ANAIS

VALUATION OF THE TAIWAN SEMICONDUCTOR COMPANY (TSMC/2330) USING MONTE CARLO SIMULATION

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RESUMO: Esta pesquisa tem como objetivo informar os investidores, sejam eles individuais ou institucionais, e os formuladores de políticas relevantes sobre as conclusões relacionadas aos resultados do valor justo da Taiwan Semiconductor Company. Para isso, primeiramente será apresentado o histórico da empresa, modelo de negócio e posição no setor. Ao utilizar essas análises, uma Avaliação com simulação de Monte Carlo utilizará esses dados para apresentar o valor justo da empresa em diferentes cenários geopolíticos.

PALAVRAS CHAVE: Valuation; foundry de semicondutores; Monte Carlo; valor justo.

ABSTRACT: This research has an objective to inform investors, be they individual or institutional, and the relevant policymakers about the findings related to Taiwan Semiconductor Company fair value results. To do that, firstly the company history, business model, and position in the sector will be presented. By utilizing these analyses, a Valuation with a Monte Carlo simulation will use this data to present the company's fair value in different geopolitical scenarios.

KEY WORDS: Valuation; semiconductor foundry; Monte Carlo; and fair value.

1. INTRODUÇÃO

The research of this company fair value is going to be divided in the company description which will bring context to the research, introducing the history of TSMC. Then, the next phase is the company analysis where the competition environment of the sector and the company position will be revealed, enabling the last part that is the Valuation with a Monte Carlo simulation, which will have the parameters based on the previous explained analysis.

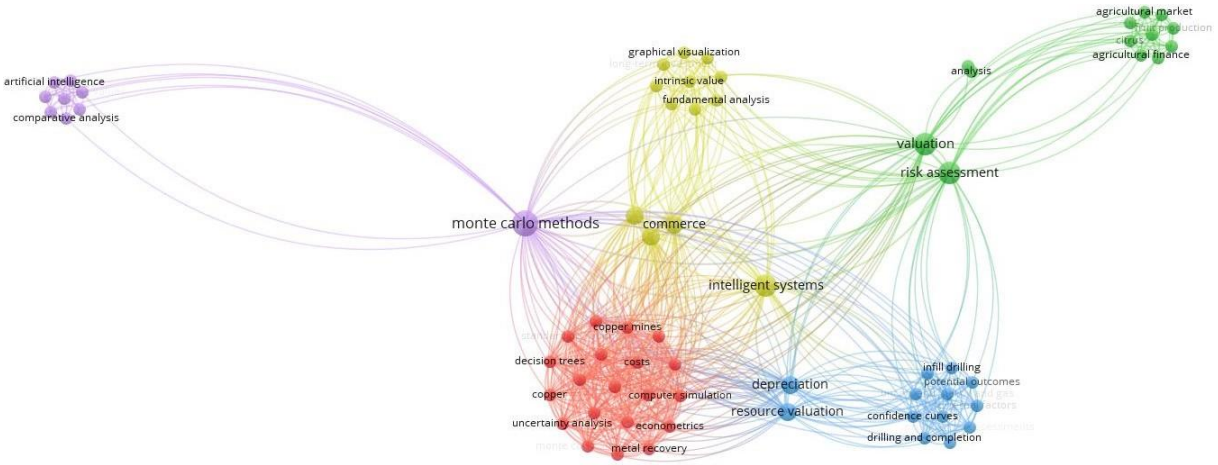
With that, a valuation of the Taiwan Semiconductor Company using Monte Carlo simulation can gather important information about a company that won't impact only financial markets, but also the current and emerging world powers. So, this article will not be important only for investors, but also for the relevant policymakers.

Finally, the methods and strategies discussed are useful to improve data analysis and inspire management decisions respectively, this is most central for companies that are in the catch-up phase and plan to become market leaders, such as TSMC. And with that, the objective of this work is to answer: "What is TSMC's fair value?".

2. REVISÃO TEÓRICA

Firstly, in order to contextualize this paper, it is going to present the ideas found in major works and in articles selected through bibliometric analysis, for that the next keywords were used in the Scopus platform: Valuation; semiconductor foundry; Monte Carlo; and fair value. Below this paragraph is a visualization of the connection between these keywords.

Figure 1 – Keyword Connections



Source: Own production from Vosviewer (2023).

More practically, this work is going to be divided into three sections. The first section will include an explanation of TSMC's industry sector and the respective business model of these companies. With that, any reader will be able to better understand the data that is going to be introduced afterward.

In this first part, the article by Yang (2013) entitled “The rise of the manufacturing service industry: The perspective of value-added chain model” will be used as a basis for contextualizing the business model. Together, the article “Semiconductors and Taiwan’s “Silicon Shield” ” by Cronin (2022) explains the geopolitical importance of TSMC. Other articles to be included must be aligned with the contexts of the texts above.

The second section is where the valuation itself will be presented. In this process, the future cash flows are going to be projected through macroeconomic variables such as Taiwan’s GDP growth, inflation and with company-specific variables such as return on assets and return on equity. After that, the Monte Carlo simulation will build all the possible cash flows through an arbitrage method, and the discount rate will adjust cash flows resultingin the free cash flows (FCF), which are the amount of money after deducting OpEX and CapEx.

The texts that are especially relevant for the previous section are, firstly, the book on macroeconomics by Barbosa (2017), which will help define parameters for the advancement of inflation and economic growth. In addition, to assist in the construction of the model, literature written by Damodaran (2012), Damodaran (2007), Assaf Neto (2020), Brealey, Myers, and Allen (2010) will be used, which present traditional valuation applications that will be the basis for the model. For the construction of the Monte Carlo simulation, the guides produced by Benninga (2014) will be used, to build this model in Excel.

In the last section, the results of the valuation will be analyzed, these results include the average, median, and standard deviation of the company’s fair value. Therefore, investors and policymakers alike can observe not only expected growth but also the risks related to the company, and how their actions influence the future of TSMC and the semiconductor industry.

When using selected keywords to search for scientific works in Scopus and Períodico Capes, there were found three different types of articles. The first kind were discussions related to the relevant industry sector, such as Wang et al (2021), and Kishimoto (2016).

The second kind of articles that were found discussed the methodological approach of using Monte Carlo simulations in valuations, again a summary of the objectives,methodologies, and conclusions of said articles was presented in Siddiaui et al (2018), Oliveira, and Medeiros (2012), Gleißner (2019), Liapiset al (2023), Ye (2021), and Gárcia et al (2018).

The last kind of selected works are case studies that used Monte Carlo simulations, so they are relevant to ensure that this valuation will be according to contemporary research, these were observed in Silva et al (2018), Aliu et al (2020), Boada and Castaño (2020), Boada and Mayorca (2019), Guj and Chandra (2019), Trejo-Pech et al (2018), Jenkins and Mclane(2019).

3. PROCEDIMENTOS METODOLÓGICOS

3.1 COMPANY DESCRIPTION

3.1.1 Company History

When TSMC was established in 1987 Texas Instrument was still the main player, Intel, and AMD were already strong in the semiconductor industry, which would make it more difficult to enter the market. Other than that, in 1985 ITRI, which would be the basis for TSMC technology, was 2 generations behind the leading edge. (PERRY, 2011)

So, the way out that was creating a new business model called a pure-play foundry, in this model the Taiwan Semiconductor Company would only produce chips that other companies designed, guaranteeing the protection of the client's intellectual property.

The first customers were sizeable companies such as Intel and TI,which could free fab capacity outsourcing production to Taiwan. After that, came the start-up companies, which were according to Morris Chang heavily benefited, among these companies, there are contemporary technology giants, like Nvidia and Qualcomm. (PERRY, 2011)

The first years of the company saw meteoric growth, in 1987 they had only one fabric where they produced semiconductors called fab 1, located inside the ITRI campus. Utilizing the lower costs related to production in Taiwan. (TSMC, 2021)

One year after the company was founded, they started a process of verticalization, integrating more services that came after the foundry work. With these services that added value to the products they offered to clients, TSMC was able to become the world's biggest foundry in 1992, only five years after the company was established. (TSMC, 2021)

With the company reaching a large enough size in 1994 it was listed on the Taiwan exchange. In 1996 the company was listed again, now on the NYSE, being the first Taiwanese company listed there. Even in the dotcom bubble and the 2008 crises wafer production was only temporarily smaller, in both cases resuming growth in the next year. (TSMC, 2021)

3.1.2 Business Model

The basis of TSMC's business model is the pure-play foundry model, which was invented by TSMC itself.

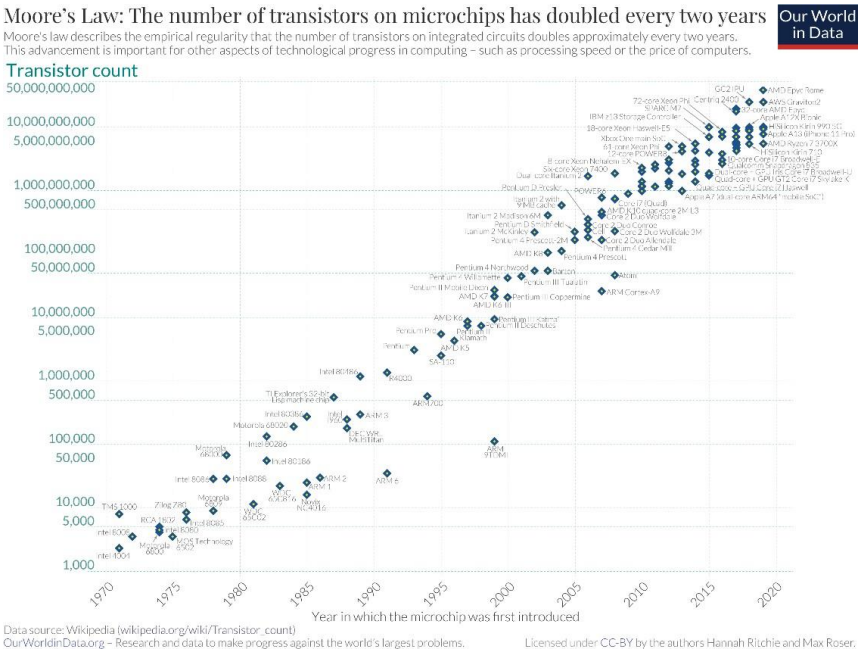
TSMC was created as a pure-play foundry for two main reasons, Morris Chang saw an opportunity to provide a new service that he believed would have enough demand and profits.

However, Chang was also a technology enthusiast, and ever since he worked at smaller design companies, he would think of ways to increase R&D spending. (PERRY, 2011)

There are 2 ways a company like TSMC can increase production, buying more machines or decreasing the defective rate. The sum of the amount expended on new machines and research to decrease defects is equal to the firm capital expenditure. (KISHIMOTO, 2016)

Moore´s law was defined by Gordon Moore one of Intel's founders in 1965. In this law, it was defined that every 18 months the number of transistors in a chip would double. Nowadays this creates demand and expectation for constant advancements. (KISHIMOTO, 2016)

Figure 2 – Moore's Law 1970 - 2020



Source: ROSER, M; RITCHIE, H; MATHIEU, E. What is Moore's law, 2023. Our World in Data. Available in:https://ourworldindata.org/moores-law

As a result of this business model that serves different clients with very heterogeneous needs in chip manufacturing, TSMC must deal with a high-volume high-variety production line. (WANG, 2021) Because of that this sector tend to have an exceedingly high capacity utilization rate, which tends to be higher than 90% in TSMS`s case. (KISHIMOTO, 2016)

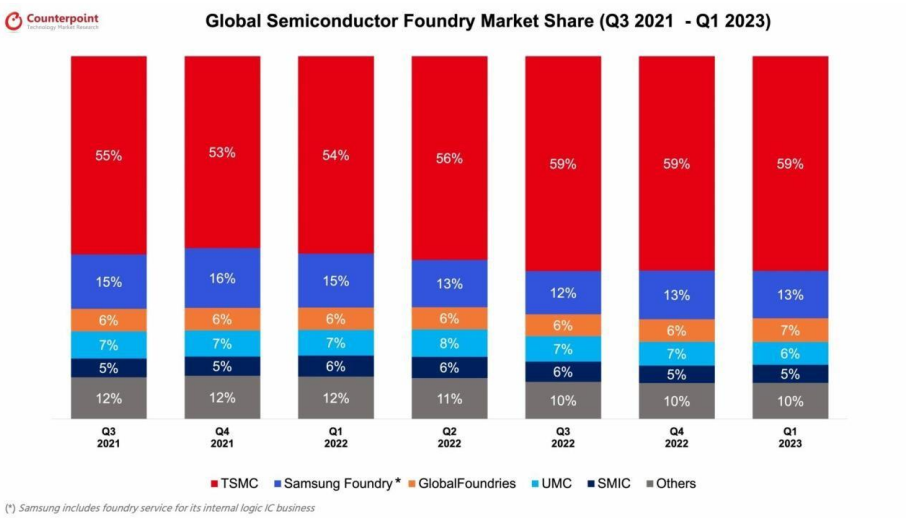
In this kind of company, management separates 3 types of process complexity levels: mature, medium, and advanced. They are treated differently because they have different uses, and the needs of the customers differs considerably. (WANG, 2021)

Three major types of players influence a company in this sector, examples relevant to TSMC will be cited next. The technology suppliers will produce the machinerynecessary for semiconductor manufacturing, TSMC's main supplier is a company called ASML, this European company produces lithography systems. After that, there are the main competitors, such as

UMC and Samsung, these companies are also foundries. Finally, we have the main clients, like Apple, MediaTek, Qualcomm, AMD, and Nvidia. (WANG, 2021)

Since TSMC has a large market share in the foundry business the needs of the company move innovation not only upstream, but also downstream. This is especially true in ASML's case, TSMC is the main customer, so to keep being on the leading edge ASML is one of the companies that invest most of their profits in R&D in the world. Also, clients have an easier time innovating when they know that their production needs will be met. (KISHIMOTO,2016)

Figure 3 – Foundry Market Share



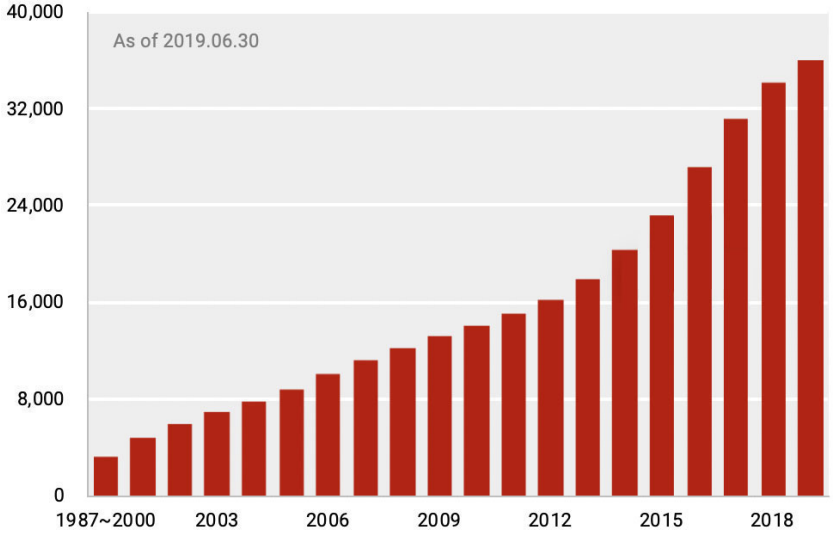
Source: Counterpoint Research. Global Semiconductor Foundry Revenue Share: Q1 2023. Counterpoint Research,2023. Available in: https://www.counterpointresearch.com/insights/global-semiconductor-foundry-market-share/

TSMC's market share is a result of the success of economies of scale over economies of scope. In this sector TSMC invested more in scale than UMC, which was a similar size as TSMC in the 2000s, ended up with a market share 3 times smaller. (KISHIMOTO, 2016)

Wafer size is another force that benefits the current market concentration, because the increase in size makes it possible for larger companies to decrease production costs. The result is that the smaller companies can’t compete with bigger factories. This process also increases the cost for new entrants, protecting the already established companies. (KISHIMOTO, 2016)

Moreover, the in-house development of process nodes is a TSMC strategy that is not present in all its competitors. This made it possible for TSMC to be on the leading edge. The cost of these advancements have been high, but recent use of a complex technology called EUV has increased these costs, which can be seen in the number of TSMC's patents. (KISHIMOTO,2016)

Figure 4 – TSMC's Patent Grants Worldwide



Source: CHEN, B; WEI, A, 2019. TSMC Creates a Global Strategic Patent Portfolio: Continue Pioneering in Top 10 of U.S. Patent Assignees for the 3rd Consecutive Year. TSMC. Available in: https://esg.tsmc.com/en/update/innovationAndService/caseStudy/18/index.html

One mechanism unique to this sector is the way that more supply directly affects demand, because lower prices and more energy-efficient microchips makes possible new uses for this technology. It is possible to observe that is through the advancements in Iot.

In an R&D-heavy sector such as this, it is necessary to keep talented employees. For that, TSMC has a stock bonus program, which helps employees feel like part of the company. The stock results seen historically have helped in that objective. (KISHIMOTO, 2016)

All that paints the picture of how TSMC is managed, with constant capital investments and higher salaries than Taiwan`s average. But even with these characteristics TSMC does not have a large amount of debt, because company management contained these expenses as routine and kept debts that when subtracted from the company cash generally float close to zero.

3.2 COMPANY ANALYSIS

3.2.1 SWOT Analysis

3.2.1.1 Strengths

The large market share of the Taiwan semiconductor company creates many advantages, one such as these is the stronger power to define prices. The thing is many companies cannot do this without consumer backlash or making these higher prices temporary, both things that TSMC did not do, and kept similar market share. (WANG, 2021)

Another pro of a larger market share is the possibility of making larger fabs, called megafabs by TSMC, which have a lower cost per chip. Not only that, but the larger demand for complex machinery also helps the company to acquire these easily. (KISHIMOTO, 2016)

The lithography machinery costs, together with other costs associated with being at the forefront of the semiconductor manufacturing sector, make this arguably the sector with the highest cost for new entrants bar none. (WANG, 2021)

By partnering with clients TSMC can increase yields when producing chips, meaning that by having the trade secrets of clients secured they can develop better manufacturing, offering lower costs, because of fewer failures. (WANG, 2021)

To stay at the leading edge in this sector it is necessary to have partnerships with universities, and in the case of TSMC, they have partner universities all over the world, in Europe, Asia, and the USA. Helping with talent acquisition and research. (TSMC, 2023a)

Nowadays, the only way to keep competing in the technological forefront is to develop yourown process nodes in-house. TSMC has been developing these since its establishment, making it a more independent company, and raising customer trust. (KISHIMOTO, 2016)

There is a ludic “silicon shield” in Taiwan, meaning that the economic impact would be too high in a conflict between Taiwan and China, discouraging escalation. The estimated impact in the global economy is 2.7 trillion dollars,which would shrink global GDP by 3% in a single year, but the impact in China and Taiwan would reach 7% and 40% respectively. (IEP,2023)

Other major suppliers, and service providers adjacent to semiconductor manufacturing are also located in Taiwan, simplifying customers production chains. (HAO, 2022)

3.2.1.2 Weaknesses

Large clients are responsible for most of the revenue. However, TSMC reliability can mitigate that. (WANG, 2021)

To maintain the company's position in the technological vanguard, there is a constant need for investment in research and new machinery. So, TSMC runs multiple research approaches to raise the chances of maintaining the technological roadmap. (KISHIMOTO, 2016)

The supplementary services supplied by TSMC are currently in a manageable size, but there is a chance that they can interfere the company's main business. (KISHIMOTO, 2016)

As mentioned before TSMC is nowadays more commonly serving larger clients, but the advancement in IoT tends to benefit smaller companies. (KISHIMOTO, 2016)

On the topic of quantum computing TSMC is behind when compared to other companies, but it is trying to catch up with research in partnership with Taiwanese universities. Even if the company is behind the financial impact is expected only in a decade. (TSMC, 2023a)

The offside of the stock bonus that TSMC uses to bring closer together Shareholder's and workers' interests, and maintain qualified workers in Taiwan, is that it can cause a crisis that affects the company's share price, to be more severe than usual. (KISHIMOTO, 2016)

ASML is also the only direct nexus supplier for TSMC, meaning that technological advancements in ASML can have profound impacts on TSMC's financial performance. Even suppliers of suppliers can affect TSMC production, especially in the medium or long term. After all, Zeiss can fail to deliver the mirrors necessary for the production of EUV lithography machines, delaying the expansion of TSMC production. (TINGTING, 2015)

3.2.1.3 Opportunities

High profit margins and low debt make it possible to make big, unexpected investments if necessary, and to invest during times of crisis. (TSMC, 2023c)

Only TSMC, Samsung, and Intel are currently able to keep up with the investments necessary for the leading edge, furthering consolidation in the sector, according to WANG, 2021. The consequence of this environment is concentration of production and decrease of the number of companies by 10% between 2012 and 2017 as investigated by Hao (2022).

Because of the geopolitical and economic importance of TSMC, the company has leverage against the government, enabling larger support if necessary. (CRONIN, 2022)

If made possible an 18-inch wafer fab would lower the cost per chip and have high building cost, strengthening TSMC's position. (ROBINSON, 2022)

The expansion of artificial intelligence has also increased demand for semiconductors, and this is expected to continue. So, the company needs to be able to keep up with demand.

3.2.1.4 Threats

When talking about machinery it is not an option to not buy new models if the company plans on staying ahead technologically, this gives more leverage to the suppliers of these machines. Also, it is not reasonable for TSMC to try and make these machines, as the research necessary is too far apart from the company's main business. (KISHIMOTO, 2016)

As is largely known China wishes to reincorporate Taiwan, and if this wish escalated to a conflict TSMC fabs would most probably stop production. (CRONIN, 2022)

The silicon shield that protects Taiwan, as a result of the impact on the Chinese economy in case war happens, is being weakened. Because of initiatives by the US and European countries to bring manufacturing back to their countries, and the barriers created by American sanctions on China in their trade war, weakening relations. (POWER-RIGGS, 2023)

Semiconductors production needs a large amount of water, but Taiwan has seasonable droughts that in some years can cause problems in production. (BARBIROGLIO, 2021)

The cycle that TSMC growth has been following is a particular cycle of gain in market share to secure profits for the next generation, but as seen there is not as much market share left to gain, so this may affect company growth in the long run. (KISHIMOTO, 2016)

Another way that new companies have been appearing is through the help of the Chinese government, in an attempt to increase national production some considerably large companies have appeared, such as SMIC, which is a direct competitor of TSMC, even if SMIC process nodes is still behind TSMC, and its production is small (only 3% of market share).(HAO, 2022)

3.2.1.5 Analysis Summary

Figure 5 – SWOT Analysis Summary

Strengths	Weaknesses
Position as price leader	Leverage of large clients
Larger Fabs with lower cost per chip	Need for constant investment
Leverage against suppliers of complex machinery	Possible overexpansion of supplementary services
Partnership with clients helping production	IoT advancement benefiting competitors
High cost for new entrants	Behind in quantum computing R&D
Supplementary services aiding in client retention	Employee retention and stock performance relation
More patents than competitors	Tech-dependent on suppliers.
Research partnerships with universities	
efoundry system	
in-house development of process nodes	
Stock bonus for employees	
Large specialized work pool in Taiwan	
Protected by the “silicon shield”	
Opportunities	**Threats**
High profit margins and low debt driving investment	Necessity to always buy new machinery

Few competitors in the leading edge	Possible Chinese invasion of Taiwan halting production and weakening the Silicon Shield
Influence in the local government	Water demand can fail to be met in droughts
18-inch wafer fabs powering industry consolidation	Slower growth cycle, because of current consolidation
Increasing demand related to the growth of AI computing necessities.	Consolidation of government sponsored Chinese companies.

Source: Own production

3.3 COMPANY VALUATION

3.3.1 Source Data

The first thing that was done was the sourcing of the necessary company data, as it is presented in the balance sheet, cash flow, and income statement. In the case of TSMC, this data was available on the company investor relation website as it is included in TSMC (2023c).

3.3.2 Free Cash Flow Calculation

Then, it was calculated the current year's free cash flow. Firstly calculating the NOPAT, which is the EBIT multiplied by 1 minus the company tax rate, then the net Capex is determined by subtracting the depreciation. With that, it is possible to find FCF according to the formula: FCF = NOPAT – Net Capex – Change of Working Capital

So, the current FCF for TSMC is 488,723,646,000 new Taiwanese dollars.

3.3.3 Cost of Debt

Firstly, the total financial debt is determined by the sum of the financial debt with the company leases, using the interest expense the debt interest rate can be found. Afterward the pension accruals interest rate is calculated, and with that, it is determined the cost of debt of 1,31% for TSMC. Still, we also need to consider that the net debt including pensions is 486,604,935,000 new Taiwanese dollars.

3.3.4 Discount Rate

The discount rate will bring our future cash flows to the present. For that, the risk-free rate utilized was the Taiwan equity risk premium as defined by Damodaran (2023). Now, for the expected market return it was used the MSCI ACWI gross returns since 31/12/1987, and for the standard deviation the MSCI ACWI for the last 5 years was used, this index was chosen

because it accounts for large and mid-cap companies, and for the standard deviation the last 5 years were used to include the higher variance in the last years as show by MSCI (2023).

The risk diversion factor used was 0,5, the standard deviation of the return and its expected return were calculated using TSMC`s EBIT for the last 5 years. With that, the variation coefficient was determined by dividing the last two quoted metrics.

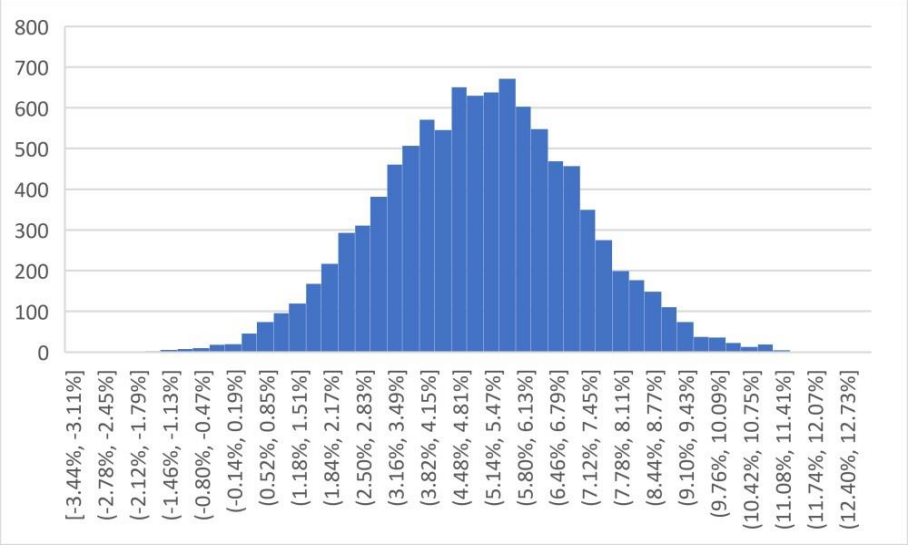
The last 2 pieces of data are the long-term growth and the default risk, the growth used was 2,92%, which is the average World GDP growth for the last 20 years according to The World Bank (2023), and the default risk for a company with a credit rating of AA is 0.02% according to S&P Global Ratings (2023).

This way, it is possible to determine that the discount rate that will be used is 8,61%.

3.3.4 Simulations

The first simulation deals with revenue growth, EBITmargin, Capex portion of revenue, depreciation portion of revenue, and change in working capital. For this, it is necessary to define expected values and standard deviations of the previous parameters. So, after preparing 10.000 columns we use the formula "INV.NORM.N(ALEATÓRIO();B$2;B$3)" or "NORM.INV(RAND();B$2;B$3)", this way excel will provide the random results inside the previous defined parameters, resulting closely to a normal distribution for the next 6 years.

Figure 8 – Revenue Growth Distribution



Source: Own production from Excel (2023).

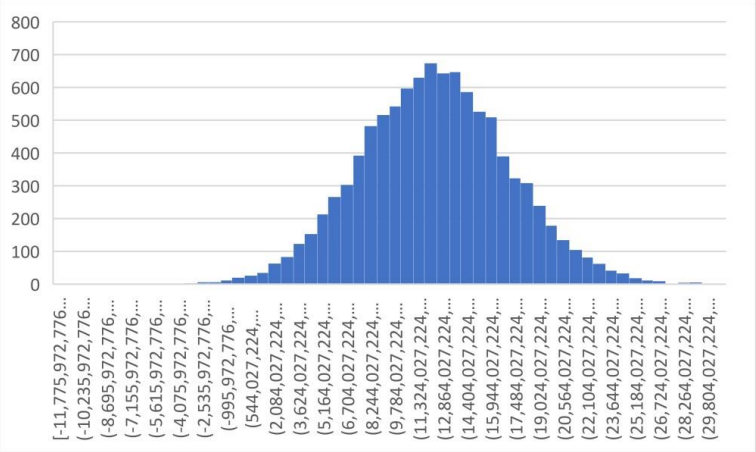
The second type is a triangular distribution, used to find the expected effective tax rate, which is more easily predicted, because of the stability of tax policy. In this method, the

researcher needs to define a minimum, a maximum, and a high probability rate. Finally, the random Excel formula is used to create the possible tax rate distribution.

3.3.6 FCF Estimation and Discounting

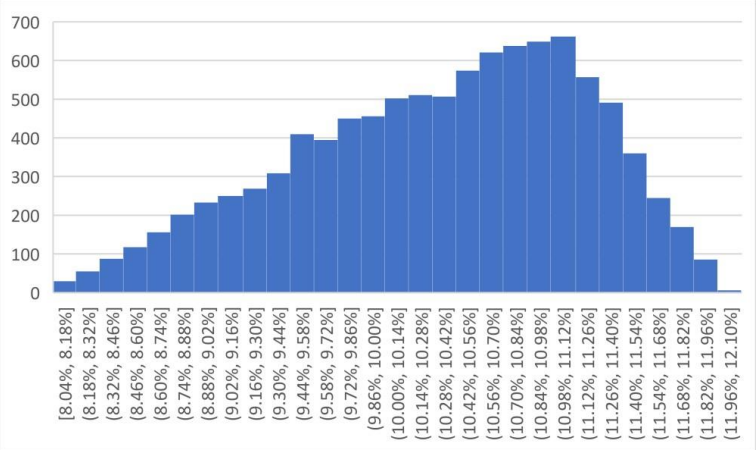
Utilizing the data extracted from the financial statements in the free cash flow calculation, and the values for possible revenue growth, the instances for these growth for the next 5 years and the long term are calculated. With this, the EBIT margin, Capex portion, depreciation portion, and change in working capital are found. Now, with the FCF formula is possible to find the values for FCF in the relevant time frame. Finally, is to discount these, and sum the values in every year, thus finding the values for TSMC's net present value.

Figure 10 – NPV Distribution



Source: Own production from Excel (2023).

Figure 9 – Tax Rate Distribution



Source: Own production from Excel (2023).

3.3.7 Enterprise Value Calculation

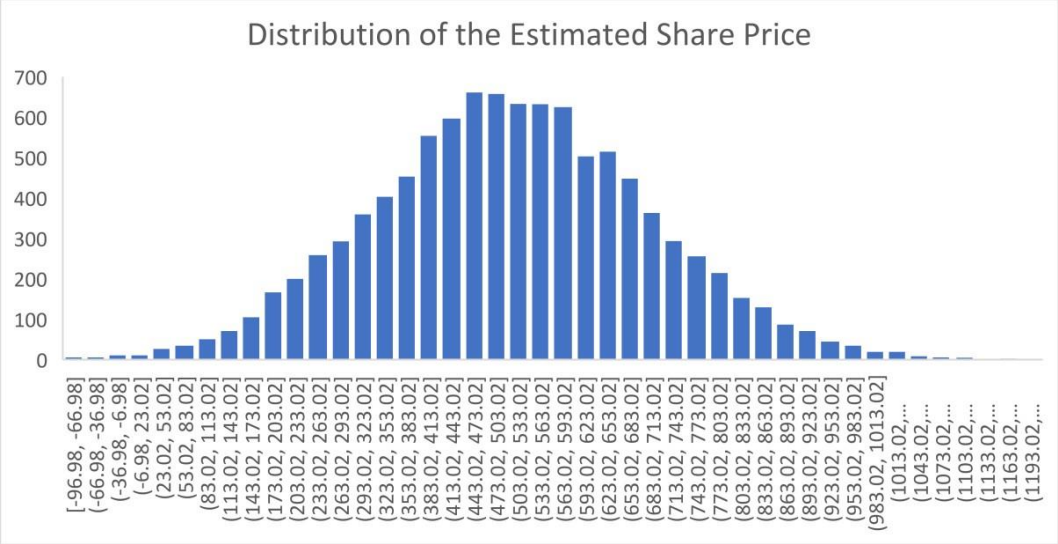
With all the data acquired up to this point calculating the simulated enterprise value will be simple, we need only to subtract the NPV by the net debt.

4. APRESENTAÇÃO DOS RESULTADOS E DISCUSSÕES

4.1 VALUATION RESULTS

The last thing necessary is to divide the enterprise value by the number of outstanding shares, finding the last estimated shares prices that are distributed as shown below:

Figure 11 – Estimated Share Price Distribution



Source: Own production from Excel (2023).

Figure 12 – Estimated Share Price Analysis

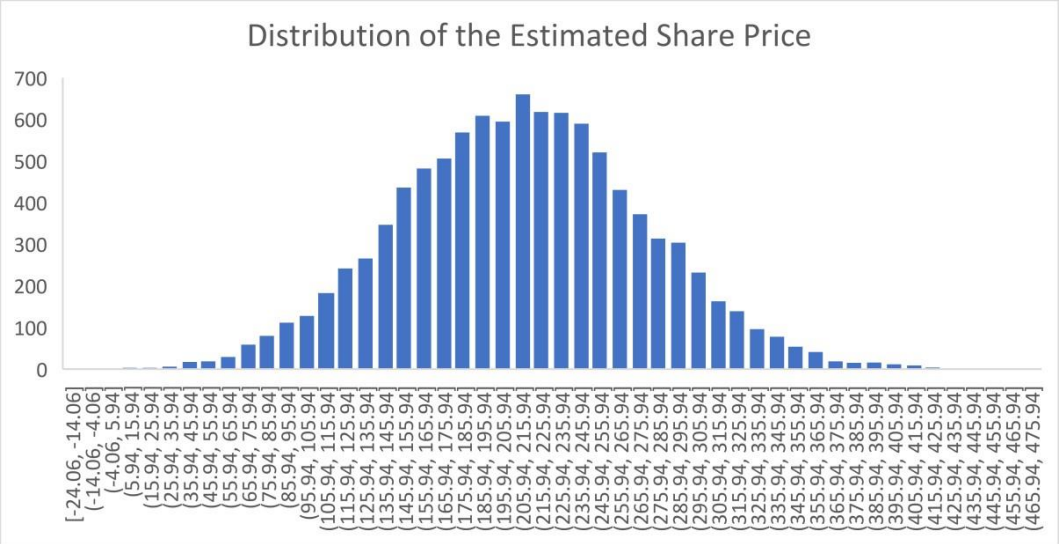
Analysis			
average	509.00	current share price	571
median	506.53	***potential return***	***-11%***
standard deviation	186.08		
		probability of a gain	
percentage > 0	99.76%	statistically	36.95%
percentage < 0	0.24%	in the model	36.52%
# observations	10000		

Source: Own production from Excel (2023).

Utilizing the model, it is simple to make a scenario analysis, for example, it is possible to show the impact of the Taiwan-China conflict at the beginning of 2025, decreasing revenue

by 50% in the same year and 10% in the following one. Also, it is achievable to model a peaceful unification with China in the same time frame, increasing revenue by 5 % in the next years, and a 0.5% increase in long-term growth as a result of easier access to the Chinese market, which is TSMC's fastest growing one, and also weakening companies such as SMIC.

Figure 13 – Estimated Share Price Distribution – Taiwan-China Conflict



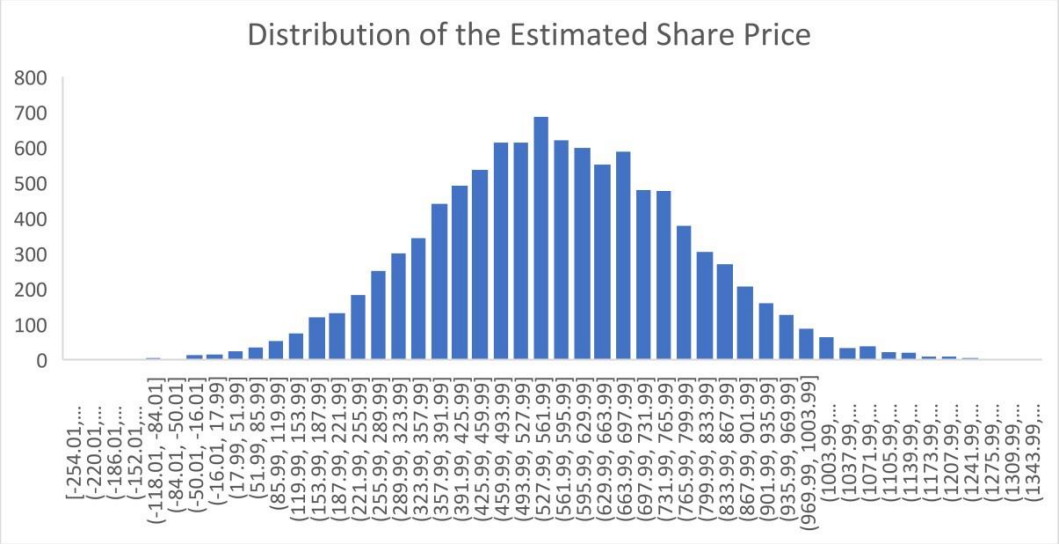
Source: Own production from Excel (2023).

Figure 14 – Estimated Share Price Analysis - Taiwan-China Conflict

Analysis			
average	210.80	current share price	571
median	210.58	***potential return***	***-63%***
standard deviation	62.68		
		probability of a gain	
percentage > 0	99.98%	statistically	0.00%
percentage < 0	0.02%	in the model	0.00%
# observations	10000		

Source: Own production from Excel (2023).

Figure 15 – Estimated Share Price Distribution – Peaceful Unification



Source: Own production from Excel (2023).

Figure 16 – Estimated Share Price Distribution - Peaceful Unification

Analysis			
average	568.92	current share price	571
median	564.42	***potential return***	***0%***
standard deviation	210.64		
		probability of a gain	
percentage > 0	99.65%	statistically	49.61%
percentage < 0	0.35%	in the model	48.68%
# observations	10000		

Source: Own production from Excel (2023).

4.2 CONCLUSION

The result for investors is a sell rating in case they expect the status quo to be maintained, or if conflict erupts between Taiwan and China, with a downside of 11% and 63% respectively. Even with a peaceful unification the company only gets a hold rating with a downside of 0,3%.

This again shows the impact that a conflict in the region would have, creating an extra downside of 52% in a major company, impacting clients such as Nvidia, Apple, AMD.

So, in the case of relevant policymakers in the region, it is important to also take into account the indirect impacts of this combat, being this remark especially relevant to Taiwanese authorities that have the existence of their country at stake. After all, even if Taiwan won the conflict, it would most probably lose years of socioeconomic development.

4. REFERÊNCIAS BIBLIOGRÁFICAS

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