**Parameter Selection and Data Selection**

To value this product, we need to know the initial value, barrier value (also the trigger value), maturity, interest date from pricing date to maturity, dividend yield of AAPL stock, volatility of AAPL stock. Next we will talk about how we collect or estimate these data.

**Initial value and barrier value (also the trigger value):** they can be found on the product website. The values are 195.09 and 152.1702.

**Interest rate:** via SWDF function on Bloomberg, we find the 450-day discount factor on March 21 2019 (the pricing date) is 0.9687454 (mid), with which we can get the compounded continuously interest rate is 0.025756.

**Dividend yield:** through Bloomberg Dividend Forecasts function, we can find the projected dividend yield of AAPL for the next one year and a half is 1.644% and we choose it for our calculation.

**Volatility:** there are ten European options, the implied volatilities of which have influence on the product value: three-month, six-month, nine-month, twelve-month and fifteen-month options with strike prices at 195.09 and 152.1702. We collected the implied volatilities of these options through Volatility Matrix on Bloomberg.



**Graph 1: Volatilities Matrix of AAPL**

We decide to use the 15-month at-the-money implied volatility for our calculation, which is 24.686%. In this way, the volatility we use is not either too large or too small.

**Model Selection and Valuation Procedure**

We choose Crank-Nicolson method to value this product, since this method is stable and also has improved convergence.

To solve the path dependent problem, we decide to use two grids, Grid A with the assumption that the trigger event has happened during the monitoring period, and Grid B with the assumption that the trigger event has not happened. We first calculate Trigger A. Then we pick the row at which the value equals to trigger value, and use it as the lower boundary of Trigger B, since that row of Grid A has contained all the information about the effects of trigger event. After solving Grid B, we get the value of the product.

The result will change very little when the numbers of rows and columns in the grid change, since CN method is really stable. For simplification, we choose imax equal to 459, which is the number of days from the pricing date to the maturity date. In this way, dt is 1/365. Meanwhile, we set the upper boundary for the stock price equal to 3\*=585.27, the lower boundary for the stock price equal to 0. We choose jmax equal to 300, so dS is 1.9509. In this way, we can make sure the initial value and barrier value is on the grids. Next, we conduct the following calculation to get the values on the grids:

**Grid A (The trigger event has happened):**

At maturity, we have:

For the upper and lower boundaries, we set:

where tac is the time from i to the next review date

For the days before maturity except review dates, we have:

For the first review date, we calculate the as above first. Then we make adjustments.

Then we replace with .

For the other review dates except the last one, we calculate the as above first. Then we make following adjustments.

Then we replace with .

**Grid B (The trigger event has not happened):**

With the above calculation, we can get Grid A. Next, we pick the row at which the value equals to trigger value, and use it as the lower boundary of Trigger B. We set the size of Trigger B equal to Trigger A. However, for the rows where stock prices are lower than barrier, we set the values equal to zero and do not calculate them. For the other part of Grid B, the calculation is nearly the same, except that for the maturity, we have:

After solving Grid B, we pick , which is our estimate of the product value. Our result is 956.66.

**Discussion of Results and Sensitivity Analysis**

From the product website, we can see that the estimated value of the notes when set is $958.9 per $1,000 principle amount note. Our result is really near it, but is a little lower.

Since in our grids, we have set the barrier value and initial value on the grid, we think we have nearly eliminate the no-linearity error. Meanwhile, CN method is really stable, and we find the change is very little when we change imax and jmax. Therefore, the main reason for the difference between our estimate and JP Morgan’s estimate on pricing date, we think, is that some parameters are not accurate enough.

Among all the parameters we use, we are confident that we have the right data for the interest rate. However, the dividend yield and volatility are just based on estimations of Bloomberg and our assumption. If the real-world values for these two parameters are not the same as our estimations, errors will happen. Since the dividend yield always has a small effect on the product price, whereas the value is very sensitive to the volatility we input, we will next conduct sensitivity analysis and discuss how the value will change if the volatility changes.

From Graph 1, we can see the implied volatilities of the ten options whose volatilities have influence on the calculation of product value. The maximum of these implied volatilities is 30%, and the minimum is 23%. So we assume the reasonable range for the real volatility is from 23% to 30%.We input volatility values in this range and calculate the prices:

**Graph 2: Values for Different Volatilities**

From the graph, we can see if the volatility deviates from our estimations in the first part, the price will also deviate from our result. In our estimated range of the volatility, the price of the product can be as high as 963.9, which happens when the volatility is 23%, and can be as low as 935.2, which happens when the volatility is 30%.