FIM 548 Research project

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Project: Pricing of a structured product, here the replicated structured product is 5.37% p.a. Callable Multi Reverse Convertible. This is a product of RAIFFEISEN. Here, I will explain the product, its payoff, assumptions and apply the Monte Carlo simulation on contract value as a function of coupon rate.

Content:

1. Product

This product is a Swiss uncertificated Security under Swiss law. This is a fixed Income product which gives fixed coupon every quarter and it has a maturity of 1.5 years. It has 3 underlying equities which include ALIBABA GROUP HOLDING LTD, ALPHABET INC-CL A, and AMAZON.COM INC. this product offers a coupon regardless of the underlying performance during its lifetime. On the maturity day, if all the underlying close above the strike level, then the investor will receive the original denomination back.

Otherwise, if any underlying is below strike level, then the worst performed underlying will be delivered in place of originally invested money as per the predefined conversion ratio. The product can be called before maturity on pre-decided early redemption dates and investor will receive their investment back in cash only.

The underlying on initial fixing date (04/25/2022) and its strike level and conversion ratio is given below.

Underlying	Initial fixing Level (100%)	Strike level (70%)	Conversion Ratio
Alibaba (HK exchange)	81.84	57.28	7454.60
Alphabet CL-A	2392.70	1674.89	29.85
Amazon	2887.00	2020.9	24.74

The conversion ratio calculation is simple here, we divide the denomination value by strike level to get the conversion ratio. Alibaba's conversion ratio calculation is explained later in the report in exchange rate section as it includes other currency.

Product details	
Issue price	100%
Denomination	USD 50,000
Coupon rate	5.37% p.a.
Issue date	04/25/2022
Maturity date	10/25/2023
Early redemption dates	04/25/2023 07/25/2023
Coupon dates	USD 671 on 08/02/2022 USD 671 on 11/02/2022 USD 671 on 02/02/2023 USD 671 on 05/02/2023 USD 671 on 08/02/2023 USD 671 on 11/02/2023
Settlement currency	USD

Coupon payment = USD 50,000 * (5.37% /4) = USD 671. (Converting annual rate into quarterly rate)

Here, Investor will receive coupon payments on dates given above. On the last coupon date coupon and the denomination or the underlying will be given.

2. Assumptions

I have taken some assumptions here to price the given product. They are as follows.

1. I have assumed the Interest rate for next 1.5 years from US treasury website, interpolating 1 year and 2-year interest rate, I got the value of 2.33% p.a. and I have taken sigma as the variance converted into annual value.

```
r = np.array(0.0233)
sigma = df.pct_change().cov() * 252
```

2. I have taken the dividend yield for the stocks from yahoo finance.

```
d = np.zeros(3)
for i,key in enumerate(tickers):
    d[i] = yf.Ticker(key).info['trailingAnnualDividendYield']
```

3. The correlation is calculated using Cholesky decomposition method.

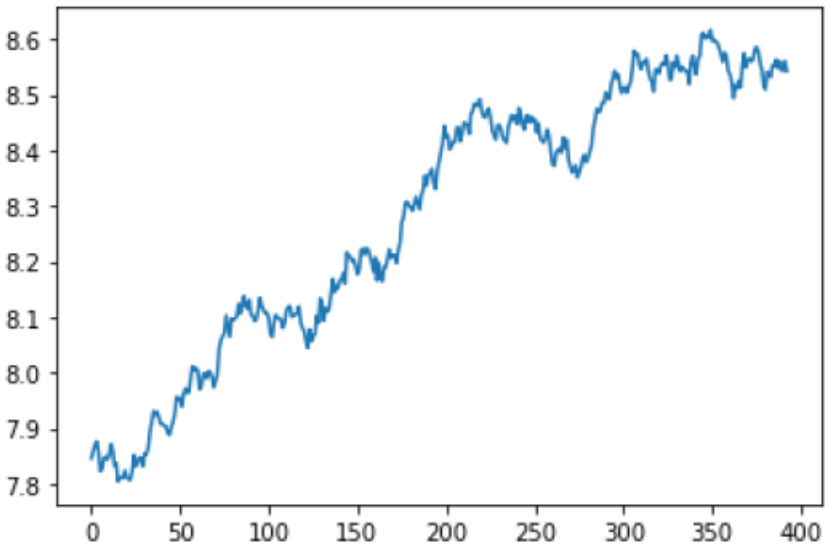
```
chol = np.matrix(np.linalg.cholesky(sigma))
```

```
def correlation_r(a=3,b=bussiness_days,c=chol):
        Z = np.zeros((a,b))
        for i in range(0,a):
            Z[i] = np.random.normal(0,1,b)
        X = np.array(c * Z)
        return(X)
```

4. There was no specific explanation given for early redemption, so I have assumed that issuer will call the product back if all the underlying is performing more than the issue date price. If anyone is below the issue date price (100%) then there will be no early redemption. The predicted prices from geometric Brownian motion will be checked on both early redemption date to check if the price is above 100% or not. Below is the example of the GBM paths we checked.

3. Exchange rate calculation

One of the underlying Alibaba is trading in Hongkong's stock market in HKD. In original product they have said that they will use the currency exchange rate of maturity date, so here I am using geometric Brownian motion to get a USD/HKD exchange rate. Given below is the simulated exchange rate, I used 393 days, that is number of business days during the lifetime of the product.



The simulated exchange rate on day 393 (10/25/2023) is 8.54. I have used that rate to convert the Alibaba's stock price from HKD to USD in the data frame.

```
df['9988.HK'] = df['9988.HK'] / df4[-1:]
df
```

I did this operation here because in a scenario where the issuer will give the worst performed underlying to investors instead of the denomination. If Alibaba perform the worst and if it gets delivered, then we can estimate the cashflow in USD by using that day's stock price which is already converted in USD by dividing it with the forecasted rate 7.52. now if we multiply this with the conversion ratio, we get the Underlying's cashflow in USD.

Conversion ratio for Alibaba = (USD 50,000 * 8.54)/strike price

= (USD 50,000 * 8.54)/57.28

=7454.60

4. Payoff

The payoff of this product is:

$$payoff = [e^{-r*T} * payments]$$

Mathematical representation of the payments:

$$payments = e^{-r*t_i} * \sum_{i=1}^{n} C_i + e^{-r*t_i} * conversion\ ratio * (current\ price) * I(0) + e^{-r*T} * Denomination * I(1)$$

Here,

C_i= Quarterly coupon rate

n = 4 or 5 or 6, depending on the early redemption option.

$I(0)$ = condition where one of the worst performed underlying is delivered

$I(1)$ = condition where denomination is delivered

here, payments are sum of 6 expected cashflows on 6 coupon dates plus the denomination or the underlying.

First 3 coupons are fixed in all cases. Early redemption option is available in coupon date 4 and 5. For early redemption options I have defined 'condition1' to check the early redemption condition earlier I assumed. At the maturity date I have checked the 'condition2', to check if any underlying is below strike (70%) or not and according to that I have created the loop. Then I used Monte Carlo simulation and simulated this payoff for 1000 times and took the average price of the payoff. Given below is the simulated payoff price for the given product.

```
103.23462284876946
```

You can check the code to see the detailed logic of payoff.

The above given payoff is for fixed coupon rate of 5.37% p.a. given quarterly.

5. Payoff as a function of coupon rate

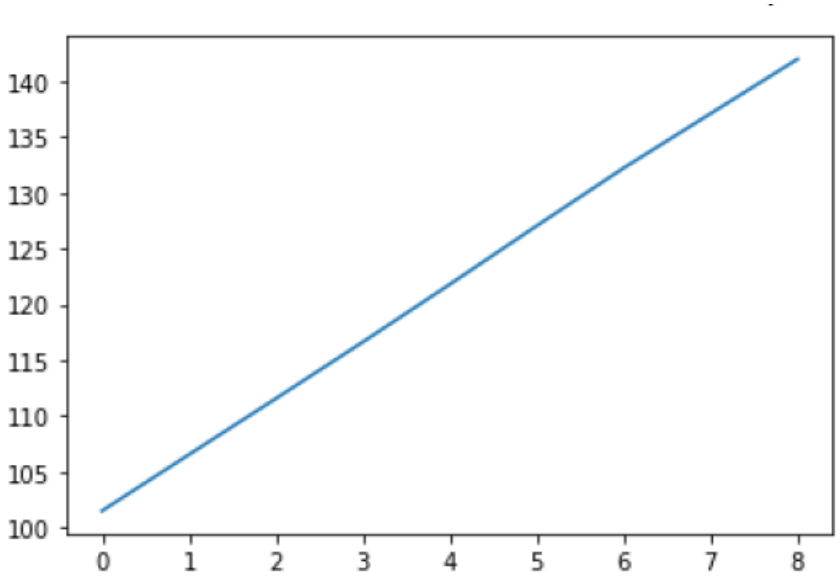
Now, I took the range of coupon rates and got different payoffs as a function of the coupon rate. You can check the code for details. Where I have taken 9 different coupon rates on which I have 9 different payoffs which are stored in dcfs.

6. Results

Given below is the result of the payoff as a function of coupon rate.

Coupon rate	Payoffs(dcfs)
1%	101.48
2%	106.53
3%	111.55
4%	116.62
5%	121.78
6%	127.03
7%	132.21
8%	137.09
9%	141.98

We can also plot a graph of coupon rate vs payoff. Below is the graph we plotted from the above result. On the y-axis we have payoff or the price of our product and on the x-axis we have the coupon rate.



7. Conclusion

The Callable Multi Reverse Convertible product gives the steady cashflow and it is used to get the profit when the market is moving sideways. But it is risky asset as the investor may not get the denomination back and must receive the underlying, theoretically the investor can lose all the money.

In our case if any one of the underlying is below 70% at the maturity date the fixed income product will be converted into equity of lowest performed underlying and if all are above 70% the investor will get the denomination back. The bond is callable, and I have already explained the early redemption assumption.

Using certain market assumptions, I tried to price the Callable Multi Reverse Convertible derivative product and as you can see the simulated results of price 103.23, we can say that in this case the product is priced on premium compared to its issue price 100.