribution

Different from exponential distribution, gamma distribution has an extra parameter β. To get what α and β is, the formulas will be show here.

Double exponential:

$$\nu(\xi) = p\alpha_1 e^{-\alpha_1 \xi} 1_{\xi>0} + (1-p)\alpha_2 e^{\alpha_2 \xi} 1_{\xi \leq 0} \tag{3.1}$$

Double gamma:

$$\nu(\xi) = p\frac{\alpha_1^{\beta_1}}{\Gamma(\beta_1)} \xi^{\beta_1 - 1} e^{-\alpha_1 \xi} 1_{\xi>0} + (1-p)\frac{\alpha_2^{\beta_2}}{\Gamma(\beta_2)} (-\xi)^{\beta_2 - 1} e^{\alpha_2 \xi} 1_{\xi \leq 0} \tag{3.2}$$

3.2 DG call value

Now we will be looking at the call values with the parameters in the above.

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3.2.1 DG call value fixing mean and variance

First we will show that when fixing $\beta = 1$, DG will replicate the results of DE. Here we will only show mean = 0, variance = 0.5, the other mean and variance parameters will replicate the results of DE as well, the rest of tables will be in the appendix. Table. 3.1 shows that the results of our FFT pricing method on Double Gamma jump diffusion model is the same as Double exponential jump diffusion model when $\beta = 1$, meaning our FFT pricing method is valid and can proceed.

DG Call value mean = 0, variance = 0.5					
parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DE mean = 0, variance = 0.5					
p = 0.3, $\alpha_{e1} = 1.3093, \alpha_{e2} = 3.0550$	0.6546	2.6428	3.8173	7.6725	13.9988
p = 0.4, $\alpha_{e1} = 1.6329, \alpha_{e2} = 2.4494$	0.3061	1.75	3.2453	7.2685	13.7794
p = 0.5, $\alpha_{e1} = \alpha_{e2} = 2.0000$	0	1.5	3.012	7.106	13.6924
p = 0.6, $\alpha_{e1} = 2.4494, \alpha_{e2} = 1.6329$	-0.3061	1.75	2.8526	6.9907	13.6246
p = 0.7, $\alpha_{e1} = 3.0550, \alpha_{e2} = 1.3093$	-0.65465	2.6428	2.7137	6.8836	13.5534
DG mean = 0, variance = 0.5 fix $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	3.8173	7.6725	13.9988
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	3.2453	7.2685	13.7794
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0	1.5	3.012	7.106	13.6924
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	2.8526	6.9907	13.6246
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	2.7137	6.8836	13.5534

Table 3.1: DG Call value mean = 0, variance = 0.5

In Table 3.1 we can also see that when fixed mean and variance, with an increase in p the lower the call value. This might sound counter-intuitive since p stands for the probability of jumps jumping upwards, shouldn't it lead to larger call value? The reason is that for DE once mean, variance and p are decided so does the distribution, and as p increases under fixed mean and variance, Skewness decrease and Kurtosis increases drastically, resulting in larger p has a fatter tail in the left and smaller p has a fatter tail in the right (shown in Figure. 2.3). Which is the reason why under fixed mean and variance, the increase in p results smaller call value.

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DG Call value fix mean and variance							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0.0	0.5	-1.125	4.875	2.5758	6.7691	13.4687
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0.0	1.0	-3.1819	19.5	2.8413	6.9757	13.6061
p = 0.8 ,$\alpha_{g1} = 2.3094, \alpha_{g2} = 0.5773$	0.0	1.5	-5.8456	43.875	3.1164	7.1822	13.7347
p = 0.8 ,$\alpha_{g1} = 1.4775, \alpha_{g2} = 4.8284$	0.5	0.5	0.60225	2.0197	4.8111	8.3768	14.3375
p = 0.8 ,$\alpha_{g1} = 1.2404, \alpha_{g2} = 1.3797$	0.5	1	0.4332	7.0057	7.6798	10.7203	15.904
p = 0.8 ,$\alpha_{g1} = 1.1169, \alpha_{g2} = 0.9249$	0.5	1.5	-0.4469	17.4745	13.9369	16.4305	20.2699

Table 3.2: DG Call value fix mean and variance a

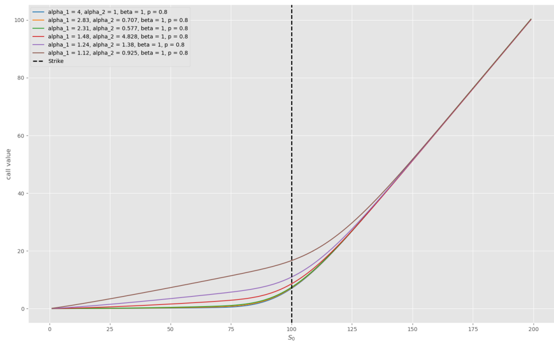

Figure 3.1: DG Call value fix mean and variance

From Table 3.1 and Figure. 3.2 we can see that the larger the mean or variance the larger the call value, the call values converges at small S_0 and large S_0.

3.2.1.1 DG call value fix mean and var with different parameters

DG Call value							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Call value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	2.5681	6.756	13.4529
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	2.8382	6.9643	13.5895
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	3.1322	7.1836	13.7244
DG Call value fix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	2.5758	6.7691	13.4687
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	2.8413	6.9757	13.6061
p = 0.8 ,$\alpha_{g1} = 2.3094\alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	3.1164	7.1822	13.7347
DG Call value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	2.5998	6.8085	13.5152
p = 0.8 ,$\alpha_1 = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	2.8655	7.0187	13.6592
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	3.1187	7.2108	13.781

Table 3.3: DG Call value

From Table. 3.3and Figure. 3.2 we can see that for DG even with fix mean, variance, we are able to change Skewness and Kurtosis by changing β and therefore increase or de-

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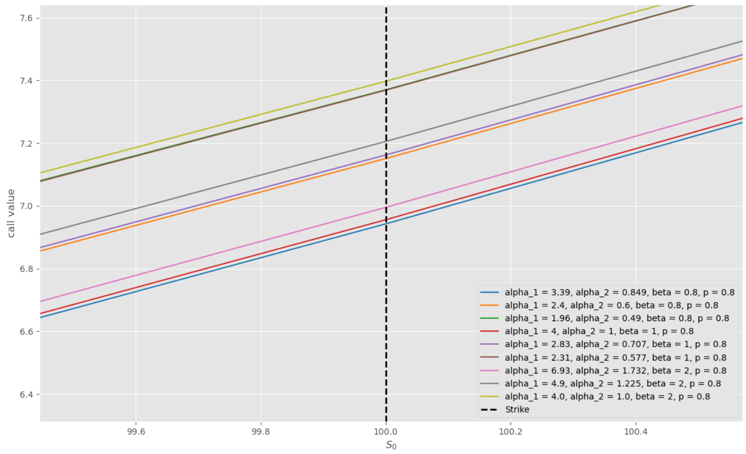

Figure 3.2: DG call value fix mean and var with different parameters

crease call value. As we increases β under fixed mean and variance, Skewness increases and Kurtosis decreases which leads to the left tail of the distribution not as fat, which leads to a larger call value.

Unlike DE, when fix mean, variance and p, parameters for α_1, α_2 are fixed, the ability to change β and therefore the change in call value shows the flexibility of DG, and with this flexibility we can adjust the model according to the market. When the economy is good we can increase mean , when the market is very volatile we can increase variance. But even when the economy is good there are still bad days, and there are good days in a bad economy, by increasing p we can increase the probability of jumps jumping up. And here is where DG's flexibility comes in , when p is fixed DG can fine-tune the parameters to fit the market, where as DE's parameters is fixed and might be in conflict with the market.

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3.2.2 DG call value fixing β, p and increasing α

Table. 3.4, shows DE Delta hedging and Delta gamma hedging for fixing. Figure. 3.3, shows the results of the data in the Table. 3.4. In Figure. 3.3 shows the DG call value as we fix β, p, and increase α. It shows that under fix β, p, the larger the α the smaller the call value, the call values converges at small S_0 and large S_0. And Table. 3.4 shows that as α decreases, variance and Kurtosis increases, resulting in fatter tails and more extreme jump events are more likely to happen. This is the reason that the larger the variance and Kurtosis the larger the call value.

DG call value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG call value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	6.3758	9.6961	15.3209
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.2473	4.2521	8.0426	14.2801
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.6621	3.5612	7.5222	13.9586
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.2862	3.2179	7.2632	13.7949
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	3.012	7.106	13.6924
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	2.8745	6.9995	13.6206
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.7233	2.7761	6.9219	13.5668
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.5251	2.7021	6.8626	13.5245
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.3904	2.6445	6.8157	13.4902
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	2.5984	6.7776	13.4618
DG call value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	31.3444	34.9548	38.6196
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	11.894	14.5295	18.8454
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	7.3436	10.5376	15.9518
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	5.5784	9.1163	15.0212
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	4.6802	8.4185	14.5783
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.g2396	5.1226	4.1457	8.009	14.3192
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1g.0416	3.6168	3.794	7.7405	14.1475
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0g.8875	2.6259	3.5461	7.5508	14.0242
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0g.7653	1.9523	3.3624	7.4093	13.9304
p = 0.5 ,$\alpha_{g1} = 3.0,_{g2} = 3.0$	0g.6666	1.4814	3.221	7.2994	13.8561

Table 3.4: DG call value fixing β, p and increasing α

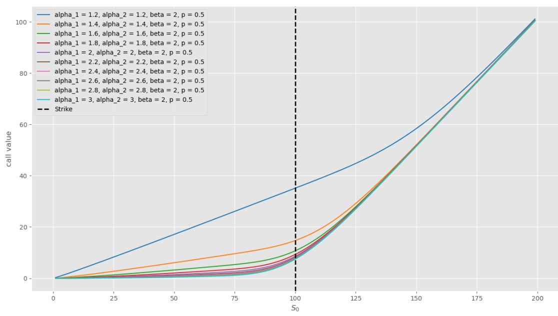

Figure 3.3: DG call value fixing β, p and increasing α

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3.2.3 DG call value fixing α, p and increasing β

Table. 3.5, shows DE Delta hedging and Delta gamma hedging for fixing .Figure. 3.4 , shows the results of the data in Table. 3.5. In Figure. 3.4 shows the DG call value as we fix α, p, and increase β. It shows that under fix α, p, the larger the β the larger the call value. And Table. 3.5 shows that as β increases, variance and Kurtosis increases, resulting in fatter tails and more extreme jump events are more likely to happen. This is the reason that the larger the variance and Kurtosis the larger the call value.

DG Call value fixing α, p and changing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG call value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	3.2573	7.3031	13.8318
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	3.5406	7.5275	13.9864
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	3.8676	7.7839	14.1595
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	4.2447	8.0784	14.3549
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	4.6802	8.4185	14.5783
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	5.1835	8.8136	14.8367
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	5.7658	9.2751	15.1391
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	6.4401	9.8169	15.4972
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	7.2214	10.4561	15.9262
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	8.1266	11.2128	16.4453
DG call value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_2 = 1.2$	0.2933	0.4380	2.7015	6.8677	13.5328
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	2.815	6.9647	13.6078
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	2.9391	7.0687	13.6866
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	3.0742	7.1801	13.7693
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	3.221	7.2994	13.8561
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	3.3804	7.4273	13.9473
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	3.5533	7.5647	14.0435
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	3.7409	7.7125	14.1453
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	3.9443	7.872	14.2535
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	4.1652	8.0445	14.3691

Table 3.5: DG Call value fixing α, p and changing β

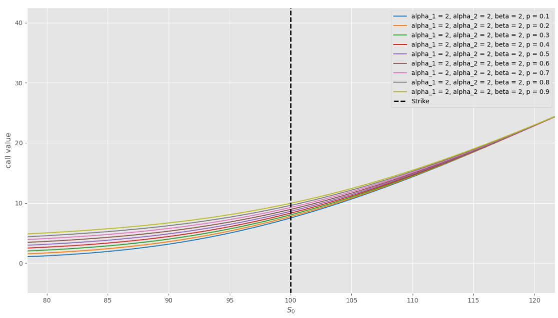

Figure 3.4: DG Call value fixing α, p and changing β

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3.2.4 DG call value fixing β, α and increasing p

Table. 3.7, Table. 3.6, shows DE Delta hedging and Delta gamma hedging for fixing. Figure. 3.5, shows the results of the data in Table. 3.7.

In Figure. 3.5 shows the DG call value as we fix β, α, and increase p. It shows that under fix α, p, the larger the p the larger the call value. And Table. 3.7 shows that as p increases, mean and Skewness increases, while variance and Kurtosis are small at both ends and largest at p = 0.5. The distribution is shown in Figure. 3.6, we can see that as p increase the positive $p(x)$ increases and the right tail becomes thicker resulting in higher call value.

DG Call value fixing α, β and changing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG call value $\alpha = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	2.9665	7.3096	14.1394
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	3.3821	7.5643	14.2288
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	3.8067	7.8342	14.3314
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	4.2397	8.119	14.4478
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	4.6802	8.4185	14.5783
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	5.1276	8.7323	14.7234
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	5.581	9.0601	14.8832
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	6.0397	9.4013	15.0581
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	6.503	9.7556	15.2483
DG call value $\alpha = 3$							
p = 0.1 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	-0.5333	0.382	0.0521	0.8594	2.6239	6.9762	13.819
p = 0.2 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	-0.4	0.5066	0.1386	1.1913	2.7706	7.0526	13.8246
p = 0.3 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	-0.2666	0.5955	0.1398	1.3714	2.9191	7.1319	13.8326
p = 0.4 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	-0.1333	0.6488	0.0841	1.4568	3.0692	7.2142	13.8431
p = 0.5 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	0.0	0.6666	0.0	1.4814	3.221	7.2994	13.8561
p = 0.6 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	0.1333	0.6488	-0.0841	1.4568	3.3744	7.3876	13.8717
p = 0.7 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	0.2666	0.5955	-0.1398	1.3714	3.5292	7.4786	13.8899
p = 0.8 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	0.4	0.5066	-0.1386	1.1913	3.6855	7.5726	13.9108
p = 0.9 ,$\alpha_{g1} = 3, \alpha_{g2} = 3$	0.5333	0.382	-0.0521	0.8594	3.843	7.6693	13.9344

Table 3.6: DG Call value fixing α, β and changing p

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DG Call value fixing α, β and changing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG call value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.1475	-0.1	0.3003	2.3694	6.6241	13.398
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	2.4118	6.6456	13.3982
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	2.4543	6.6675	13.3986
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	2.497	6.6895	13.3992
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	2.5398	6.7119	13.4001
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	2.5828	6.7345	13.4012
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	2.6259	6.7574	13.4025
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	2.6691	6.7806	13.404
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	2.7125	6.804	13.4057
DG call value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	2.5313	6.8365	13.6435
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	2.65	6.9013	13.6536
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	2.7697	6.9678	13.6651
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	2.8904	7.0361	13.678
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	3.012	7.106	13.6924
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	3.1346	7.1778	13.7083
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	3.2581	7.2512	13.7257
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	3.3824	7.3263	13.7447
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	3.5075	7.4031	13.7652
DG call value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	2.9665	7.3096	14.1394
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	3.3821	7.5643	14.2288
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	3.8067	7.8342	14.3314
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	4.2397	8.119	14.4478
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	4.6802	8.4185	14.5783
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	5.1276	8.7323	14.7234
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	5.581	9.0601	14.8832
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	6.0397	9.4013	15.0581
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	6.503	9.7556	15.2483

Table 3.7: DG Call value fixing α, β and changing p

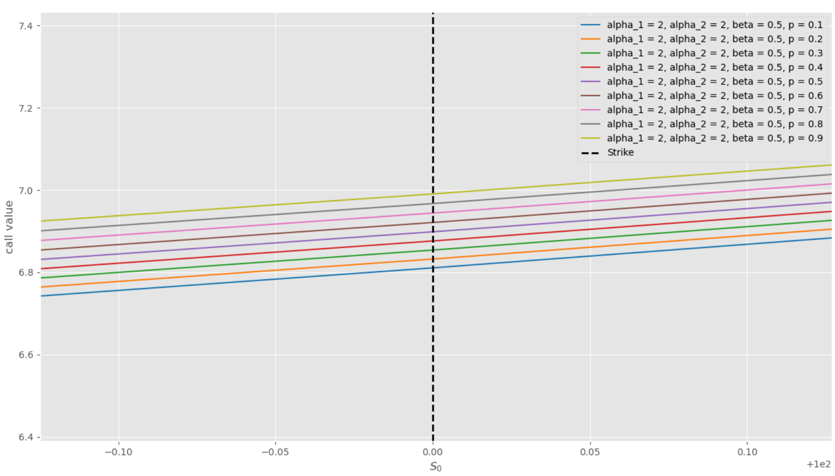

Figure 3.5: DG Call value fixing α, β and changing p

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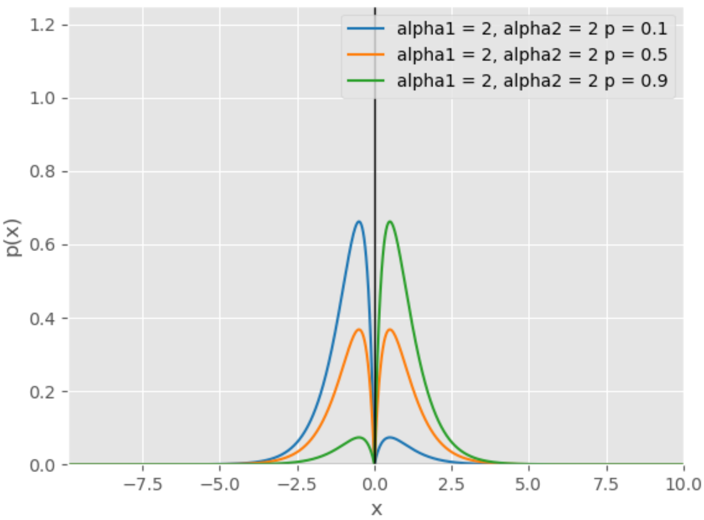

Figure 3.6: DE distribution fixing mean and variance - 1

3.2.5 DG call value conclusion

We can see that the larger the mean, variance, skewness and kurtosis the larger the call value. We can also see that when fixed mean and variance, with the change in β we can increase or decrease call value from double exponential model. Under fixed α, p the larger the β the larger the variance and kurtosis , resulting in fatter tails and more extreme jump events are more likely to happen. This is the reason that the larger the variance and Kurtosis the larger the call value. Under fixed β, p the larger the $\alpha$the smaller the variance and kurtosis ,resulting in smaller call value. Under fixed α, β as p increases, mean and Skewness increases, while variance and Kurtosis are small at both ends and largest at p = 0.5, resulting in larger call value. We can see that fat-tails has a great impact on call value.

We can also see that Double gamma has way more flexibility compared to Double exponential. And with this flexibility we can adjust the model according to the market. When the economy is good we can increase mean , when the market is very volatile we can in-

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crease variance. But even when the economy is good there are still bad days, and there are good days in a bad economy, by increasing p we can increase the probability of jumps jumping up. And here is where DG’ s flexibility comes in , when p is fixed DG can fine-tune the parameters to fit the market, where as DE’ s parameters is fixed and might be in conflict with the market. This is one of the reasons why DG is better than DE model.

3.3 DG Greeks

Here we will be looking at the double gamma model’s Greeks values with the parameters in the section above.

3.3.1 DG Greeks value fixing mean and variance

First we will show that when fixing $\beta = 1$, DG will replicate the results of DE Greeks value, for demonstration here we will only show mean = 0, variance = 0.5, the other mean and variance parameters will replicate the results of DE as well, the rest of tables will be in the appendix. Table. 3.8 shows that the results of our FFT pricing method on Double Gamma jump diffusion model is the same as Double exponential jump diffusion model when $\beta = 1$, meaning our FFT pricing method is valid and can proceed.

parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DE mean = 0, var = 0.5					
p = 0.3, $\alpha_{e1} = 1.3093, \alpha_{e2} = 3.0550$	0.6546	2.6428	0.2635	0.513	0.741
p = 0.4, $\alpha_{e1} = 1.6329, \alpha_{e2} = 2.4494$	0.3061	1.75	0.2763	0.5322	0.7575
p = 0.5, $\alpha_{e1} = \alpha_{e2} = 2.0000$	0	1.5	0.2819	0.5401	0.7642
p = 0.6, $\alpha_{e1} = 2.4494, \alpha_{e2} = 1.6329$	-0.3061	1.75	0.2854	0.5451	0.7684
p = 0.7, $\alpha_{e1} = 3.0550, \alpha_{e2} = 1.3093$	-0.65465	2.6428	0.2877	0.5488	0.7717
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	0.2635	0.513	0.741
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	0.2763	0.5322	0.7575
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.0000$	0	1.5	0.2819	0.5401	0.7642
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	0.2854	0.5451	0.7684
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	0.2877	0.5488	0.7717

Table 3.8: DG Delta value mean = 0, var = 0.5

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parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	0.0222	0.0255	0.0189
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	0.0234	0.0257	0.0184
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0	1.5	0.0238	0.0258	0.0181
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	0.0241	0.0258	0.018
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	0.0243	0.0258	0.0179
DG mean = 0, var = 1.5 fix DG $\beta = 2$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	2.6186	13.2142	0.0102	0.0186	0.0209
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	1.2247	8.75	0.0185	0.0243	0.0203
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0.0	7.5	0.0209	0.0251	0.0194
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-1.2247	8.75	0.022	0.0254	0.0189
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-2.6186	13.2142	0.0228	0.0255	0.0185

Table 3.9: DG Gamma value mean = 0, var = 0.5

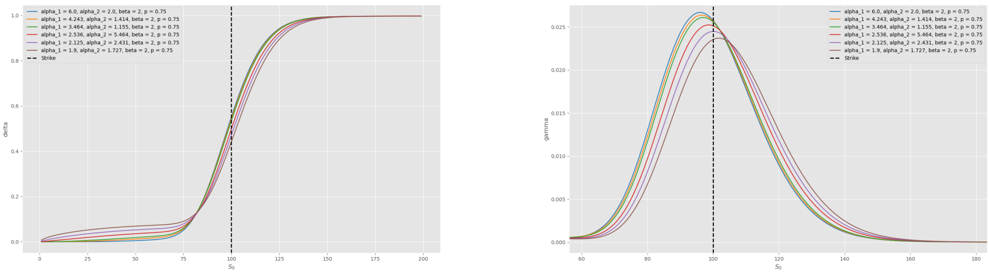

Figure 3.7: DG Delta and Gamma value fixing mean and var.
Left: Delta, Right: Gamma

parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	6.7844	9.5913	8.601
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	7.1077	9.6463	8.337
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0	1.5	7.2315	9.6596	8.2299
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	7.3101	9.67	8.1677
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	7.3757	9.684	8.126
DG mean = 0, var = 1.5 fix DG $\beta = 2$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	2.6186	13.2142	3.1	6.9669	9.4912
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	1.2247	8.75	5.6187	9.0948	9.2053
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0.0	7.5	6.3437	9.4086	8.7996
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-1.2247	8.75	6.6922	9.5135	8.5654
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-2.6186	13.2142	6.9174	9.568	8.4076

Table 3.10: DG Vega value mean = 0, var = 0.5

In Figure. 3.7 we can see that as mean and variance increases delta curves shifts right and gamma curves shifts right and decrease in height. In Figure. 3.8 we can see that as mean and variance increases vega curves shifts right and theta curves shifts down. In Figure. 3.9 we can see that as mean and variance increases rho curves shifts right. In conclusion as mean and variance increases delta, gamma, vega and rho curves shifts right and theta curves shifts down.

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parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	-15.2481	-18.2497	-16.3031
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	-13.3687	-16.6802	-15.0686
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0	1.5	-12.6052	-16.0587	-14.5948
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	-12.0804	-15.625	-14.2579
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	-11.6212	-15.2296	-13.9351
DG mean = 0, var = 1.5 fix DG $\beta = 2$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	2.6186	13.2142	-39.7389	-39.892	-38.6992
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	1.2247	8.75	-22.5129	-22.6042	-22.3675
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0.0	7.5	-18.0382	-18.1145	-18.9207
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-1.2247	8.75	-15.7684	-15.8363	-17.2573
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-2.6186	13.2142	-14.1725	-14.2342	-16.0733

Table 3.11: DG Theta value mean = 0, var = 0.5

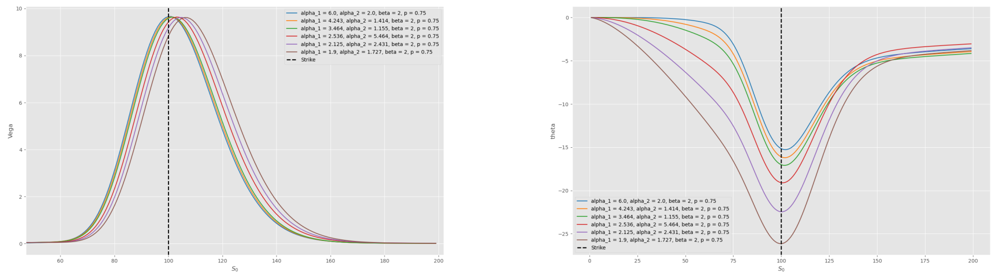

Figure 3.8: DG Vega and Theta value fixing mean and var.
Left: Vega, Right: Theta

parameters	Skewness	Kurtosis	S = 90	ATM	S = 110
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	0.6546	2.6428	4.9744	10.9066	16.877
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	0.3061	1.75	5.4054	11.4879	17.3852
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0	1.5	5.5899	11.7267	17.5913
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-0.3061	1.75	5.7078	11.8795	17.7258
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-0.65465	2.6428	5.7956	11.9981	17.8342
DG mean = 0, var = 1.5 fix $\beta = 2$					
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	2.6186	13.2142	1.7653	5.2579	10.6225
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	1.2247	8.75	3.8372	9.1185	15.1313
p = 0.5, $\alpha_{g1} = 2.0000, \alpha_{g2} = 2.0000$	0.0	7.5	4.6298	10.3197	16.3001
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	-1.2247	8.75	5.0651	10.9338	16.8685
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	-2.6186	13.2142	5.3638	11.3425	17.2404

Table 3.12: DG Rho value mean = 0, var = 0.5

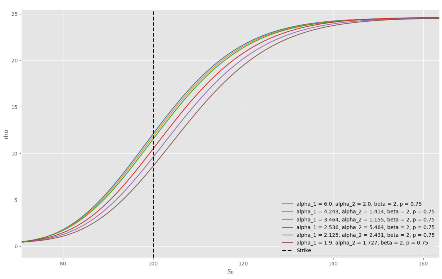

Figure 3.9: DG Rho value fixing mean and var

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3.3.1.1 DG Greeks value fixing mean and var with different parameters

Table. 3.13, Table. 3.14, Table. 3.15, Table. 3.16, Table. 3.17 shows DE Delta, Gamma, Vega, Theta, and Rho value by fixing mean and variance. Figure. 3.10, Figure. 3.11 , Figure. 3.12 , Figure. 3.13 , Figure. 3.14 shows the results of the data in the Tables above and the figure in the right is the enlarged version of the one on the left.

In Figure. 3.10 we can see that under fixed mean and variance as we increase β the delta curves shifts left. In Figure. 3.11 we can see that under fixed mean and variance as we increase β the gamma curves shifts left. In Figure. 3.12 we can see that under fixed mean and variance as we increase β the vega curves shifts left. In Figure. 3.13 we can see that under fixed mean and variance as we increase β the delta curves shifts downward. In Figure. 3.10 we can see that under fixed mean and variance as we increase β the delta curves shifts left.

parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Delta value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	0.2886	0.5513	0.7744
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	0.2844	0.5439	0.768
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	0.2791	0.5351	0.7605
DG Delta value fix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	0.2892	0.5517	0.7745
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	0.2853	0.5445	0.7684
p = 0.8 ,$\alpha_{g1} = 2.3094 \alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	0.2805	0.5365	0.7615
DG Delta value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	0.2912	0.5528	0.7749
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	0.2877	0.546	0.7691
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	0.2835	0.5387	0.7629

Table 3.13: DG Delta value fixing mean and var with different parameters

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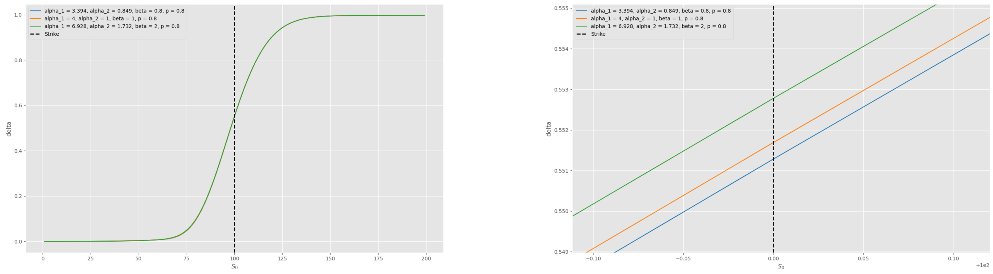

Figure 3.10: DG Delta value fixing mean and var with different parameters

parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Gamma value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	0.0245	0.0259	0.0179
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	0.024	0.0258	0.0181
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	0.0234	0.0257	0.0184
DG Gamma value fix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	0.0245	0.0259	0.0178
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	0.024	0.0258	0.0181
p = 0.8 ,$\alpha_{g1} = 2.3094\alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	0.0234	0.0257	0.0183
DG Gamma value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	0.0244	0.0258	0.0178
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	0.0239	0.0257	0.018
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	0.0234	0.0256	0.0183

Table 3.14: DG Gamma value fixing mean and var with different parameters

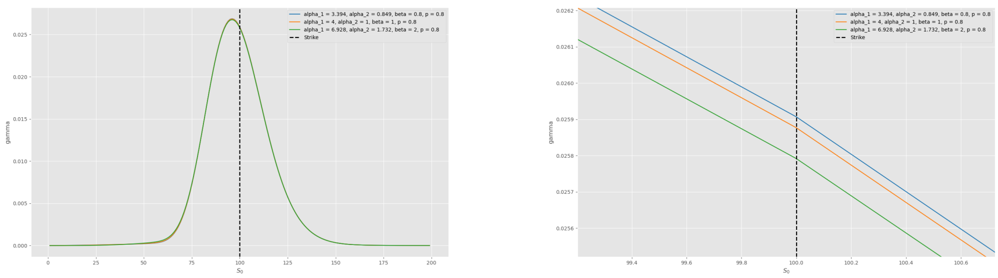

Figure 3.11: DG Gamma value fixing mean and var with different parameters

parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Vega value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	7.4485	9.7168	8.1062
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	7.2856	9.6845	8.2164
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	7.1122	9.6527	8.3441
DG Vega value fix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	7.4421	9.7056	8.0968
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	7.2803	9.6723	8.2034
p = 0.8 ,$\alpha_{g1} = 2.3094\alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	7.1171	9.6418	8.3218
DG Vega value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	7.4201	9.6737	8.073
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	7.2529	9.6379	8.1777
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_2 = 1.0$	0	1.5	-4.5	24.375	7.1003	9.6093	8.2857

Table 3.15: DG Vega value fixing mean and var with different parameters

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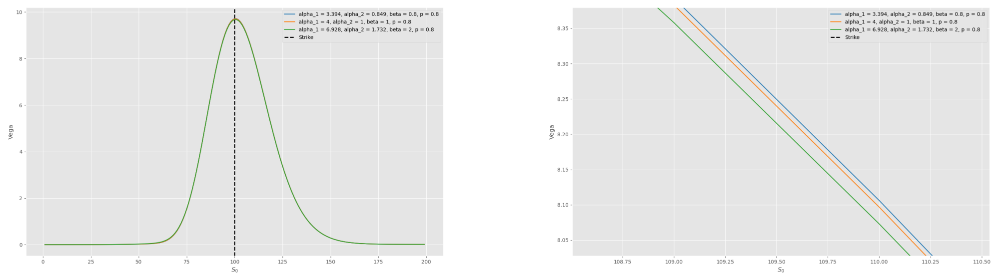

Figure 3.12: DG Vega value fixing mean and var with different parameters

parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Theta value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	-11.0943	-11.1408	-13.5246
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	-11.9429	-11.9939	-14.1802
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	-12.876	-12.9314	-14.8609
DG Theta value fix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	-11.1181	-11.1648	-13.5754
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	-11.9498	-12.0009	-14.2303
p = 0.8 ,$\alpha_{g1} = 2.3094\alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	-12.8203	-12.8757	-14.8739
DG Theta value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	-11.1912	-11.2384	-13.7302
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	-12.0146	-12.0665	-14.4082
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	-12.8092	-12.8653	-15.0125

Table 3.16: DG Theta value fixing mean and var with different parameters

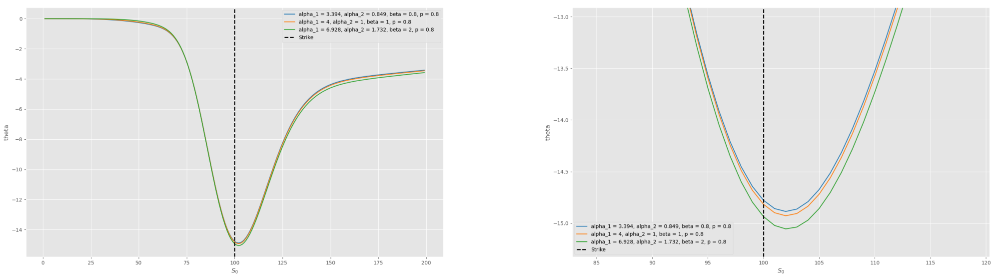

Figure 3.13: DG Theta value fixing mean and var with different parameters

parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Rho value fix $\beta = 0.8$							
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	5.8505	12.0932	17.9326
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	5.6892	11.8555	17.7235
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	5.4958	11.5814	17.4837
DG Rho value ix $\beta = 1$							
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	5.8639	12.1	17.9326
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	5.7099	11.8699	17.7295
p = 0.8 ,$\alpha_{g1} = 2.3094\alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	5.532	11.6158	17.507
DG Rho value fix $\beta = 2$							
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	5.9017	12.1174	17.9317
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	5.7571	11.8941	17.7342
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	5.5984	11.6646	17.5332

Table 3.17: DG Rho value fixing mean and var with different parameters

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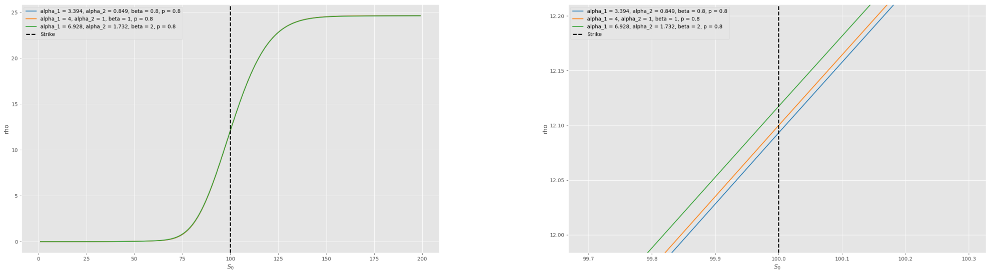

Figure 3.14: DG Rho value fixing mean and var with different parameters

3.3.2 DG Greeks value fixing β, p and increasing α

Table. 3.18, Table. 3.19, Table. 3.20, Table. 3.21, Table. 3.22 shows DG Delta, Gamma, Vega, Theta, and Rho value by fixing mean and variance. Figure. 3.15, Figure. 3.16 , Figure. 3.17 , Figure. 3.18 , Figure. 3.19 shows the results of the data in the Tables above.

DG Delta value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG delta value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	0.2298	0.4449	0.6744
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.24739	0.2602	0.5043	0.7327
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.66210	0.2723	0.5246	0.7508
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.28623	0.2784	0.5344	0.7593
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	0.2819	0.5401	0.7642
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	0.2841	0.5437	0.7672
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.72337	0.2856	0.5462	0.7694
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.52519	0.2866	0.548	0.7709
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.39046	0.2873	0.5493	0.772
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	0.2878	0.5502	0.7729
DG delta value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	0.3601	0.3625	0.3727
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	0.2044	0.3368	0.5319
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	0.2244	0.4262	0.6529
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	0.2446	0.472	0.7013
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	0.2578	0.497	0.7253
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.2396	5.1226	0.2664	0.5121	0.7391
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1.0416	3.61689	0.2723	0.522	0.7478
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.8875	2.62595	0.2764	0.5288	0.7538
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.7653	1.95231	0.2795	0.5338	0.758
p = 0.5 ,$\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.6666	1.48148	0.2817	0.5375	0.7611

Table 3.18: DG Delta value fixing β, p and increasing α

In Figure. 3.15 shows the DG delta value as we increase α. We can see that as α increases delta value curves shifts left and at far OTM delta value decreases.

In Figure. 3.16 shows the DG gamma value as we increase α. We can see that as α in-

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DG Gamma value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG gamma value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	0.0176	0.0239	0.0206
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.24739	0.0216	0.0253	0.0192
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.66210	0.0228	0.0256	0.0186
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.28623	0.0234	0.0257	0.0183
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	0.0238	0.0258	0.0181
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	0.024	0.0258	0.018
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.72337	0.0242	0.0258	0.0179
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.52519	0.0243	0.0258	0.0179
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.39046	0.0244	0.0259	0.0179
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	0.0245	0.0259	0.0178
DG gamma value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	0.0001	0.0005	0.0018
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	0.0089	0.0173	0.0205
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	0.016	0.023	0.0209
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	0.0192	0.0245	0.02
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	0.0209	0.0251	0.0194
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.2396	5.1226	0.0219	0.0253	0.019
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1.0416	3.61689	0.0225	0.0255	0.0187
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.8875	2.62595	0.0229	0.0255	0.0185
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.7653	1.95231	0.0232	0.0256	0.0183
p = 0.5 ,$\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.6666	1.48148	0.0235	0.0256	0.0182

Table 3.19: DG Gamma value fixing β, p and increasing α

DG Vega value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG Vega value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	5.3515	8.9602	9.3624
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.24739	6.5494	9.5029	8.7217
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.66210	6.9354	9.6036	8.4505
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.28623	7.1221	9.6405	8.3114
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	7.2315	9.6596	8.2299
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	7.303	9.672	8.178
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.72337	7.3534	9.6812	8.143
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.52519	7.3909	9.6887	8.1185
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.39046	7.4198	9.6952	8.101
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	7.4429	9.701	8.0881
DG Vega value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	0.0343	0.1742	0.8119
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	2.7152	6.4713	9.3067
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	4.8711	8.6304	9.4801
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	5.8419	9.2027	9.0886
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	6.3437	9.4086	8.7996
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.2396	5.1226	6.6389	9.5007	8.6043
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1.0416	3.61689	6.8296	9.5488	8.4692
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.8875	2.62595	6.9612	9.577	8.3725
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.7653	1.95231	7.0569	9.5953	8.3012
p = 0.5 ,$\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.6666	1.48148	7.1292	9.608	8.2472

Table 3.20: DG Vega value fixing β, p and increasing α

creases gamma value curves shifts left and increases in height.

In Figure. 3.17 shows the DG Vega value as we increase α. We can see that as α increases Vega value curves shifts left.

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DG Theta value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG theta value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	-23.8494	-26.1834	-23.2701
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.24739	-16.6809	-19.6389	-17.6022
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.66210	-14.4018	-17.6349	-15.9223
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.28623	-13.278	-16.6509	-15.0965
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	-12.6052	-16.0587	-14.5948
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	-12.1557	-15.6594	-14.2528
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.72337	-11.8334	-15.3704	-14.0023
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.52519	-11.5908	-15.1506	-13.8098
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.39046	-11.4016	-14.9774	-13.6566
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	-11.2499	-14.8372	-13.5316
DG theta value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	-97.4034	-98.315	-119.7144
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	-42.5701	-42.7451	-42.2165
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	-27.0253	-27.134	-26.3723
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	-21.0382	-21.1256	-21.2873
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	-18.0382	-18.1145	-18.9207
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.2396	5.1226	-16.2713	-16.3406	-17.5678
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1.0416	3.61689	-15.1158	-15.1805	-16.6909
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.8875	2.62595	-14.3038	-14.3651	-16.0736
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.7653	1.95231	-13.7027	-13.7615	-15.6129
p = 0.5 ,$\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.6666	1.48148	-13.24	-13.2968	-15.2544

Table 3.21: DG Theta value fixing β, p and increasing α

DG Rho value fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG rho value $\beta = 1$					
p = 0.5, $\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	1.3888	11.5741	3.5764	8.6983	14.7173
p = 0.5, $\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	1.0204	6.24739	4.7908	10.5966	16.5805
p = 0.5, $\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	0.7812	3.66210	5.2358	11.2338	17.1571
p = 0.5, $\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	0.6172	2.28623	5.459	11.5453	17.4321
p = 0.5, $\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	0.5	1.5	5.5899	11.7267	17.5913
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	0.4132	1.0245	5.6741	11.8439	17.6941
p = 0.5, $\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	0.3472	0.72337	5.7317	11.9248	17.7657
p = 0.5, $\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.2958	0.52519	5.7729	11.9835	17.8181
p = 0.5, $\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.2551	0.39046	5.8032	12.0276	17.858
p = 0.5, $\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.2222	0.2962	5.8262	12.0617	17.8894
DG rho value $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = 1.2, \alpha_{g2} = 1.2$	4.1666	57.8703	0.2666	0.3242	0.5929
p = 0.5 ,$\alpha_{g1} = 1.4, \alpha_{g2} = 1.4$	3.0612	31.2369	1.6256	4.7876	9.915
p = 0.5 ,$\alpha_{g1} = 1.6, \alpha_{g2} = 1.6$	2.3437	18.3105	3.2129	8.0215	13.9679
p = 0.5 ,$\alpha_{g1} = 1.8, \alpha_{g2} = 1.8$	1.8518	11.4311	4.1087	9.5201	15.5301
p = 0.5 ,$\alpha_{g1} = 2.0, \alpha_{g2} = 2.0$	1.5	7.5	4.6298	10.3197	16.3001
p = 0.5, $\alpha_{g1} = 2.2, \alpha_{g2} = 2.2$	1.2396	5.1226	4.9576	10.8004	16.7442
p = 0.5 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 2.4$	1.0416	3.61689	5.1779	11.115	17.0278
p = 0.5 ,$\alpha_{g1} = 2.6, \alpha_{g2} = 2.6$	0.8875	2.62595	5.3334	11.3336	17.2221
p = 0.5 ,$\alpha_{g1} = 2.8, \alpha_{g2} = 2.8$	0.7653	1.95231	5.4476	11.4928	17.3622
p = 0.5 ,$\alpha_{g1} = 3.0, \alpha_{g2} = 3.0$	0.6666	1.48148	5.5341	11.6127	17.4674

Table 3.22: DG Rho value fixing β, p and increasing α

In Figure. 3.18 shows the DG theta value as we increase α. We can see that as α increases theta value curves shifts up.

In conclusion we can see that under fixed β, p as α increases, the more left the Delta, Gamma, Vega, and Rho curves and the higher(larger) the Theta curves are.

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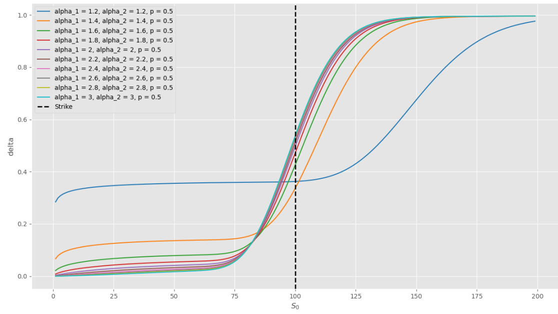

Figure 3.15: DG Delta value fixing β, p and increasing α

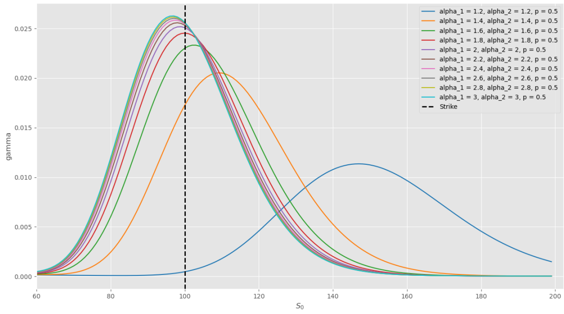

Figure 3.16: DG Gamma value fixing β, p and increasing α

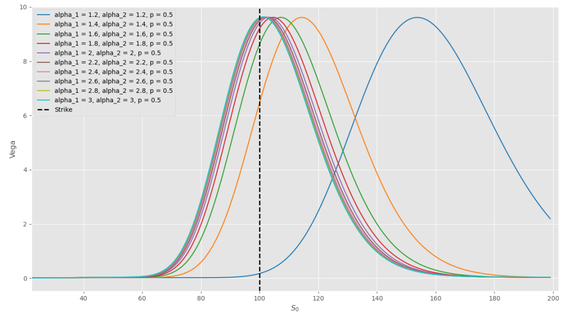

Figure 3.17: DG Vega value fixing β, p and increasing α

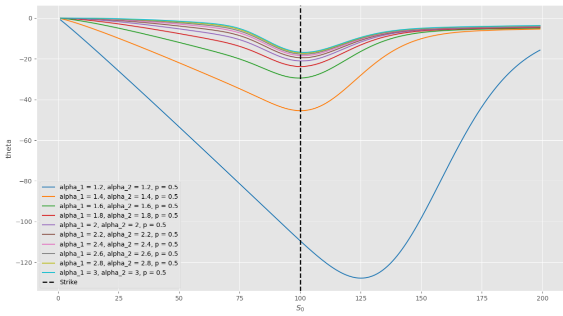

Figure 3.18: DG Theta value fixing β, p and increasing α

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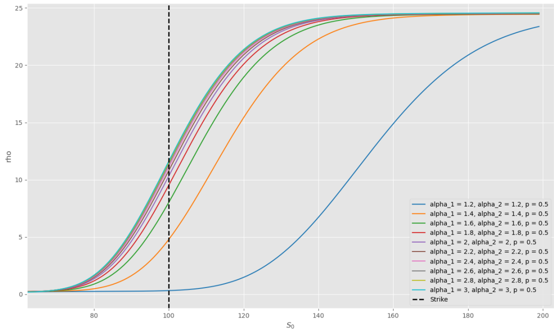

Figure 3.19: DG Rho value fixing β, p and increasing α

3.3.3 DG Greeks value fixing α, p and increasing β

Table. 3.23, Table. 3.24, Table. 3.25, Table. 3.26, Table. 3.27 shows DE Delta, Gamma, Vega, Theta, and Rho value by fixing fixing α, p and increasing β. Figure. 3.20, Figure. 3.21 , Figure. 3.22 , Figure. 3.23 , Figure. 3.24 shows the results of the data in the Tables above.

DG Delta value fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG delta value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	0.2787	0.5343	0.7589
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	0.2747	0.5272	0.7526
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	0.2698	0.5187	0.7451
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	0.2642	0.5087	0.736
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	0.2578	0.497	0.7253
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	0.2507	0.4835	0.7125
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	0.243	0.4681	0.6973
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	0.2351	0.4507	0.6795
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	0.2271	0.4314	0.6585
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	0.2196	0.4103	0.6341
DG delta value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.2933	0.4380	0.2872	0.5484	0.7711
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	0.2863	0.5463	0.769
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	0.2851	0.5437	0.7667
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	0.2836	0.5408	0.7641
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	0.2817	0.5375	0.7611
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	0.2796	0.5337	0.7579
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	0.2771	0.5295	0.7542
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	0.2744	0.5248	0.75
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	0.2713	0.5195	0.7454
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	0.2679	0.5137	0.7403

Table 3.23: DG Delta value fixing α, p and increasing β

In Table. 3.23 and Figure. 3.20 shows the DG Delta value when fixing α, p and increases β with two different values of α. We can see that as β increases Delta value curves shifts

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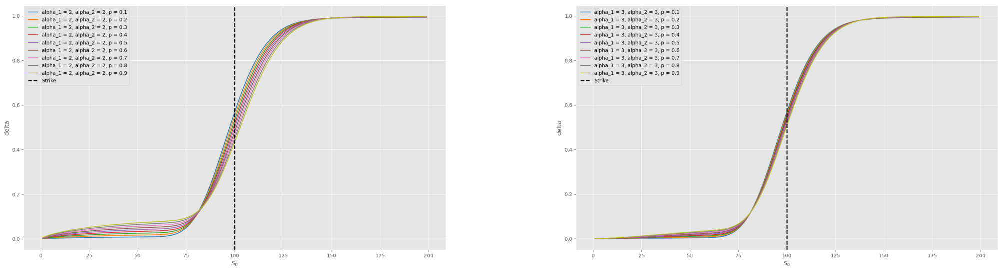

Figure 3.20: DG Delta value fixing α, p and increasing β.
Left:$\alpha = 2$,Right:$\alpha = 3$

right. And that as α increases the curves becomes more compact.

DG Gamma value fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG gamma value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	0.0234	0.0257	0.0183
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	0.0229	0.0256	0.0185
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	0.0223	0.0255	0.0188
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	0.0217	0.0253	0.0191
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	0.0209	0.0251	0.0194
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	0.02	0.0248	0.0197
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	0.0189	0.0244	0.0201
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	0.0177	0.0239	0.0205
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	0.0163	0.0232	0.0208
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	0.0148	0.0222	0.0211
DG gamma value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.2933	0.4380	0.0243	0.0258	0.0179
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	0.0241	0.0258	0.0179
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	0.0239	0.0257	0.018
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	0.0237	0.0257	0.0181
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	0.0235	0.0256	0.0182
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	0.0232	0.0256	0.0183
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	0.0229	0.0255	0.0184
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	0.0226	0.0255	0.0186
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	0.0223	0.0254	0.0187
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	0.0219	0.0253	0.0189

Table 3.24: DG Gamma value fixing α, p and increasing β

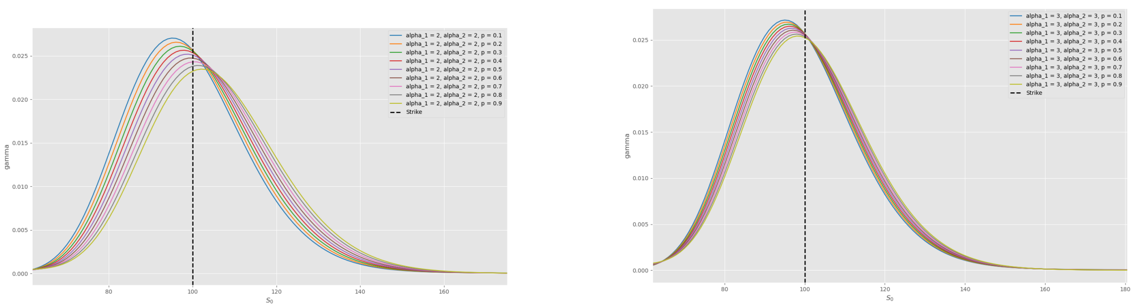

Figure 3.21: DG Gamma value fixing α, p and increasing β.
Left:$\alpha = 2$,Right:$\alpha = 3$

In Table. 3.24 and Figure. 3.21 shows the DG Gamma value when fixing α, p and increases

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β with two different values of α. We can see that as β increases Delta value curves shifts right and decreases in height. And that as α increases the curves becomes more compact.

DG Vega value fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG Vega value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	7.1037	9.6268	8.3078
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	6.9552	9.59	8.4042
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	6.7821	9.5452	8.519
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	6.5799	9.4869	8.6514
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	6.3437	9.4086	8.7996
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	6.0685	9.3016	8.9605
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	5.7492	9.1556	9.1284
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	5.3808	8.9572	9.2944
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	4.96	8.6907	9.4448
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	4.4851	8.3379	9.5591
DG Vega value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.2933	0.4380	7.3894	9.679	8.1055
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	7.3318	9.6593	8.1301
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	7.2697	9.6415	8.1619
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	7.2024	9.6246	8.201
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	7.1292	9.608	8.2472
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	7.0494	9.5907	8.3006
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	6.962	9.5718	8.3608
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	6.8662	9.5502	8.4278
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	6.761	9.5249	8.5012
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	6.6454	9.4946	8.5809

Table 3.25: DG Vega value fixing α, p and increasing β

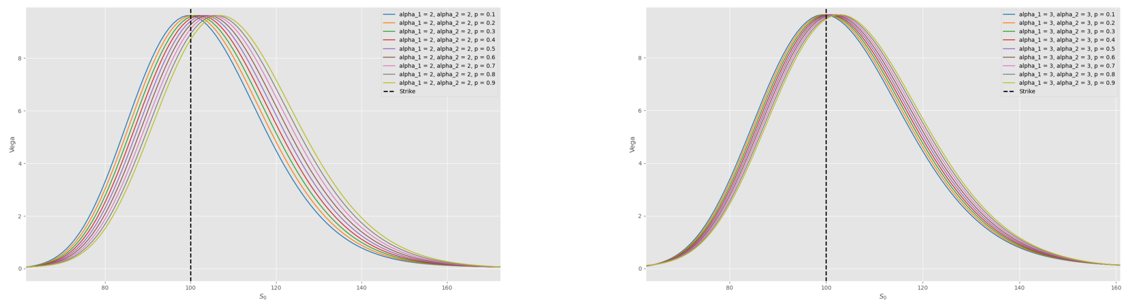

Figure 3.22: DG Vega value fixing α, p and increasing β.
Left:$\alpha = 2$,Right:$\alpha = 3$

In Table. 3.25 and Figure. 3.22 shows the DG Vega value when fixing α, p and increases β with two different values of α. We can see that as β increases Vega value curves shifts right and decreases in height. And that as α increases the curves becomes more compact.

In Table. 3.26 and Figure. 3.23 shows the DG Theta value when fixing α, p and increases

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DG Theta value fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG theta value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	-13.3522	-13.4091	-15.2361
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	-14.2792	-14.3401	-15.9688
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	-15.3522	-15.4177	-16.8104
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	-16.5954	-16.6659	-17.784
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	-18.0382	-18.1145	-18.9207
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	-19.716	-19.7986	-20.2604
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	-21.6699	-21.7599	-21.8546
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	-23.9477	-24.046	-23.7692
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	-26.6027	-26.7107	-26.0874
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	-29.693	-29.8126	-28.9136
DG theta value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.2933	0.4380	-11.5387	-11.5877	-13.8266
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	-11.9094	-11.9603	-14.1461
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	-12.3155	-12.3682	-14.49
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	-12.7583	-12.813	-14.859
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	-13.24	-13.2968	-15.2544
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	-13.7631	-13.8222	-15.6781
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	-14.331	-14.3926	-16.1331
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	-14.9478	-15.0119	-16.6228
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	-15.6178	-15.6847	-17.1517
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	-16.3465	-16.4163	-17.7249

Table 3.26: DG Theta value fixing α, p and increasing β

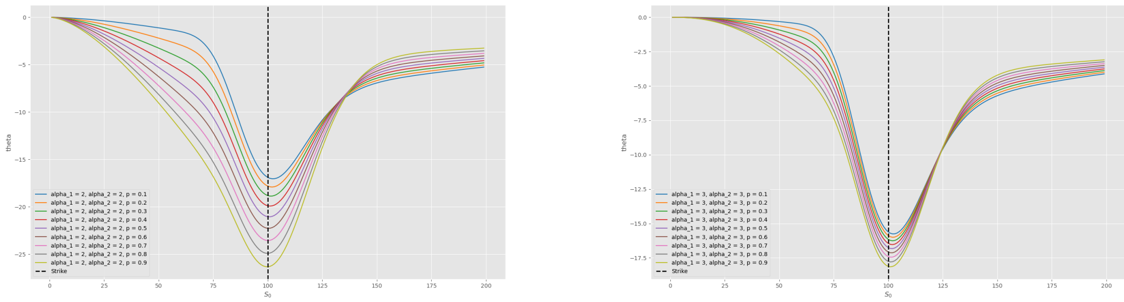

Figure 3.23: DG Theta value fixing α, p and increasing β.
Left:$\alpha = 2$,Right:$\alpha = 3$

β with two different values of α. We can see that as β increases Theta value curves shifts downward. And that as α increases the curves becomes more compact.

In Table. 3.27 and Figure. 3.24 shows the DG Rho value when fixing α, p and increases β with two different values of α. We can see that as β increases the Rho value, the curves shift right and decrease in height. And that as α increases, the curves become more compact.

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DG Rho value fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	variance	Kurtosis	S = 90	ATM	S = 110
DG rho value $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.66	2.2176	5.4566	11.5308	17.4122
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.84	3.1416	5.2952	11.297	17.2002
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	1.04	4.3056	5.1045	11.0206	16.9492
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	1.26	5.7456	4.883	10.6967	16.652
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	1.5	7.5	4.6298	10.3197	16.3001
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	1.76	9.6096	4.3443	9.8839	15.8838
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	2.04	12.1176	4.0269	9.3838	15.3917
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	2.34	15.0696	3.6793	8.8144	14.811
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	2.66	18.5136	3.3047	8.1719	14.1276
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	3.0	22.5	2.9089	7.4551	13.3268
DG rho value $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = 1.2, \beta_{g2} = 1.2$	0.2933	0.4380	5.7872	11.9939	17.8209
p = 0.5 ,$\beta_{g1} = 1.4, \beta_{g2} = 1.4$	0.3733	0.6205	5.7387	11.9157	17.7453
p = 0.5 ,$\beta_{g1} = 1.6, \beta_{g2} = 1.6$	0.46222	0.8504	5.6804	11.8266	17.6618
p = 0.5 ,$\beta_{g1} = 1.8, \beta_{g2} = 1.8$	0.56	1.1349	5.6122	11.7258	17.5696
p = 0.5 ,$\beta_{g1} = 2.0, \beta_{g2} = 2.0$	0.6666	1.4814	5.5341	11.6127	17.4674
p = 0.5 ,$\beta_{g1} = 2.2, \beta_{g2} = 2.2$	0.78222	1.8981	5.4457	11.4864	17.3543
p = 0.5 ,$\beta_{g1} = 2.4, \beta_{g2} = 2.4$	0.9066	2.3936	5.347	11.346	17.2289
p = 0.5 ,$\beta_{g1} = 2.6, \beta_{g2} = 2.6$	1.04	2.9767	5.2379	11.1907	17.09
p = 0.5 ,$\beta_{g1} = 2.8, \beta_{g2} = 2.8$	1.1822	3.6570	5.1181	11.0195	16.936
p = 0.5 ,$\beta_{g1} = 3.0, \beta_{g2} = 3.0$	1.3333	4.4444	4.9874	10.8313	16.7655

Table 3.27: DG Rho value fixing α, p and increasing β

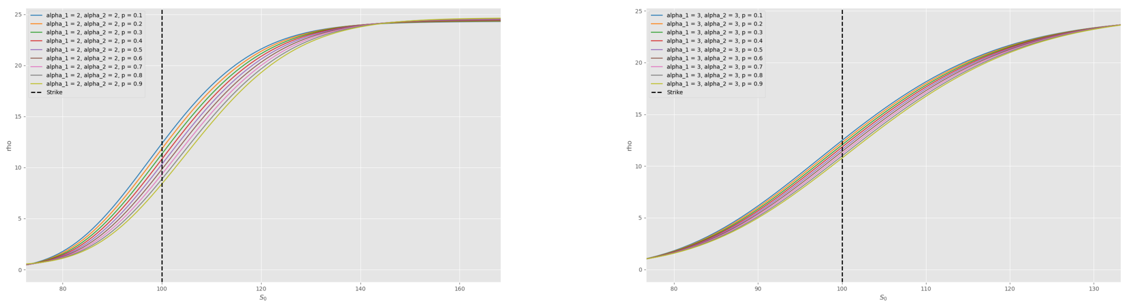

Figure 3.24: DG Rho value fixing α, p and increasing β.
Left:$\alpha = 2$,Right:$\alpha = 3$

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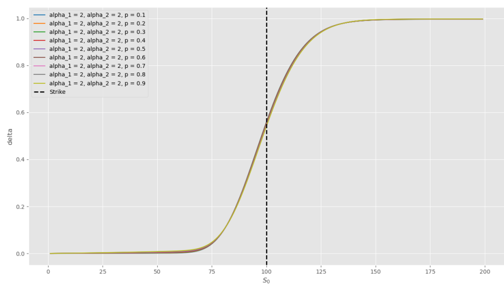
3.3.4 DG Greeks value fixing β, α and increasing p

Table. 3.28, Table. 3.29, Table. 3.30, Table. 3.31, Table. 3.32 , shows DE Delta, Gamma, Vega, Theta, and Rho value by fixing β, α and increasing p. Figure. 3.25, Figure. 3.26 , Figure. 3.27 , Figure. 3.28 , Figure. 3.29 shows the results of the data in the Tables above.

DG Delta value fixing β, α and increasing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG delta value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.1475	-0.1	0.3003	0.2926	0.5595	0.7808
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	0.291	0.5572	0.779
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	0.2895	0.5548	0.7773
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	0.288	0.5525	0.7755
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	0.2865	0.5502	0.7737
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	0.285	0.5478	0.7719
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	0.2835	0.5455	0.7701
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	0.2821	0.5432	0.7682
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	0.2807	0.5408	0.7664
DG delta value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	0.2978	0.564	0.7828
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	0.2936	0.558	0.7783
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	0.2896	0.552	0.7736
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	0.2857	0.5461	0.7689
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	0.2819	0.5401	0.7642
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	0.2782	0.5342	0.7593
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	0.2747	0.5283	0.7544
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	0.2712	0.5225	0.7495
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	0.2679	0.5167	0.7445
DG delta value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	0.3022	0.5671	0.7843
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	0.2897	0.5492	0.7702
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	0.2781	0.5315	0.7557
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	0.2675	0.514	0.7407
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	0.2578	0.497	0.7253
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	0.249	0.4803	0.7095
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	0.2413	0.4641	0.6935
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	0.2344	0.4485	0.6773
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	0.2285	0.4335	0.6609

Table 3.28: DG Delta value fixing β, α and increasing p



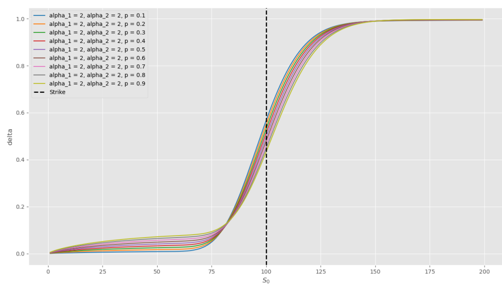


Figure 3.25: DG Delta value fixing β, α and increasing p.
Left:$\beta = 0.5$,Right:$\beta = 2$

In Table. 3.28 and Figure. 3.25 shows the DG Delta value when fixing α, β and increases p with two different values of p. We can see that as β increases Delta value curves shifts right. And that as β increases the curves becomes less compact.

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DG Gamma value fixing β, α and increasing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG gamma value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.1475	-0.1	0.3003	0.0252	0.026	0.0175
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	0.0251	0.026	0.0176
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	0.0249	0.026	0.0177
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	0.0248	0.026	0.0178
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	0.0246	0.026	0.0179
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	0.0245	0.026	0.018
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	0.0243	0.026	0.0181
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	0.0242	0.026	0.0182
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	0.024	0.0259	0.0182
DG gamma value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	0.0253	0.0258	0.0172
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	0.0249	0.0258	0.0175
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	0.0246	0.0258	0.0177
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	0.0242	0.0258	0.0179
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	0.0238	0.0258	0.0181
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	0.0234	0.0257	0.0184
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	0.023	0.0257	0.0186
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	0.0227	0.0256	0.0188
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	0.0223	0.0255	0.019
DG gamma value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	0.0252	0.0257	0.0171
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	0.0241	0.0256	0.0177
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	0.0231	0.0255	0.0183
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	0.022	0.0254	0.0189
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	0.0209	0.0251	0.0194
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	0.0198	0.0247	0.0198
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	0.0186	0.0243	0.0202
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	0.0175	0.0238	0.0206
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	0.0164	0.0232	0.0208

Table 3.29: DG Gamma value fixing β, α and increasing p

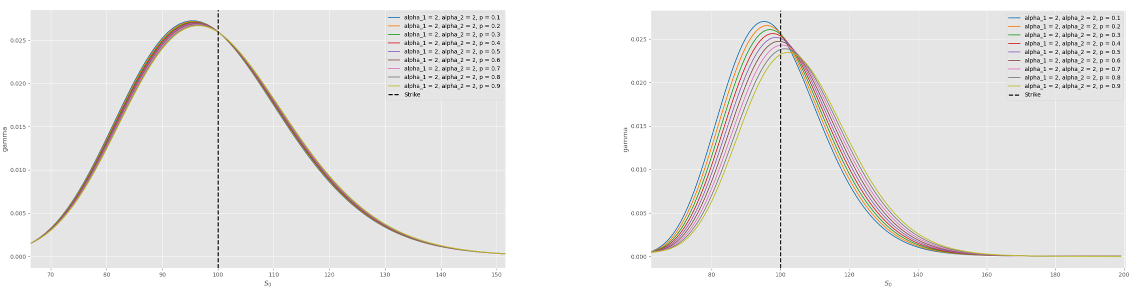

Figure 3.26: DG Gamma value fixing β, α and increasing p.
Left:$\beta = 0.5$,Right:$\beta = 2$

In Table. 3.29 and Figure. 3.26 shows the DG Delta value when fixing α, β and increases p with two different values of p. We can see that as β increases Delta value curves shifts right and decreases in height. And that as β increases the curves becomes less compact.

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DG Vega value fixing β, α and increasing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG Vega value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.1475	-0.1	0.3003	7.666	9.7475	7.9402
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	7.62	9.7478	7.9839
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	7.5738	9.7474	8.0273
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	7.5273	9.7461	8.0704
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	7.4806	9.7442	8.1131
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	7.4336	9.7414	8.1554
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	7.3865	9.738	8.1974
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	7.3391	9.7337	8.239
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	7.2916	9.7288	8.2802
DG Vega value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	7.6818	9.677	7.8187
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	7.5715	9.6791	7.9246
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	7.4596	9.6769	8.0286
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	7.3462	9.6704	8.1304
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	7.2315	9.6596	8.2299
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	7.1155	9.6445	8.3271
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	6.9986	9.625	8.4218
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	6.8807	9.6014	8.5138
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	6.762	9.5735	8.603
DG Vega value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	7.6458	9.6191	7.751
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	7.3346	9.6158	8.0421
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	7.0121	9.5793	8.3156
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	6.6809	9.51	8.5689
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	6.3437	9.4086	8.7996
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	6.0033	9.2761	9.0054
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	5.662	9.1139	9.1843
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	5.3223	8.9238	9.3343
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	4.9865	8.7075	9.4541

Table 3.30: DG Vega value fixing β, α and increasing p

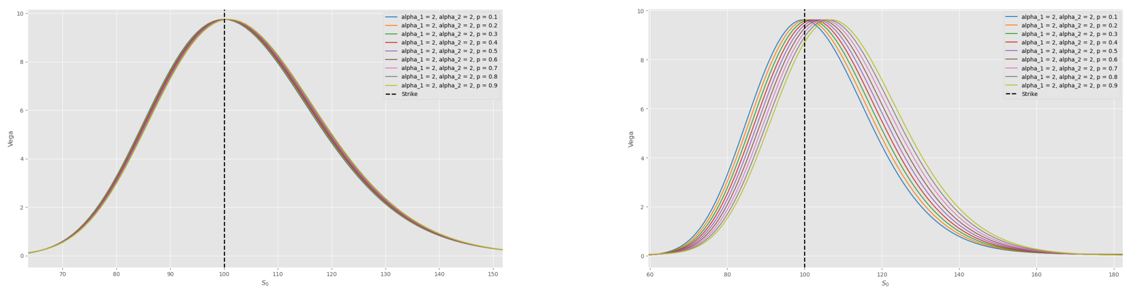

Figure 3.27: DG Vega value fixing α, p and increasing β.
Left:$\beta = 0.5$,Right:$\beta = 2$

In Table. 3.30 and Figure. 3.27 shows the DG Vega value when fixing α, β and increases p with two different values of p. We can see that as β increases Vega value curves shifts right. And that as β increases the curves becomes less compact.

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DG Theta value fixing β, α and increasing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG theta value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.1475	-0.1	0.3003	-10.5962	-10.6383	-13.1336
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	-10.6997	-10.7429	-13.1789
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	-10.8043	-10.8484	-13.2256
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	-10.9098	-10.9549	-13.2735
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	-11.0162	-11.0623	-13.3226
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	-11.1235	-11.1706	-13.3731
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	-11.2318	-11.2799	-13.4247
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	-11.3409	-11.39	-13.4778
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	-11.4509	-11.501	-13.5321
DG theta value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	-11.3169	-15.0973	-13.9607
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	-11.6293	-15.3248	-14.1063
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	-11.9483	-15.5609	-14.2605
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	-12.2737	-15.8056	-14.4233
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	-12.6052	-16.0587	-14.5948
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	-12.9426	-16.3202	-14.7753
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	-13.2857	-16.59	-14.9647
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	-13.6342	-16.868	-15.1632
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	-13.988	-17.1541	-15.3708
DG theta value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	-12.9513	-12.9969	-15.8267
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	-14.1389	-14.1926	-16.4754
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	-15.3863	-15.4479	-17.2058
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	-16.688	-16.7571	-18.0204
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	-18.0382	-18.1145	-18.9207
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	-19.431	-19.5143	-19.908
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	-20.8602	-20.9506	-20.9827
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	-22.3199	-22.4174	-22.1446
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	-23.8041	-23.9089	-23.3928

Table 3.31: DG Theta value fixing β, α and increasing p

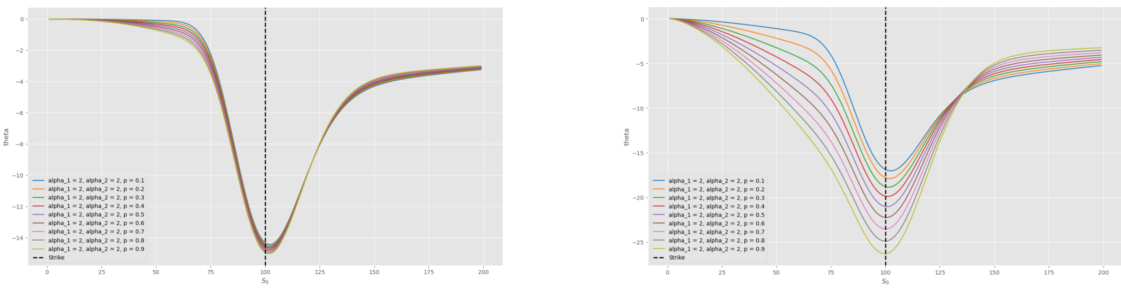

Figure 3.28: DG Theta value fixing α, p and increasing β,.
Left:$\beta = 0.5$,Right:$\beta = 2$

In Table. 3.31 and Figure. 3.28 shows the DG Theta value when fixing α, β and increases p with two different values of p. We can see that as β increases Theta value curves shifts downward. And that as β increases the curves becomes less compact.

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DG Rho value fixing β, α and increasing p, mean = 0, Skewness = 0							
parameters	mean	variance	Skewness	Kurtosis	S = 90	ATM	S = 110
DG call value $\beta = 0.5$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{2g} = 2$	-0.2	0.1475	-0.1	0.3003	5.9909	12.3323	18.1223
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.15	0.165	-0.063	0.3495	5.9452	12.2683	18.0739
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.1775	-0.0395	0.3836	5.8999	12.2042	18.0251
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.05	0.185	-0.019	0.4035	5.855	12.1401	17.9758
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.1875	0.0	0.4101	5.8105	12.0761	17.9262
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.05	0.185	0.019	0.4035	5.7664	12.0121	17.8763
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1775	0.0395	0.3836	5.7227	11.9481	17.8259
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.15	0.165	0.063	0.3495	5.6794	11.8842	17.7752
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.1475	0.1	0.3003	5.6366	11.8203	17.7242
DG rho value $\beta = 1$							
p = 0.1 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.4	0.34	-0.128	0.9432	6.0675	12.3913	18.1165
p = 0.2 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.3	0.41	-0.054	1.2057	5.9446	12.225	17.9885
p = 0.3 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.2	0.46	-0.016	1.3752	5.824	12.0588	17.8583
p = 0.4 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	-0.1	0.49	-0.002	1.4697	5.7057	11.8927	17.7258
p = 0.5 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.0	0.5	0.0	1.5	5.5899	11.7267	17.5913
p = 0.6 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.1	0.49	0.002	1.4697	5.4765	11.5611	17.4546
p = 0.7 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.2	0.46	0.016	1.3752	5.3655	11.3958	17.3159
p = 0.8 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.3	0.41	0.054	1.2057	5.2571	11.2309	17.1753
p = 0.9 ,$\alpha_{g1} = 2, \alpha_{g2} = 2$	0.4	0.34	0.128	0.9432	5.1511	11.0666	17.0327
DG rho value $\beta = 2$							
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	-0.8	0.86	0.176	4.3512	6.0589	12.3494	18.034
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	-0.6	1.14	0.468	6.0312	5.6731	11.8383	17.6243
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	-0.4	1.34	0.472	6.9432	5.3059	11.3283	17.198
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	-0.2	1.46	0.284	7.3752	4.958	10.8215	16.7562
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	0.0	1.5	0.0	7.5	4.6298	10.3197	16.3001
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	0.2	1.46	-0.284	7.3752	4.3214	9.8248	15.8311
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	0.4	1.34	-0.472	6.9432	4.0332	9.3386	15.3508
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	0.6	1.14	-0.468	6.0312	3.7649	8.8627	14.8608
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	0.8	0.86	-0.176	4.3512	3.5166	8.3989	14.3628

Table 3.32: DG Rho value fixing β, α and increasing p

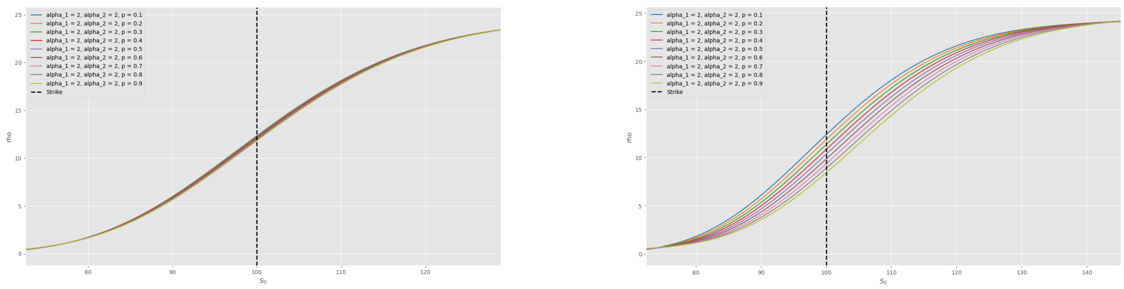

Figure 3.29: DG Rho value fixing α, p and increasing β.
Left:$\beta = 0.5$,Right:$\beta = 2$

In Table. 3.32 and Figure. 3.29 shows the DG Rho value when fixing α, β and increases p with two different values of p. We can see that as β increases Rho value curves shifts right. And that as β increases the curves becomes less compact.

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3.3.5 DG Greeks value conclusion

We can produce the same results as the DE by setting the $\beta = 1$ and set α the same as DE. And by changing $\beta = 1$ higher or lower we can change the Greeks value higher or lower. Under the same mean, variance, Poisson lambda and probability, Double gamma's Greeks value can be greater or smaller than is greater than DE depending on the value of β and α.

We can see that the larger the mean, variance, skewness and kurtosis the more right the Delta, Gamma, Vega, and Rho curves and the lower (smaller) the Theta curves are. Under fixed α, p the larger the β the less compacted curves are and the more right the Delta, Gamma, Vega, and Rho curves and the lower(smaller) the Theta curves are. Under fixed β, p the larger the α the more compacted curves are and the more left the Delta, Gamma, Vega, and Rho curves and the higher(larger) the Theta curves are. Under fixed α, β as p increases the more right the Delta, Gamma, Vega, and Rho curves and the lower(smaller) the Theta curves are. We can also see that when we increases DG's β, DG's delta hedging has better hedging effect than DE's delta hedging.

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3.4 DG Greeks hedging

Here we will be how a Delta hedged and a Delta gamma hedged portfolio performs under DG, the details are in Section. 1.5.2.

3.4.1 DG Greeks hedging fixing mean and variance

First we will show that when fixing $\beta = 1$, DG will replicate the results of DE Greeks hedging results, for demonstration here we will only show mean = 0, variance = 0.5, the other mean and variance parameters will replicate the results of DE as well, the rest of tables will be in the appendix. Table 3.33 shows the results of delta hedging and Table 3.34 shows the results of delta gamma hedging; we can see that fixing $\beta = 1$ replicates the results of the double exponential model.

DG Delta hedging mean = 0, variance = 0.5				
parameters	stock position	call position	S = 90	S = 110
DE mean = 0, var = 0.5				
p = 0.3, $\alpha_{e1} = 1.3093, \alpha_{e2} = 3.0550$	51.2984	-100	-127.4594	-119.6449
p = 0.4, $\alpha_{e1} = 1.6329, \alpha_{e2} = 2.4494$	53.2198	-100	-129.8797	-118.8947
p = 0.5, $\alpha_{e1} = \alpha_{e2} = 2.0000$	54.0127	-100	-130.7227	-118.5087
p = 0.6, $\alpha_{e1} = 2.4494, \alpha_{e2} = 1.6329$	54.5088	-100	-131.274	-118.3028
p = 0.7, $\alpha_{e1} = 3.0550, \alpha_{e2} = 1.3093$	54.8762	-100	-131.7789	-118.2215
DG mean = 0, var = 0.5 fix DG $\beta = 1$				
p = 0.3, $\alpha_{g1} = 1.3093, \alpha_{g2} = 3.0550$	51.2984	-100	-127.4594	-119.6449
p = 0.4, $\alpha_{g1} = 1.6329, \alpha_{g2} = 2.4494$	53.2198	-100	-129.8797	-118.8947
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.0000$	54.0127	-100	-130.7227	-118.5087
p = 0.6, $\alpha_{g1} = 2.4494, \alpha_{g2} = 1.6329$	54.5088	-100	-131.274	-118.3028
p = 0.7, $\alpha_{g1} = 3.0550, \alpha_{g2} = 1.3093$	54.8762	-100	-131.7789	-118.2215

Table 3.33: DG Delta hedging mean = 0, variance = 0.5

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DG Greeks hedging mean = 0, variance = 0.5					
parameters	stock position	call position	put position	S = 90	S = 110
DE mean = 0, var = 0.5					
p = 0.3, α_{e1} = 1.3093, α_{e2} = 3.0550	99.7517	-100	100.0	-0.014	0.014
p = 0.4, α_{e1} = 1.6329, α_{e2} = 2.4494	99.7496	-100	100.0	0.0073	-0.0073
p = 0.5, $\alpha_{e1} = \alpha_{e2} = 2.0000$	99.7493	-100	100.0	0.0105	-0.0105
p = 0.6, α_{e1} = 2.4494, α_{e2} = 1.6329	99.7503	-100	100.0	0.0	-0.0
p = 0.7, α_{e1} = 3.0550, α_{e2} = 1.3093	99.7502	-100	100.0	0.0015	-0.0015
DG mean = 0, var = 0.5 fix DG $\beta = 1$					
p = 0.3, α_{g1} = 1.3093, α_{g2} = 3.0550	99.7517	-100	100.0	-0.014	0.014
p = 0.4, α_{g1} = 1.6329, α_{g2} = 2.4494	99.7496	-100	100.0	0.0073	-0.0073
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.0000$	99.7493	-100	100.0	0.0105	-0.0105
p = 0.6, α_{g1} = 2.4494, α_{g2} = 1.6329	99.7503	-100	100.0	0.0	-0.0
p = 0.7, α_{g1} = 3.0550, α_{g2} = 1.3093	99.7502	-100	100.0	0.0015	-0.0015

Table 3.34: DG Delta gamma hedging mean = 0, variance = 0.5

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DG Delta hedging fix mean and variance								
parameters	mean	var	Skewness	Kurtosis	stock position	call position	S = 90	S = 110
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0.0	0.5	-1.125	4.875	55.169	-100	-132.3525	-118.2633
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} =$ 0.7071	0.0	1.0	-3.1819	19.5	54.4549	-100	-131.1078	-118.4946
p = 0.8 ,$\alpha_{g1} = 2.3094, \alpha_{g2} =$ 0.5773	0.0	1.5	-5.8456	43.875	53.6457	-100	-129.8789	-118.7912
p = 0.8 ,$\alpha_{g1} = 1.4775, \alpha_{g2} =$ 4.8284	0.5	0.5	0.6022	2.0197	47.6637	-100	-120.0623	-119.4313
p = 0.8 ,$\alpha_{g1} = 1.2404, \alpha_{g2} =$ 1.3797	0.5	1	0.4332	7.0057	40.5371	-100	-101.3271	-112.9993
p = 0.8 ,$\alpha_{g1} = 1.1169, \alpha_{g2} =$ 0.9249	0.5	1.5	-0.4469	17.4745	30.4795	-100	-55.442	-79.1495

Table 3.35: DG Delta hedging fix mean and variance

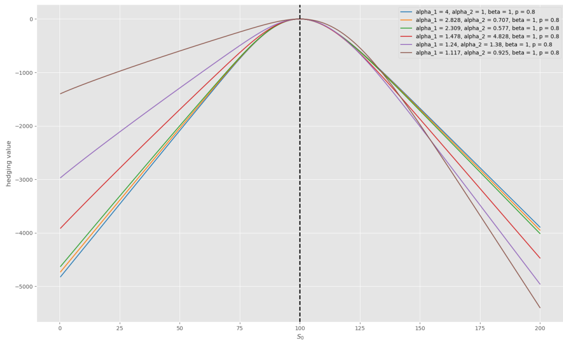

Figure 3.30: figure:DG Delta hedging fix mean and variance

From Table 3.35 we can see that the larger the mean and variance the smaller the stock position. From Figure. 3.30 we can see that Delta hedging $\Delta\Pi$ curves are like Quadratic function with Opening facing down and that the larger the mean and variance the more clockwise the $\Delta\Pi$ curves rotates.

DG Delta gamma hedging fix mean and variance									
parameters	mean	var	Skewness	Kurtosis	stock position	call position	put position	S = 90	S = 110
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0.0	0.5	-1.125	4.875	99.7501	-100	100.0	0.0021	-0.0021
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} =$ 0.7071	0.0	1.0	-3.1819	19.5	99.75	-100	100.0	0.0028	-0.0028
p = 0.8 ,$\alpha_{g1} = 2.3094, \alpha_{g2} =$ 0.5773	0.0	1.5	-5.8456	43.875	99.7502	-100	100.0	0.0014	-0.0014
p = 0.8 ,$\alpha_{g1} = 1.4775, \alpha_{g2} =$ 4.8284	0.5	0.5	0.6022	2.0197	99.7496	-100	100.0	0.007	-0.0069
p = 0.8 ,$\alpha_{g1} = 1.2404, \alpha_{g2} =$ 1.3797	0.5	1	0.4332	7.0057	99.7502	-100	100.0	0.0013	-0.0013
p = 0.8 ,$\alpha_{g1} = 1.1169, \alpha_{g2} =$ 0.9249	0.5	1.5	-0.4469	17.4745	99.7501	-100	100.0	0.0017	-0.0017

Table 3.36: DG Delta gamma hedging fix mean and variance

From Table 3.36 we can see that stock position doesn't really change in relation with the

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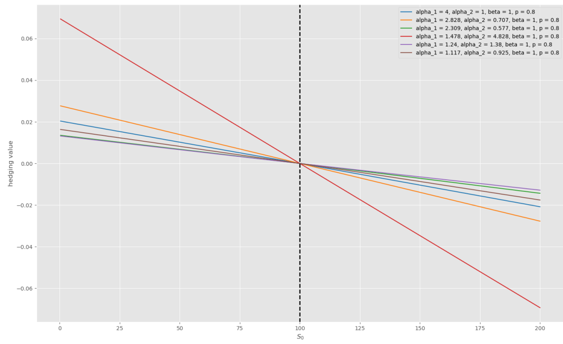

Figure 3.31: DG Delta gamma hedging fix mean and variance

change in mean and variance. Gamma for call and put is the same, the reason for this is because of put call parity, when differentiate by S twice we will get $\frac{\partial^2 C}{\partial S^2} = \frac{\partial^2 P}{\partial S^2}$. . The hedging results are quite similar for delta gamma hedging for all parameters.

From Figure. 3.31 we can see that Delta gamma hedging $\Delta\Pi$ curves are like linear functions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign.

3.4.1.1 DG Greeks value fixing mean and var with different parameters

Table. 3.37, Table. 3.38 shows Delta hedging and Delta gamma hedging results by fixing mean and variance. Figure. 3.32, Figure. 3.33 shows the results of the data in the Tables above.

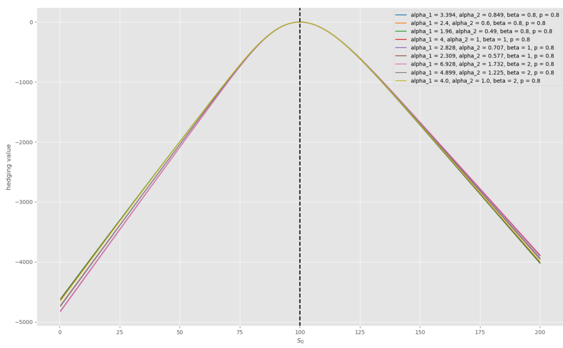

Figure 3.32: figure:DG Delta hedging fixing mean and var with different parameters

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DG Delta hedging fix mean and variance with different parameters								
parameters	mean	var	Skewness	Kurtosis	stock position	call position	S = 90	S = 110
DG Delta hedging fix $\beta = 0.8$								
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	55.1283	-100	-132.4936	-118.4068
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	54.3862	-100	-131.2552	-118.6578
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	53.5088	-100	-129.947	-118.9916
DG Delta hedging fix $\beta = 1$								
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	55.169	-100	-132.3525	-118.2633
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	54.4549	-100	-131.1078	-118.4946
p = 0.8 ,$\alpha_{g1} = 2.3094 \alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	53.6457	-100	-129.8789	-118.7912
DG Delta hedging fix $\beta = 2$								
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	55.2779	-100	-131.9141	-117.8882
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	54.5953	-100	-130.6283	-118.0884
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	53.8687	-100	-129.477	-118.36

Table 3.37: DG Delta hedging fixing mean and var with different parameters

From Table 3.37 we can see that the larger the mean and variance the smaller the stock position. From Figure. 3.32 we can see that Delta hedging $\Delta\Pi$ curves are like Quadratic function with Opening facing down and that the larger the mean and variance the more clockwise the $\Delta\Pi$ curves rotates.

DG Delta gamma hedging fix mean and variance with different parameters									
parameters	mean	var	Skewness	Kurtosis	stock position	call position	put position	S = 90	S = 110
DG Delta gamma hedging fix $\beta = 0.8$									
p = 0.8 ,$\alpha_{g1} = 3.3941, \alpha_{g2} = 0.8485$	0	0.5	-1.2374	6.0034	99.7497	-100	100.0	0.006	-0.006
p = 0.8 ,$\alpha_{g1} = 2.4, \alpha_{g2} = 0.6$	0	1.0	-3.45	24.0138	99.7502	-100	100.0	0.0015	-0.0015
p = 0.8 ,$\alpha_{g1} = 1.9595, \alpha_{g2} = 0.4898$	0	1.5	-6.4299	54.0312	99.6963	-100	100.0	0.002	-0.0063
DG Delta gamma hedging fix $\beta = 1$									
p = 0.8 ,$\alpha_{g1} = 4, \alpha_{g2} = 1$	0	0.5	-1.125	4.875	99.7501	-100	100.0	0.0021	-0.0021
p = 0.8 ,$\alpha_{g1} = 2.8284, \alpha_{g2} = 0.7071$	0	1.0	-3.1819	19.50	99.75	-100	100.0	0.0028	-0.0028
p = 0.8 ,$\alpha_{g1} = 2.3094 \alpha_{g2} = 0.5773$	0	1.5	-5.8456	43.875	99.7502	-100	100.0	0.0014	-0.0014
DG Delta gamma hedging fix $\beta = 2$									
p = 0.8 ,$\alpha_{g1} = 6.9282, \alpha_{g2} = 1.7320$	0	0.5	-0.8660	2.7083	99.7499	-100	100.0	0.0043	-0.0043
p = 0.8 ,$\alpha_{g1} = 4.8989, \alpha_{g2} = 1.2247$	0	1	-2.4494	10.8333	99.7503	-100	100.0	0.0005	-0.0005
p = 0.8 ,$\alpha_{g1} = 4.0, \alpha_{g2} = 1.0$	0	1.5	-4.5	24.375	99.7498	-100	100.0	0.0047	-0.0047

Table 3.38: DG Delta gamma hedging fixing mean and var with different parameters

From Table 3.38 we can see that stock position doesn't really change in relation with the change in mean and variance. The hedging results are quite similar for delta gamma hedging for all parameters.

From Figure. 3.33 we can see that Delta gamma hedging $\Delta\Pi$ curves are like linear func-

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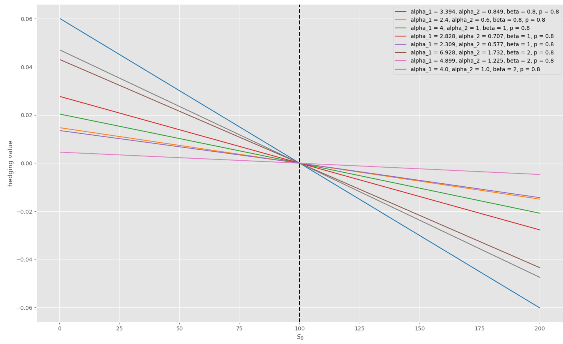

Figure 3.33: DG Delta gamma hedging fixing mean and var with different parameters

tions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign.

3.4.2 DG Greeks hedging fixing β, p and increasing α

Table. 3.39, Table. 3.40, shows DG Delta hedging and Delta gamma hedging for fixing β, p and increasing α. Figure. 3.34, Figure. 3.35 , shows the results of the data in the Tables above.

DG Delta hedging fixing β, p and increasing α, mean = 0, Skewness = 0				
parameters	stock position	call position	S = 90	S = 110
DG $\beta = 1$				
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 1.2$	44.4896	-100	-112.8689	-117.5845
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 1.4$	50.4293	-100	-125.2406	-119.4516
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 1.6$	52.4572	-100	-128.4708	-119.0659
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 1.8$	53.4443	-100	-129.9112	-118.7281
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.0$	54.0127	-100	-130.7227	-118.5087
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.2$	54.3748	-100	-131.2531	-118.3655
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.4$	54.6208	-100	-131.6283	-118.2772
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.6$	54.7961	-100	-131.9127	-118.2236
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.8$	54.9258	-100	-132.1399	-118.1921
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 3.0$	55.024	-100	-132.325	-118.1791
DG $\beta = 2$				
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.2$	36.2508	-100	-1.4722	-3.9799
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.4$	33.6799	-100	-73.248	-94.7953
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.6$	42.6235	-100	-106.8365	-115.1905
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.8$	47.1961	-100	-118.1697	-118.5314
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.0$	49.6969	-100	-123.1422	-119.0154
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.2$	51.2107	-100	-125.7732	-118.9129
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.4$	52.2002	-100	-127.3526	-118.7004
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.6$	52.8849	-100	-128.3884	-118.4935
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.8$	53.3802	-100	-129.1213	-118.3112
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 3.0$	53.75	-100	-129.6594	-118.1668

Table 3.39: DG Delta hedging fixing β, p and increasing α

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DG Delta gamma hedging fixing β, p and increasing α, mean = 0, Skewness = 0					
parameters	stock position	call position	put position	S = 90	S = 110
DG $\beta = 1$					
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.2$	99.7495	-100	100.0	0.0078	-0.0078
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.4$	99.7507	-100	100.0	-0.0046	0.0046
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.6$	99.7495	-100	100.0	0.0084	-0.0084
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.8$	99.7504	-100	100.0	-0.001	0.001
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.0$	99.7493	-100	100.0	0.0106	-0.0106
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.2$	99.749	-100	100.0	0.0132	-0.0132
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.4$	99.7486	-100	100.0	0.0173	-0.0173
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.6$	99.7505	-100	100.0	-0.0017	0.0017
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.8$	99.7495	-100	100.0	0.0081	-0.0081
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 3.0$	99.7491	-100	100.0	0.0125	-0.0126
DG $\beta = 2$					
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.2$	99.7481	-100	100.0	0.0096	-0.0096
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.4$	99.7496	-100	100.0	0.0074	-0.0074
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.6$	99.7497	-100	100.0	0.0058	-0.0058
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 1.8$	99.7499	-100	100.0	0.0044	-0.0044
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.0$	99.7514	-100	100.0	-0.0109	0.0109
p = 0.5, $\alpha_{g1} = \alpha_{g2} = 2.2$	99.7505	-100	100.0	-0.0024	0.0024
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.4$	99.7506	-100	100.0	-0.0028	0.0028
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.6$	99.7492	-100	100.0	0.0112	-0.0112
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2.8$	99.7503	-100	100.0	0.0	0.0
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 3.0$	99.748	-100	100.0	0.0229	-0.0229

Table 3.40: DG Delta gamma hedging fixing β, p and increasing α

In Figure. 3.34 shows the DE Delta hedging $\Delta\Pi$ curves as we fix β, p and increasing α. We can see that Delta hedging $\Delta\Pi$ curves looks like Quadratic function with Opening facing down and as α increases $\Delta\Pi$ value curves rotates clockwise. In Table. 3.39, under fixed β, p, the larger the α the larger the stock position.

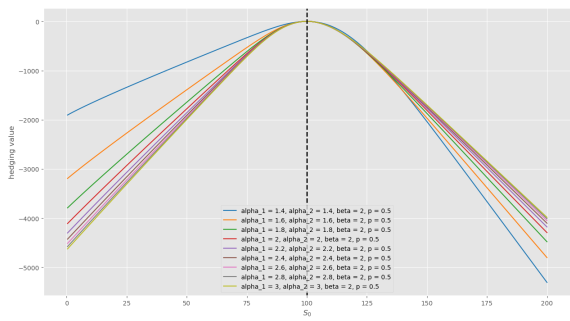

Figure 3.34: DG Delta hedging fixing β, p and increasing α

In Figure. 3.35 shows the DE Delta gamma hedging $\Delta\Pi$ curves as we fix β, p and increasing α. We can see that $\Delta\Pi$ value curves are like linear functions with a negative slope, that's why S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in α.

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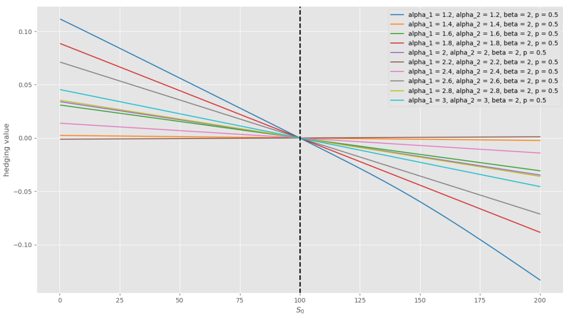

Figure 3.35: DG Delta gamma hedging fixing β, p and increasing α

3.4.3 DG Greeks hedging fixing α, p and increasing β

Table. 3.41, Table. 3.42, shows DG Delta hedging and Delta gamma hedging for fixing α, p and increasing β. Figure. 3.36, Figure. 3.37 shows the results of the data in the Tables above.

DG Delta hedging fixing α, p and increasing β, mean = 0, Skewness = 0				
parameters	stock position	call position	S = 90	S = 110
DG $\alpha = 2$				
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.2$	53.4263	-100	-129.6773	-118.5994
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.4$	52.7154	-100	-128.4686	-118.7413
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.6$	51.8661	-100	-127.0298	-118.8974
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.8$	50.8651	-100	-125.2892	-119.0087
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.0$	49.6969	-100	-123.1422	-119.0154
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.2$	48.3489	-100	-120.4808	-118.8194
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.4$	46.8099	-100	-117.1689	-118.2991
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.6$	45.0742	-100	-113.0557	-117.2877
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.8$	43.1432	-100	-107.961	-115.5834
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 3.0$	41.0331	-100	-101.7097	-112.9195
DG $\alpha = 3$				
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.2$	54.8432	-100	-131.8154	-118.0778
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.4$	54.6274	-100	-131.302	-118.0343
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.6$	54.3747	-100	-130.7774	-118.0412
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.8$	54.0832	-100	-130.2357	-118.0862
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.0$	53.75	-100	-129.6594	-118.1668
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.2$	53.3726	-100	-129.0352	-118.2742
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.4$	52.9487	-100	-128.3517	-118.396
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.6$	52.475	-100	-127.5864	-118.5295
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.8$	51.9498	-100	-126.7326	-118.6537
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 3.0$	51.3696	-100	-125.7646	-118.7634

Table 3.41: DG Delta hedging fixing α, p and increasing β, mean = 0, Skew = 0

In Figure. 3.36 shows the DG Delta hedging $\Delta\Pi$ curves as we fix α, p and increasing β. We can see that Delta hedging $\Delta\Pi$ curves looks like Quadratic function with Opening

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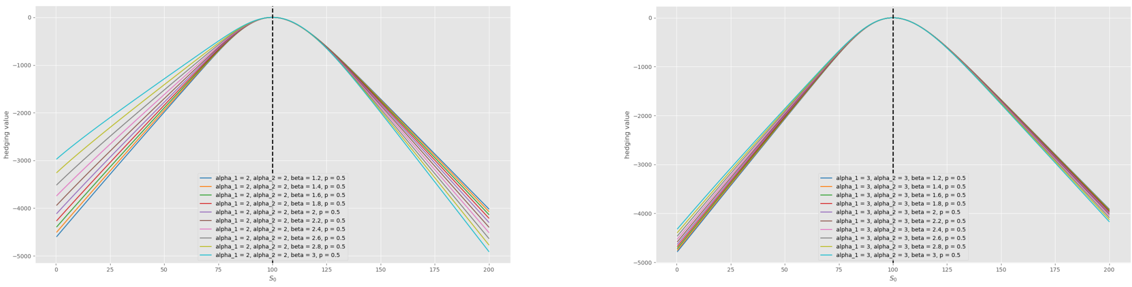

Figure 3.36: DG Delta hedging fixing α, p and increasing β
Left:$\alpha = 2$,Right:$\alpha = 3$

facing down and as β increases $\Delta\Pi$ value curves rotates clockwise and as α increases the curves become more compact. In Table. 3.41, under fixed α, p, the larger the β the smaller the stock position.

DG Delta gamma hedging fixing α, p and increasing β, mean = 0, Skewness = 0					
parameters	stock position	call position	put position	S = 90	S = 110
DG $\alpha = 2$					
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.2$	99.75	-100	100.0	0.003	-0.003
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.4$	99.75	-100	100.0	0.0033	-0.0033
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.6$	99.7494	-100	100.0	0.0092	-0.0092
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.8$	99.7504	-100	100.0	-0.0009	0.0009
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.0$	99.7514	-100	100.0	-0.0109	0.0109
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.2$	99.7509	-100	100.0	-0.0056	0.0056
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.4$	99.7504	-100	100.0	-0.0009	0.0009
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.6$	99.7508	-100	100.0	-0.0045	0.0045
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.8$	99.7503	-100	100.0	0.0004	-0.0004
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 3.0$	99.7493	-100	100.0	0.0103	-0.0103
DG $\alpha = 3$					
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.2$	99.7513	-100	100.0	-0.0093	0.0093
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.4$	99.7515	-100	100.0	-0.012	0.012
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.6$	99.7498	-100	100.0	0.0055	-0.0055
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 1.8$	99.7512	-100	100.0	-0.009	0.009
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.0$	99.748	-100	100.0	0.0229	-0.0229
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.2$	99.7515	-100	100.0	-0.0121	0.0121
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.4$	99.7506	-100	100.0	-0.0027	0.0027
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.6$	99.751	-100	100.0	-0.0068	0.0068
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 2.8$	99.7493	-100	100.0	0.01	-0.01
p = 0.5 ,$\beta_{g1} = \beta_{g2} = 3.0$	99.7504	-100	100.0	-0.0013	0.0013

Table 3.42: DG Delta gamma hedging fixing α, p and increasing β, mean = 0, Skew = 0

In Figure. 3.37 shows the DG Delta gamma hedging $\Delta\Pi$ curves as we fix α, p and increasing β. We can see that $\Delta\Pi$ value curves are like linear functions with a negative slope, that's why S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in α.

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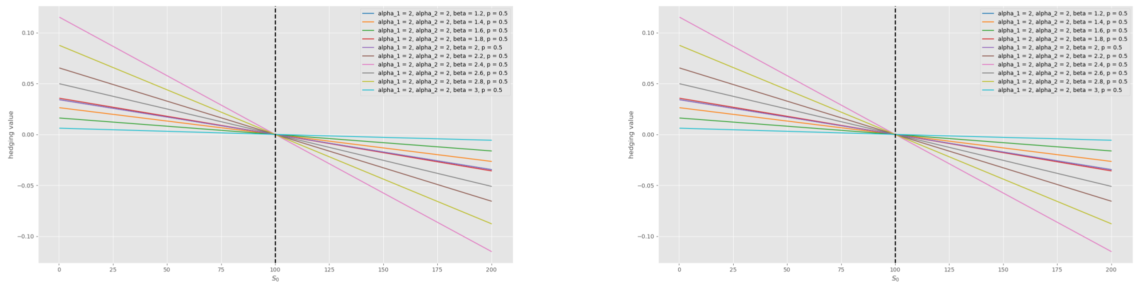

Figure 3.37: DG Delta gamma hedging fixing α, p and increasing β
Left:$\alpha = 2$, Right:$\alpha = 3$

3.4.4 DG Greeks hedging fixing α, β, and increasing p

Table. 3.43, Table. 3.44, shows DG Delta hedging and Delta gamma hedging for fixing α, β, and increasing p.

To make it easier to see, Figure. 3.38, Figure. 3.39 , shows the results of the data in the Tables above.

DG Delta hedging fixing α, β and increasing p				
parameters	stock position	call position	S = 90	S = 110
DG $\beta = 0.5$				
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.9533	-100	-134.0598	-117.856
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.7184	-100	-133.7962	-118.0705
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.484	-100	-133.5236	-118.2761
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.2503	-100	-133.2466	-118.4682
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.0159	-100	-132.9509	-118.6612
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.7828	-100	-132.654	-118.8375
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.5496	-100	-132.3435	-119.0096
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.317	-100	-132.0267	-119.1702
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.0848	-100	-131.6998	-119.3232
DG $\beta = 1$				
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	56.4011	-100	-133.4901	-116.6955
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.801	-100	-132.8787	-117.223
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	55.2029	-100	-132.2153	-117.6991
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.6064	-100	-131.4937	-118.1305
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.0127	-100	-130.7227	-118.5087
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	53.4217	-100	-129.8992	-118.8372
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	52.8339	-100	-129.0247	-119.1153
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	52.25	-100	-128.1056	-119.3374
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	51.6693	-100	-127.1319	-119.5143
DG $\beta = 2$				
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	56.7069	-100	-132.763	-115.9139
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	54.9174	-100	-130.9509	-117.2733
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	53.1474	-100	-128.7275	-118.25
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	51.4049	-100	-126.1175	-118.8312
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	49.6969	-100	-123.1422	-119.0154
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	48.0313	-100	-119.8385	-118.7927
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	46.4143	-100	-116.2325	-118.1706
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	44.8525	-100	-112.3606	-117.1529
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	43.351	-100	-108.2492	-115.7589

Table 3.43: DG Delta hedging fixing α, β and increasing p

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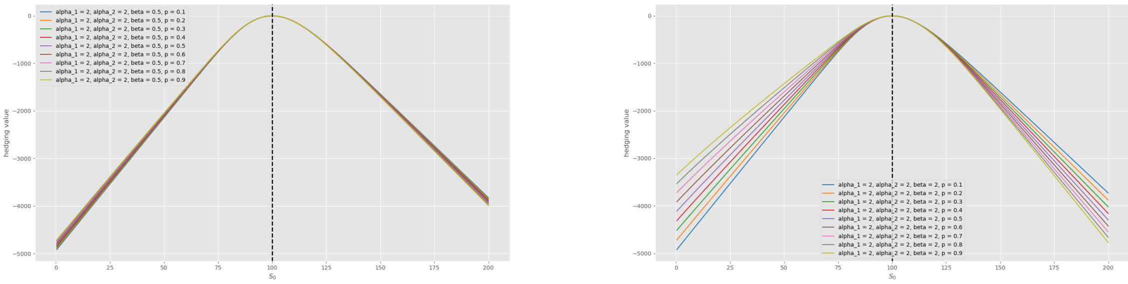

Figure 3.38: DG Delta hedging fixing α, β and increasing p
Left:$\beta = 0.5$,Right:$\beta = 2$

In Figure 3.38 shows the DE Delta hedging $\Delta\Pi$ curves as we fix α, β and increase p. We can see that as p increases $\Delta\Pi$ value curves are like Quadratic function with Opening facing down and as we fix α, β and increases p $\Delta\Pi$ value curves rotates counter clockwise. In Table 3.43, under fixed p, the larger the α the smaller the stock position.

DG Delta gamma hedging fixing α, β and increasing p					
parameters	stock position	call position	put position	S = 90	S = 110
DG $\beta = 0.5$					
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7513	-100	100.0	-0.01	0.01
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7517	-100	100.0	-0.0138	0.0138
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7509	-100	100.0	-0.006	0.006
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7498	-100	100.0	0.0046	-0.0046
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7509	-100	100.0	-0.0063	0.0063
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7506	-100	100.0	-0.0032	0.0032
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7489	-100	100.0	0.0141	-0.0141
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7499	-100	100.0	0.0045	-0.0045
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7511	-100	100.0	-0.0074	0.0074
DG $\beta = 1$					
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7481	-100	100.0	0.0221	-0.0221
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7503	-100	100.0	0.0006	-0.0006
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7516	-100	100.0	-0.0131	0.0131
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7499	-100	100.0	0.0038	-0.0038
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7493	-100	100.0	0.0105	-0.0105
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7498	-100	100.0	0.005	-0.005
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7517	-100	100.0	-0.014	0.014
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7503	-100	100.0	-0.0003	0.0003
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7501	-100	100.0	0.0024	-0.0024
DG $\beta = 2$					
p = 0.1 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7479	-100	100.0	0.0238	-0.0238
p = 0.2 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7494	-100	100.0	0.0091	-0.0091
p = 0.3 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7501	-100	100.0	0.0026	-0.0026
p = 0.4 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7514	-100	100.0	-0.011	0.011
p = 0.5 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7514	-100	100.0	-0.0109	0.0109
p = 0.6 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7485	-100	100.0	0.018	-0.018
p = 0.7 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7495	-100	100.0	0.0083	-0.0083
p = 0.8 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7506	-100	100.0	-0.0032	0.0032
p = 0.9 ,$\alpha_{g1} = \alpha_{g2} = 2$	99.7523	-100	100.0	-0.0202	0.0202

Table 3.44: DG Delta gamma hedging fixing α, β and increasing p

In Figure 3.39 shows the DE Delta gamma hedging $\Delta\Pi$ curves as we fix α, β and increase p. We can see that $\Delta\Pi$ value curves are like linear functions with a negative slope, that's

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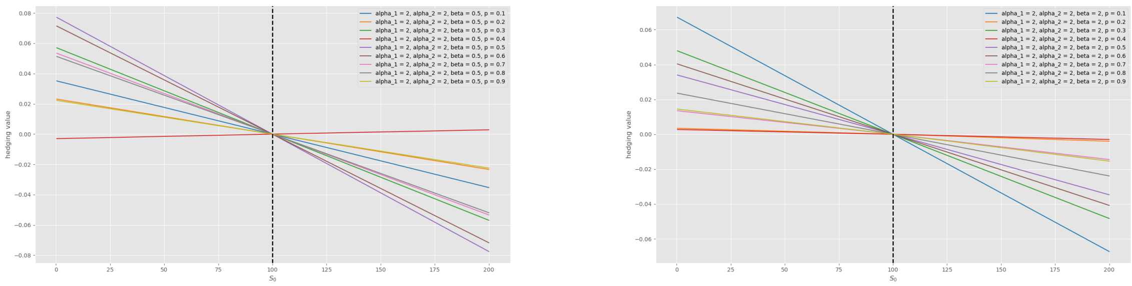

Figure 3.39: DG Delta gamma hedging fixing α, β and increasing p
Left:$\beta = 0.5$,Right:$\beta = 2$

why S = 90 and S = 100 are the same but opposite in sign, but $\Delta\Pi$ value doesn't change in relation with the change in p.

3.4.5 DG Greeks hedging conclusion

For delta hedging here are the following results. Delta hedging $\Delta\Pi$ curves are like Quadratic function with Opening facing down, the larger the mean, variance, Skewness and Kurtosis the more clockwise the $\Delta\Pi$ curves rotates and the smaller the stock position. Under fixed α, p the larger the β the less compact the $\Delta\Pi$ curves and the more clockwise the $\Delta\Pi$ curves rotates. Under fixed β, p the larger the $\alpha$the the more compact the $\Delta\Pi$ curves are and the more counter clockwise the $\Delta\Pi$ curves rotates. Under fixed α, β the larger the p the more clockwise the $\Delta\Pi$ curves rotates.

For delta gamma hedging here are the following results. Delta gamma hedging $\Delta\Pi$ curves are like linear functions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign. We can see that delta gamma hedging has better hedging effect than delta hedging. But we can see that the stock position and hedging effect doesn't really change in relation with the change in mean, variance, Skewness and, Kurtosis, α, β and

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p.

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Chapter 4 Results

4.0.1 Data results

4.0.1.1 Moments of DG

We can know from chapters before that the moments of double gamma distribution, especially fat-tailed distributions, have great impact on the results of the call value, Greeks and hedging.

4.0.1.2 Call value results

We can see that the larger the mean, variance, skewness and kurtosis the larger the call value. We can also see that when fixed mean and variance, with the change in β we can increase or decrease the call value from the double exponential model. Under fixed α, p the larger the β the larger the variance and kurtosis , resulting in fatter tails and more extreme jump events are more likely to occur. This is the reason that the larger the variance and Kurtosis, the larger the call value. Under fixed β, p the larger α the smaller the variance and kurtosis,resulting in a smaller call value. Under fixed α, β as p increases, mean and Skewness increases, while variance and Kurtosis are small at both ends and largest at p = 0.5, resulting in larger call value. We can see that fat-tails has a great impact on call value.

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We can also see that Double gamma has way more flexibility compared to Double exponential. And with this flexibility we can adjust the model according to the market. When the economy is good we can increase mean , when the market is very volatile we can increase variance. But even when the economy is good there are still bad days, and there are good days in a bad economy, by increasing p we can increase the probability of jumps jumping up. And here is where DG' s flexibility comes in , when p is fixed DG can fine-tune the parameters to fit the market, where as DE' s parameters is fixed and might be in conflict with the market. This is one of the reasons why DG is better than the DE model.

4.0.1.3 Greeks results

We can see that the larger the mean, variance, skewness and kurtosis the more right the Delta, Gamma, Vega, and Rho curves and the lower (smaller) the Theta curves are. Under fixed α, p the larger the β the less compacted curves are and the more right the Delta, Gamma, Vega, and Rho curves and the lower(smaller) the Theta curves are. Under fixed β, p the larger the α the more compacted curves are and the more left the Delta, Gamma, Vega, and Rho curves and the higher(larger) the Theta curves are. Under fixed α, β as p increases the more right the Delta, Gamma, Vega, and Rho curves and the lower(smaller) the Theta curves are. We can also see that when we increases DG's β, DG's delta hedging has better hedging effect than DE's delta hedging.

4.0.1.4 Greeks hedging results

For delta hedging here are the following results. Delta hedging $\Delta\Pi$ curves are like Quadratic function with Opening facing down, the larger the mean, variance, Skewness and Kurto-

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sis the more clockwise the $\Delta\Pi$ curves rotates and the smaller the stock position. Under fixed α, p the larger the β the less compact the $\Delta\Pi$ curves and the more clockwise the $\Delta\Pi$ curves rotates. Under fixed β, p the larger the $\alpha$the the more compact the $\Delta\Pi$ curves are and the more counter clockwise the $\Delta\Pi$ curves rotates. Under fixed α, β the larger the p the more clockwise the $\Delta\Pi$ curves rotates.

For delta gamma hedging here are the following results. Delta gamma hedging $\Delta\Pi$ curves are like linear functions with a negative slope, so values for S = 90 and S = 100 are the same but opposite in sign. We can see that delta gamma hedging has better hedging effect than delta hedging. But we can see that the stock position and hedging effect doesn't really change in relation with the change in mean, variance, Skewness and, Kurtosis, α, β and p.

4.0.2 Regards on implementing FFT

Now that we are finished with the results of the data sets, we talk about the problems encountered when pricing the double exponential model with FFT. I found that for DE, whenever α_{fft} equals the value $\alpha_1 = \alpha_{fft} + 1$, problems will occur. The problem is that when $\alpha_1 = \alpha_{fft} + 1$, the FFT will have a mathematical error and the call values around where $\alpha_1 = \alpha_{fft} + 1$ will also be affected and will show mispricing. The cause of this is because of DE's jump size characteristic function. The following equation is:

$$\phi_J(v) = p(\frac{\alpha_1}{\alpha_1 - iv}) + (1-p)(\frac{\alpha_2}{\alpha_2 + iv}) \tag{4.1}$$

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when using the Trapezoidal method, we sum from j = 1

$$v = v_j - (\alpha_{fft} + 1)i = \eta(j-1) - (\alpha_{fft} + 1)i \tag{4.2}$$

For example when $\alpha_{fft} = 0.5$, $\alpha_1 = \alpha_{fft} + 1 = 0.5 + 1 = 1.5$, and when we sum from j = 1 we will get $v = v_j - (\alpha_{fft} + 1)i = \eta(1-1) - 1.5i = 0 - 1.5i$.

Now when we insert v into $\phi_J(v)$, on the left we will get

$$p(\frac{\alpha_1}{\alpha_1 - iv}) = p(\frac{1.5}{1.5 - i(-1.5i)}) = p(\frac{1.5}{0}) \tag{4.3}$$

which will result in an error.

You might think that if we adjust α_{fft} to be very small or very big, then it might not be a problem, but adjusting α_{fft} to be very small or very big will cause mispricing, so choosing the right parameters for FFT is important.

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Chapter 5 Conclusions

In our research of generalizing Kou's double exponential model to double gamma, we have the following conclusions.

First we are able to price double gamma options and Greeks by FFT and FDM with speed and accuracy. With our numerical results we found that not only double gamma model can reproduce Kou's model by setting $\beta = 1$ double gamma also has way more flexibility in fine-tuning it's parameters to fit the market.

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