Report 5 Palmeri Claudio N° 2062671
Company: **Chipotle Mexican Grill (CMG)**

The **objective** of this **report** is to **visualize the implied volatility surface**. We will also check for the **presence** of the **implied volatility smile** and that the **Greeks** calculated on the real data **gets smoother** as the **time to maturity increases**.

Company description:

Chipotle Mexican Grill, Inc., together with its subsidiaries, owns and operates **Chipotle Mexican Grill restaurants**. It offers burritos, burrito bowls, quesadillas, tacos, and salads. The **company was founded** in **1993** and is headquartered in **Newport Beach, California**.

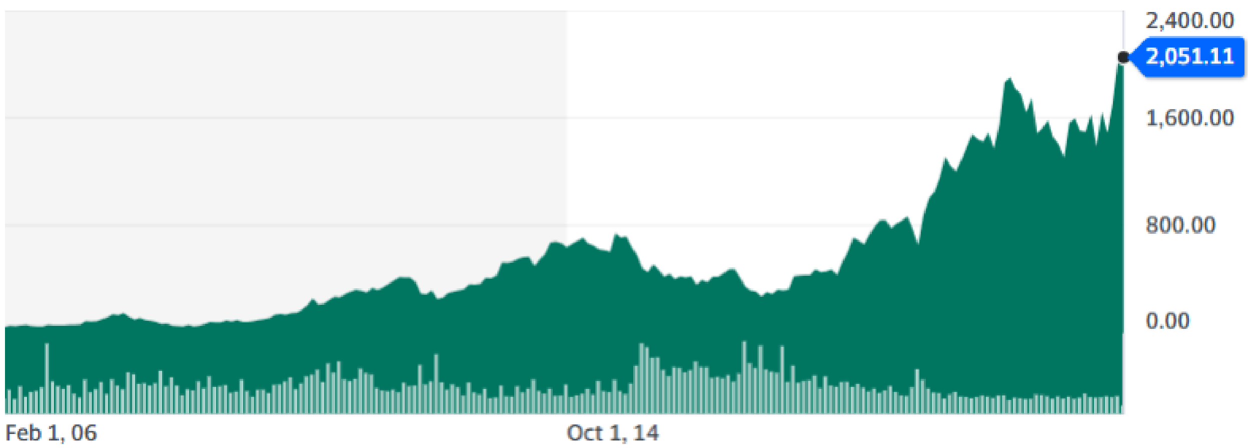
Its most **influential executives** are:

Name	Title	Pay($)	Year of birth
Mr. Brian R. Niccol	Chairman & CEO	3.68M	1974
Mr. John R. Hartung	CFO & Chief Admin. Officer	1.84M	1957
Mr. Curtis E. Garner III	Chief Technology Officer	1.52M	1970
Mr. Christopher Brandt	Chief Marketing Officer	1.34M	1969
Mr. Scott Boatwright	Chief Restaurant Officer	1.08M	1973
Ms. Cynthia Henn Olsen CFA	Head of Investor Relations & Strategy	N/A	1959
Mr. Roger E. Theodoredis	Chief Legal Officer, Gen. Counsel & Corp. Sec.	N/A	N/A
Dr. James Marsden Ph.D.	Exec. Director of Food Safety	N/A	N/A
Mr. Jim Slater	Managing Director of Europe	N/A	1968
Ms. Laurie Schalow	Chief Corp. Affairs & Food Safety Officer	N/A	N/A

Some **useful statistics** of the company **Chipotle Mexican Grill (CMG)** are:

Statistic	Value
Market Cap	49.15B $
Enterprise Value	51.98B $
Revenue per Share	310.03$
Gross profit	3.37B $
52 week High	2055.92$
52 week Low	1196.28$
50 day average	1651.04$
Average volume (last 3 months)	307.4k
% shares held by institutions	95.17%
Annual Dividend Yield	0.00%

This is the **overall evolution** of the **stock price from the beginning**:



Chipotle Mexican Grill, Inc.'s ISS **Governance QualityScore** as of April 1, 2023 is **6**.

95.17% of the **shares** are held by **institutions**, more precisely the **top institutional holders** are:

Holder	Shares	% of the total	Value ($)
Vanguard Group, Inc. (The)	2,658,715	9.63%	5,450,764,297
Blackrock Inc.	1,982,298	7.18%	4,064,008,051
Price (T.Rowe) Associates Inc	1,720,260	6.23%	3,526,790,871
Pershing Square Capital Management, L.P.	1,105,208	4.00%	2,265,842,073
Capital International Investors	1,047,028	3.79%	2,146,564,351
State Street Corporation	1,037,611	3.76%	2,127,258,090
Capital World Investors	942,383	3.41%	1,932,026,415
Edgewood Management Company	917,764	3.32%	1,881,553,774
JP Morgan Chase & Company	801,531	2.90%	1,643,258,701
Geode Capital Management, LLC	555,959	2.01%	1,139,799,289

Data Analysis:

All the **data** in this **report** were taken on the **4/28/2023**

We are tasked to **visualize the implied volatility surface** as a **function** of both the **strike price** and the **time** to **maturities**. According to the **B&S equation**, the **price of a call option** is given by:

price(t)=S*N(d1)-Ke^(-r*(Tau-t))*N(d2) where **N(x)=Prob(N(0.1)<=x)**

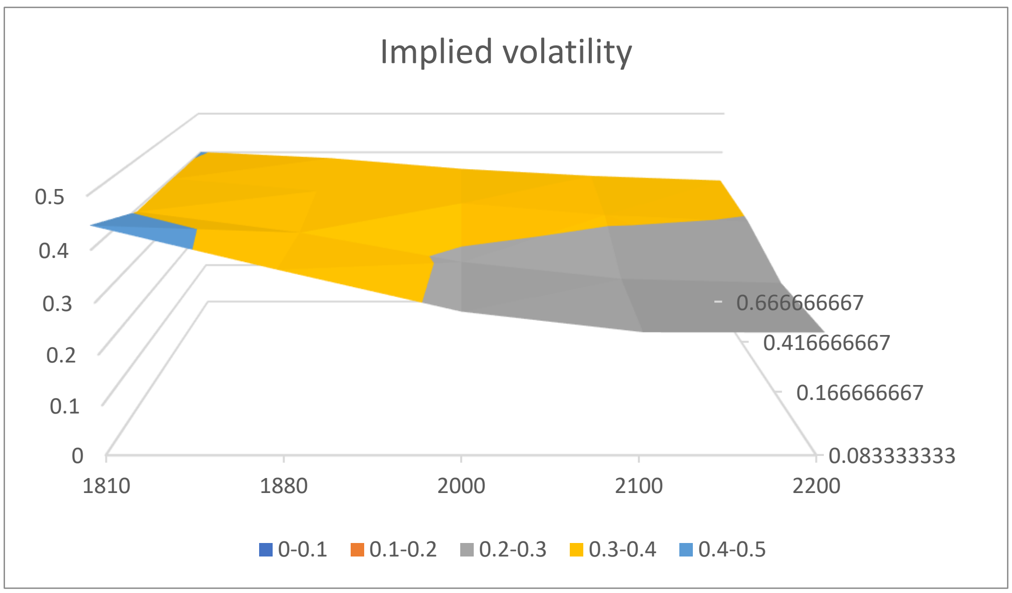
Where we have that:
K is the **strike price**
r is the **interest rate**
vol is the **volatility**
S is the **underlying price**
Tau is the **time to maturity**

t is the **current time** (and thus **0<=t<=Tau**)
d1=(ln(S/K)+(Tau-t)(r+0.5vol^2))/(vol*sqrt(Tau-t))
d2=d1-vol*sqrt(Tau-t)

The **implied volatility** is the value of **vol** that make **price(t)=real price of the call option** (i.e. the **average** of the current **bid and ask prices**). The **B&S equation can't** be **solved** directly for the **volatility** but we know that if all the **other parameters** stay **fixed**, the **price** of a call option is an **increasing function** of the **volatility**. This is because an **higher volatility** implies having a very **unstable price**. Since the **payoff** of a call option is the **positive part of the difference between final and strike price**, having an **higher volatility** means that the **final price** could be **very far** from **initial price**. This implies a potentially **huge prayoff** if the **market** goes in the **right direction** while if it goes in the **wrong direction** we **won't** be **losing money** anyway. Thus the **higher** the **volatility**, the **higher the price of the call option** (or of the **put option** since it is the **same reasoning**).

Using this information we can **estimate the implied volatility** by simply trying to **make a guess** and then going **higher or lower** depending if the **price** we got was **higher or lowe**r than the **actual market price**. **Yahoo Finance** already calculates the **implied volatility**.

We can now **plot** the **implied volatility** as a **function** of the **strike price** and the **time to maturity** (which is expressed in years). Here are the results:



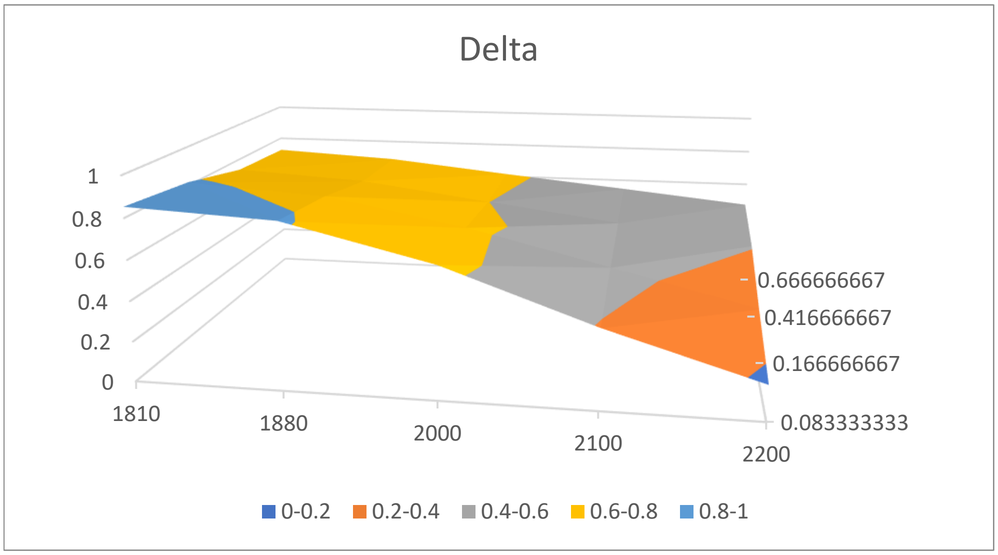
As we can see, the **implied volatility smile** doesn't appear in **ALL** the possible time maturities.
We can **observe** two things:
1) The **left part** of the **smile always appears**
2) The **current price** is the **all time high** for this particular stock.

We can see how **traders** are willingly to buy/sell **out of the money call options** at a **price lower** than what we would **expect** if the **implied volatility smile appeared.** This can be explained by the fact that we are at a **all time high** and thus it is "**more reasonable from a human perspective**" that the **price** of the **underlying** will go **lower** in the future (and thus making the **call option less valuable** than in a standard situation)

We can **focus** now on **plotting the Greeks** by using the same **VBA script** that I created in the **previous report**.
We will use as **indipendent variables K and Tau** with the **values of the graph above**.
I'll use the **implied volatility as vol** and **S=2051.11$** (which is today's price)
The **only** remaining **parameter** is the interest rate **r**. In order to calculate it we can do the **same procedure** of the **second report** to calculate the **discount factor D=(p(call, k1)-p(call,k2)+p(put,k2)-p(put,k1))/(K2-K1)** and then use the relationship **D=exp(-r*t)**. I can then **repeat the same procedure** for **all time maturities**.

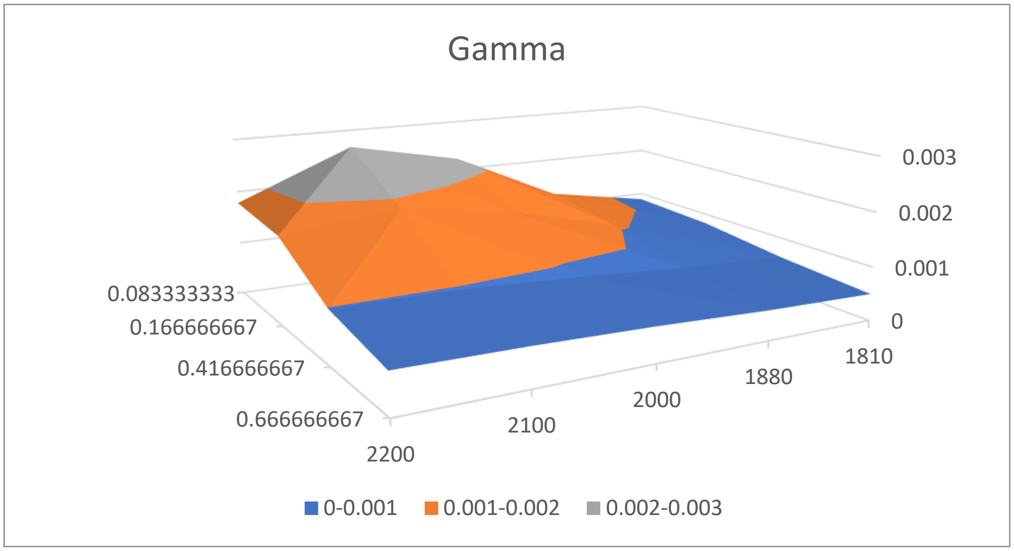
I got the following results:

Delta



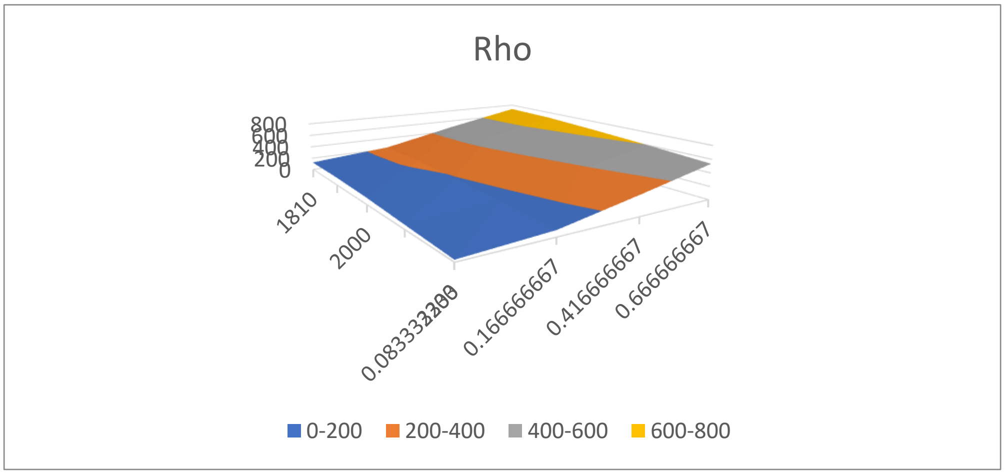
We can see how the **shape of the Greek gets smoother as Tau increases**.

Gamma



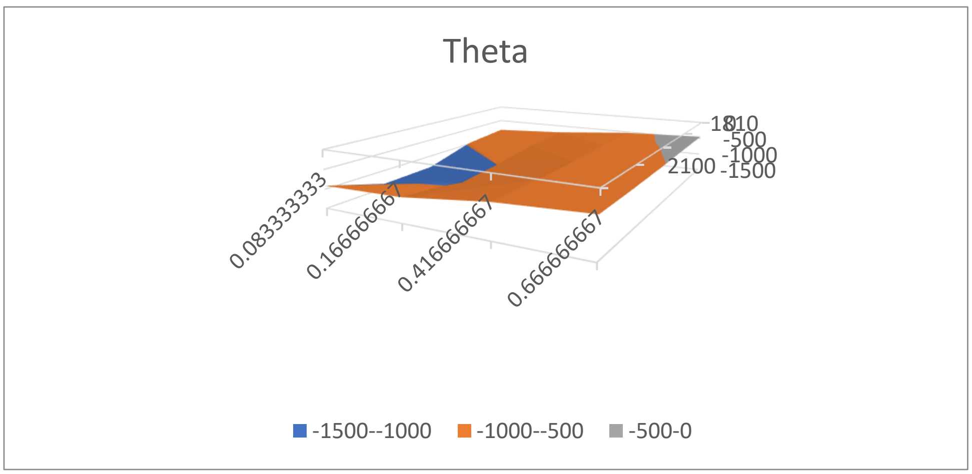
We can see how the **Bell curve shape get flatter as Tau increases and thus smoother**.

Rho



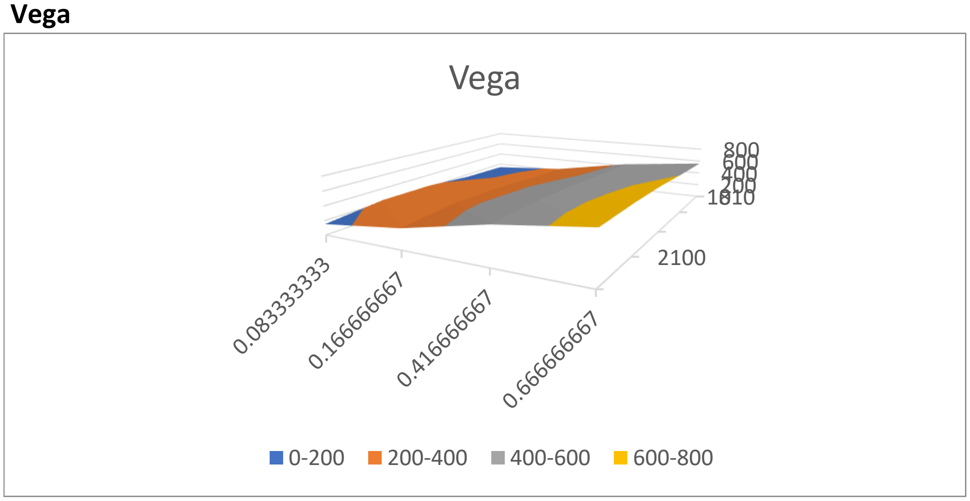
Rho doesn't get smoother as Tau increases, in only **increases in absolute value** while remaining of the **same shape**.

Theta



We can see how the (**inverted** since **Theta<0**) **Bell curve gets flatter** and **smoother as Tau increases**.

Vega



Vega doesn't get smoother as Tau increases, in only **increases in absolute value** while remaining of the **same shape**.