LISBON
SCHOOL OF
ECONOMICS &
MANAGEMENT
UNIVERSIDADE DE LISBOA

MASTER OF SCIENCE IN

FINANCE

MASTER FINAL WORK

PROJECT

EQUITY RESEARCH:

MICRON TECHNOLOGY

MARIUS GRØNLI

15.OCTOBER.2019

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SUPERVISOR:

PROFESSOR JOÃO CARVALHO DAS NEVES

Abstract

This project is the final work as a part of the MSc. Finance degree at Lisbon School of Economics and Management (ISEG). Students can choose to write a master thesis or write an equity research of a chosen company. The project is structured after ISEG's guidelines and the CFA institutes research report recommendations. I choose to analyze Micron Technology Inc. because of my interest in the technology sector, especially the semiconductor industry. The industry displays a lot of special traits like cyclicality and extreme capital requirements, which was both educational and demanding to analyze.

Acknowledgements

To friends, family and girlfriend who have helped me through long hours of studying and especially trough this project which has taken a lot of my time and effort.

To all the professors at ISEG who have guided me through the MSc. Degree at ISEG. Especially Professor João Carvalho das Neves for being my supervisor and giving me a lot of constructive feedback and help on this project.

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University of Lisbon- ISEG

Marius Grønli (L49479@iseg.ulisboa.pt)

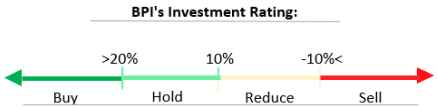
Micron Technology, inc.	NASDAQ Stock Exchange	Industry: Semiconductor

KEY DATA			
	Recommendation date: 30.05.2019	**Current price:** $33,32	**Recommendation**: Buy (+24,19%)
	Ticker: MU	**Risk assesment:** Medium	**DCF Target prce:** $41,38

Table 1: Micron market data

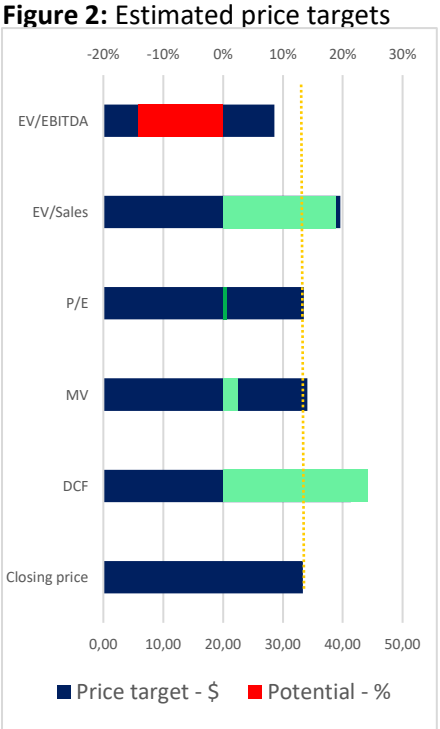
Market profile	
Closing price(Q3 2019)	33,32
Volume	16,342M
Shares outstanding	1 134M
Market capitalization	37 784M
52-week price range	30.32-61.39

Figure 1: Recommendation scale



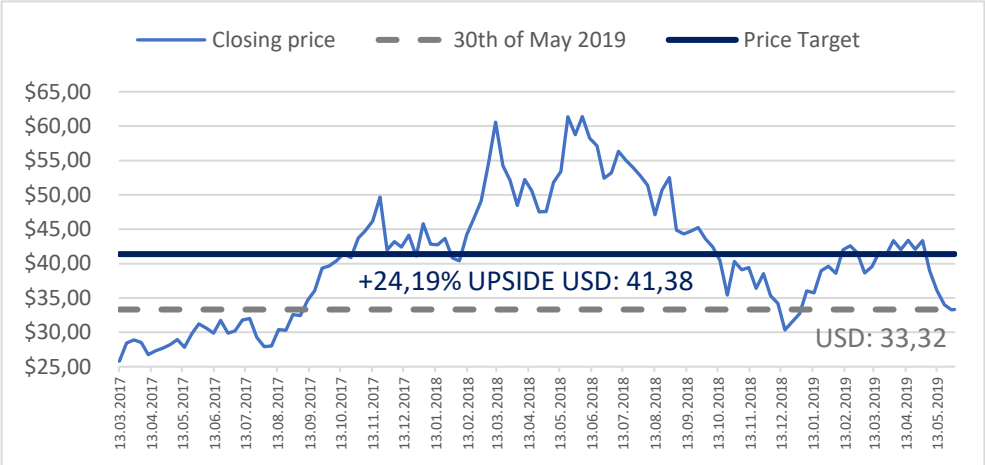
***Source**: BPI investment*

Figure 2: Estimated price targets



***Source**: Author*

MU: Entering a new bust cycle



Buy is the recommendation for Micron with an estimated **price target of $41,38** from a DCF model. Multiple valuation support that Micron is undervalued, with an estimated price target of **$34,10**. Mean variance theory indicates that Micron should be included in a constructed asset that covers the US semiconductor industry. The current closing price 30.05.2019 indicates an **upside potential of 24,19%.** Microns efficient use of its employed capital (**Appendix: 8**) in an extreme capital intense industry result in a robust business model, estimated to generate positive cash flows during the bust cycle.

Debt repayment prepare Micron for a new bust cycle. As the average selling prices peaked in the last quarter of 2018 (DRAM ASP: +37% YoY) the industry went into a new bust cycle with the ASP in free fall due to the increasing oversupply. With revenues estimated to decline 25% YoY and an estimated CAPEX of $9 billion in 2019F Micron must be able to acquire capital at reasonable rate. In 2016 Microns debt/equity ratio reached 113% after acquiring Inotera memories. After using the boom cycle to deleverage, Micron reached a debt/equity ratio of 30% in 2018. The deleveraging made Micron able to negotiate a new desirable credit agreement with an interest rate equal to LIBOR +1,5% to 2%.

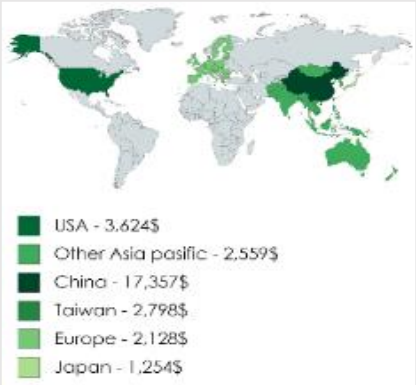
Introducing the first new memory class to the markets since NAND was introduced in 1989. The introduction of 3D Xpoint will result in a new revenue driver for Micron with a revenue potential of $3,36 billion in 2023. DRAM and NAND accounted for 96% of Microns revenues in 2018, which both have very volatile prices. By introducing 3D Xpoint Micron will strengthen its revenue diversification and be able to target niche markets, which require high speed memory chips.

Table 2: Price traget sensitivity to **ROCE**

			Terminal ROCE			Δ =	1,00 %
9,60 %	10,60 %	11,60 %	12,6 %	13,60 %	14,60 %	15,60 %
-15,8 %	-2,5 %	10,9 %	24,2 %	37,5 %	50,8 %	64,2 %
			Economic profit			
-2,0 %	-1,0 %	0,0 %	1,0 %	2,0 %	3,0 %	4,0 %

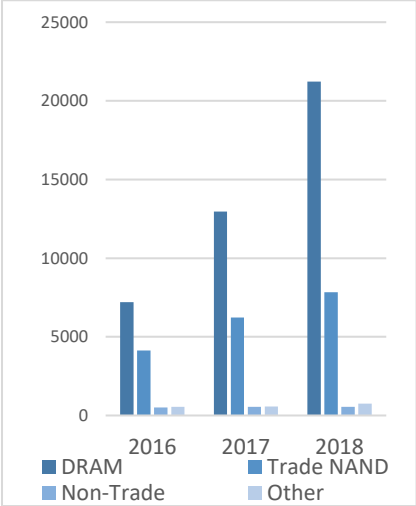
***Source**: Author*

Figure 3: Important markets



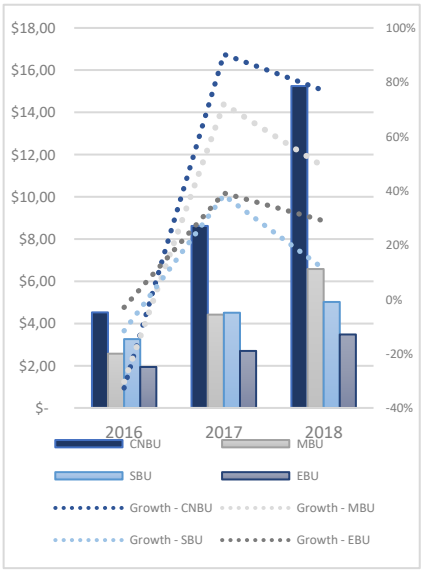
Source: *Company(10k), Author*

Figure 4: Revenues by product



Source: *Company(10k), Author*

Figure 5: Revenues by segment



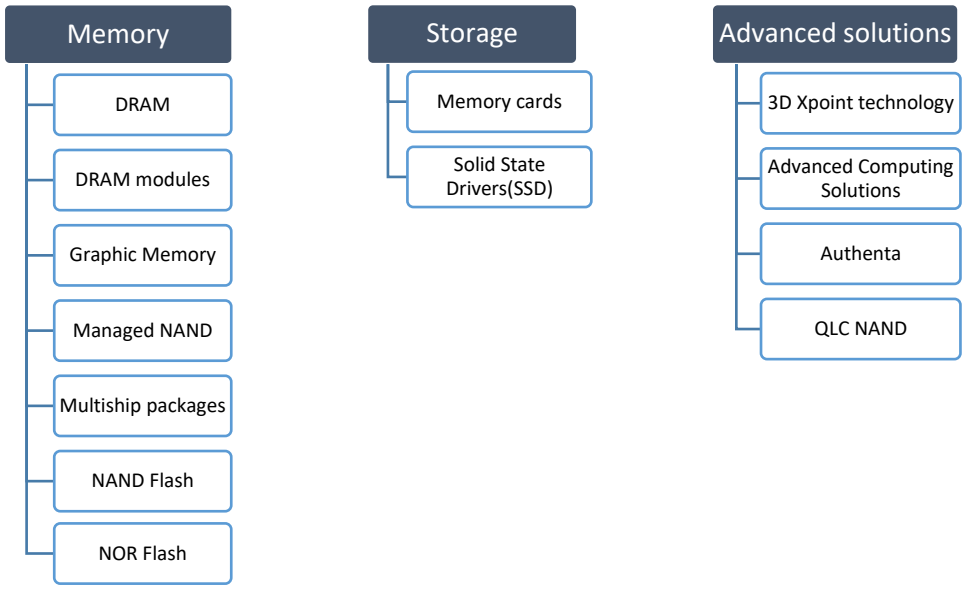
Source: *Company(10k), Author*

Business description

Micron Technology, Inc., Including its subsidiaries, is one of the industry leaders in innovating memory and storage technologies. Most of Microns Technologies revenue is generated through its global brands – Micron®, Crucial®, and Ballistix®. The broad portfolio of products is transforming how the world uses information. Their products are key elements of technologies like artificial intelligence, machine learning and autonomous vehicles.

The history of Micron Technology starts in 1978 when the company was founded as a semiconductor design company. In 1980 the company acquired its first plant and few year later they had produced the world's smallest 256k DRAM chip. In 1994 the company was listed on Fortune 500 and since that the company has grown steadily through innovation, acquisitions and partnerships to be one of the market leaders in the semiconductor industry. Micron technologies products can be categorized in the three different core categories and are sold in four different segments.

Products



Compute and Networking Business Unit (CNBU)

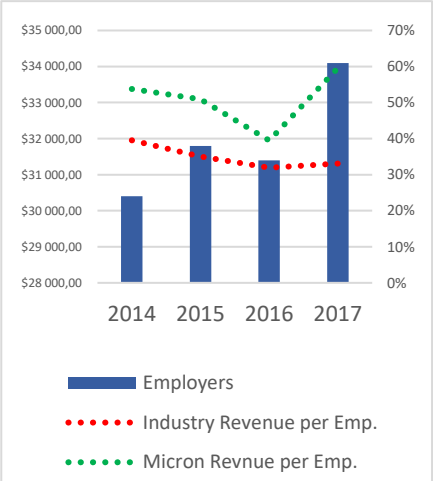
CNBU sells memory products and advanced solutions for cloud servers, enterprises, clients, graphics and networking markets. CNBU accounted for 50% of the total revenues in 2018 and had a growth rate of 77% from the previous fiscal year. Total sales were 15,25$ billion.

Mobile Business unit (MBU)

MBU sells memory products sold into smartphones and other mobile-device markets and includes discrete DRAM, discrete NAND and managed NAND. For the smartphone market speed/power output is extremely important since battery life is limited. In 2018, Micron announced a new 64-layer, second-generation 3D NAND storage product, which supports the high-speed UFS 2.1[1] standard and eMMC 5.1 standard. The UFS 2.1 speed supports technologies like AI, virtual

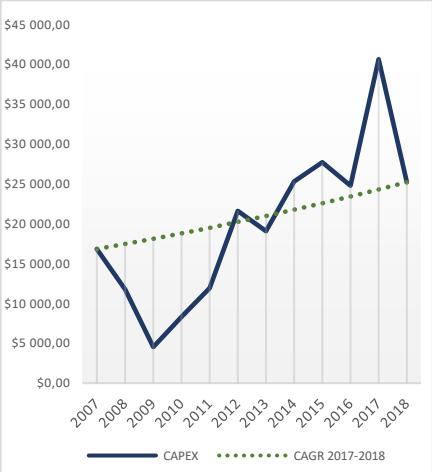
[1] Universal Flash Storage(UFS) aims to bring higher data transfer speed and increased reliability to flash memory storage, while reducing market confusion and removing the need for different adapters for different types of cards.

Figure 6: Revenues by employee



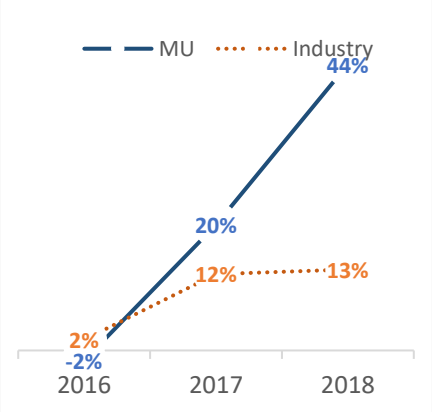
Source: *Bloomberg, Author*

Figure 7: CAPEX Semiconductor



Source: *Bloomberg, Author*

Figure 8: ROCE analysis



Source: *Bloomberg, Author*

reality and face recognition which is becoming more frequent on high end smartphones. MBU accounted for 22% of the total revenues in 2018 and had a growth rate of 49% from the previous fiscal year. Total sales were 6,58$ billion.

Storage Business Unit (SBU)

SBU sells SSDs and component-level solutions into enterprise, cloud, client and consumer storage markets. SBU also include "non-trade" products. Micron have a long-term supply agreement with intel through IMFT[2], where they supply intel with 3D Xpoint memory and NAND products at prices approximated to cost. MBU accounted for 11% of the total revenues in 2018 and had a growth rate of 17% from the previous fiscal year. Total sales were 5,02$ billion.

Embedded Business Unit (EBU)

EBU sells memory and storage products to the automotive, industrial and consumer market. The products sold are discrete DRAM, discrete NAND, managed NAND and Flash. The market is characterized by long life-cycle DRAM and NAND products manufactured using mature technologies. The products enable edge devices to store, connect and share information in the growing internet of things("IoT"). MBU accounted for 11% of the total revenues in 2018 and had a growth rate of 29% from the previous fiscal year. Total sales were 3,48$ billion.

Key drivers of profitability

Extreme capital requirements in the industry

The semiconductor has one of the highest capital requirements off all industries. The total CAPEX of all semiconductor memory firms reached $25 221 million in 2018. For Micron CAPEX amounted to 20% and 28% of the sales for 2017 and 2018. The reason the industry is so capital- and technology intense is because of the complexity in producing memory chips. The chips are produced at a nanometer level and require extreme clean rooms for production, where only one dust particle could ruin the chip. The most current estimate regarding the cost of a production facility is from 2017, when Samsung built its new DRAM FAB (production facility). The cost where estimated to accumulate to $14 billion.

Return on invested capital (ROCE)

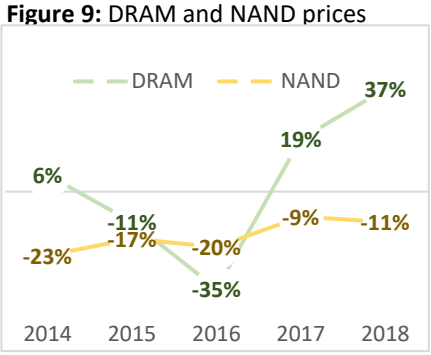
Since the capital requirements for the industry is very high the industry players must maximize their ROCE to stay competitive. By decomposing ROCE and inspecting each element we can determine what drives profitability (See **Appendix: 8** for the full analysis).

DRAM is the key revenues generator for MU accounting for 70% of the revenues in 2018, which is an increase from 58% in 2016. NAND accounted for 26% of the revenue, a decreased from 33% in 2016. The prices for DRAM have increased substantially since 2016, while the NAND price has continued to stagnate resulting in the current revenue shares. However, DRAM prices are extremely volatile (Figure 9) which makes the big revenue share of DRAM increase Microns risk.

Micron delegates a part of their R&D investments to improve process technology, which enables continues improvement to cost structures and performance

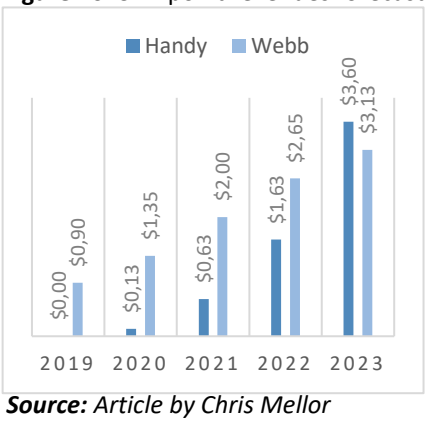
[2] IMFT is a joint venture between Micron Technologies and Intel. The purpose of the venture is to share R&D costs to develop NAND and 3D XPoint technologies. Micron owns 51% of IMFT and is governed by a Board of Directors, for which the number of managers is appointed by each member varies based on the members' respective ownership interests. Source: Micron 10-k report, 2018.

Figure 9: DRAM and NAND prices



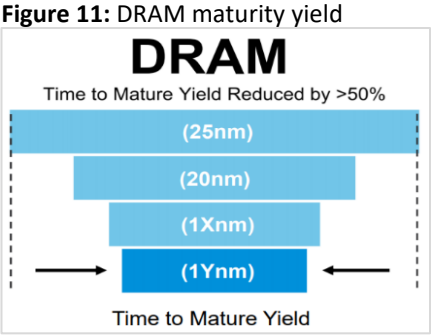
Source: *Company(10-k), Author*

Figure 10: 3D Xpoint revenues forecast



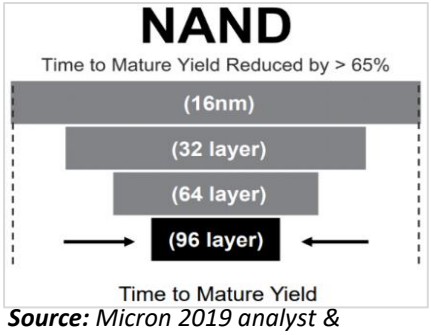
Source: *Article by Chris Mellor (See footnote 3)*

Figure 11: DRAM maturity yield



Source: *Micron 2019 analyst & investor webcast.*

Figure 12: NAND maturity yield



Source: *Micron 2019 analyst & investor webcast.*

enhancements for their future product. The R&D effort on cost structures have yielded results. The COGS-to-Sales 3Y average is **56%** for Micron while the industry average is **67%**, resulting in a cost advantage for Micron (see **Appendix: 9** for full metrics analysis).

The capital employed has increased every year since 2016 combined with an increasing ROCE which means that Micron is managing to efficiently utilize their assets. For 2019 the Q2 (10-Q) report has indicated an increase of CAPEX to $9Billion, an increase of $0,121Billion. The increase is due to an effort to increase the amount of clean rooms used for production.

Company strategies

IMFT takeover and 3D Xpoint introduction

On the 14th of January 2019 Micron disclosed that they are exercising their call option to buyout Intel from IMFT. The price is estimated to be around $1.5 billion in cash. This will dissolve Intel's non-controlling interest in IMFT, as well as IMFT's member debt. The takeover will result in IMFT being a wholly owned subsidiary of Micron. Micron plans to introduce 3D Xpoint to the market by the end of 2019, with a revenue ramp starting in 2020. However, based on prior agreements, Micron must sell 3D Xpoint memory wafers to intel one year after the deal is closed.

The IMFT takeover is a part of the Microns strategy to diversify their products as DRAM accounted of 70% of the revenues in 2018. The investment provides Micron with an established manufacturing facility to produce 3D Xpoint[3].

R&D with high focus on improving yields

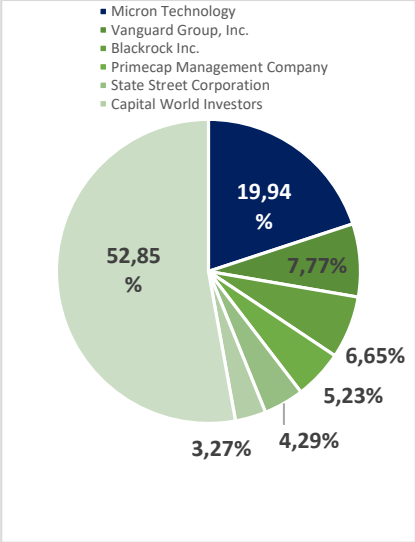
Micron spent on average 9% of sales on R&D research the last three years. They recently expanded the amount of clean rooms used specifically for R&D. Their strategy is to improv how fast they can ramp up production from a certified product to full production, which maximizes the yields of the products. The past R&D results have improved the NAND "time to mature yields" with over 65% from the 16nm to the new 96layer chip. For DRAM the "time to mature yield" is reduced by over 50% from the 25nm chip to the 1Ynm chip.

Collaborations with startup and universities to follow the AI market

In 2018 Micron announced that they would launch a new $100 million venture fund program to target AI start-ups. Micron also announced a $1 million research and teaching grant program through Micron Foundation, targeting AI development. Since AI is at its early phase of industrialization a collaboration with start-ups and universities will give Micron valuable information about market developments and emerging technologies. New technologies like AI may require new chip architectures to optimize utilization. By collaborating with the market Micron can be pioneers in new emerging technologies.

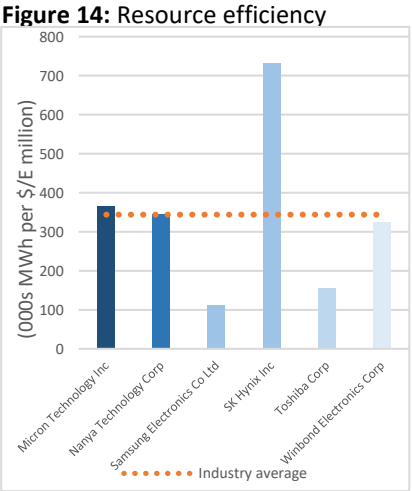
[3] Forecast collected from Chris Mellor's article in Blocks and Files (https://bit.ly/2NBWUCK). Forecast is done by Jim Handy, the memory guy at Objective Analysis and Mark Webb of MKW Ventures Consulting.

Figure 13: Microns shareholders



Source: *Yahoo finance – 04.09.2019*

Figure 14: Resource efficiency



Source: *Bloomberg, Author*

Figure 15: Corporate governance

Ratio	Micron	Industry
Corporate Governance		
% independent directors	86 %	63 %
% Women on board	14 %	9 %
Compensation		
CEO Salary as % of Total Exec Salary	32 %	58 %
Labor Relations		
Revenue per Employee	$ 0,60	$ 0,33

Source: *Bloomberg, Author*

Corporate governance

Mr. Sanjay Mehrotra is the current CEO. Mehrotra was one of the co-founders of SanDisk Corporation founded in 1988. He eventually served as CEO from 2011 until SanDisk's sale in 2016. He became CEO of Micron shortly after, in May 2017.

Board of directors' structure and independence

The board of directors are elected each year by the annual shareholder meeting. The board of directors consist of 8 members, where Robert E. Switz act as the chairman of the board. Per 2018, 85% of the board are independent. The industry average per 2018 is 62,5% independence, while the general recommendation is that 2/3 of the members should be independent.

The board of directors has a standing of four committees

- **Audit committee –** The committee has the purpose of overseeing and monitoring the integrity of the financial statement, the company's compliance with legal and regulatory requirements, the independence of the auditors and performance of the company's internal audit function.
- **Finance committee –** The purpose is to represent and assist the board in conducting its responsibilities with respect to the Company's financial policies, financial strategies and capital structure.
- **Governance and sustainability committee –** The main responsibilities of the G&S committee are: Director compensation, Identification of candidates (board members), Sustainability, Development of corporate governance guidelines and oversight and evaluation.
- **Compensation Committee –** The purpose is to assist the board in deciding the compensation to the Company's officers.

The board of directors is independent and diversified, there is not a single group or entity with major control over the decision making.

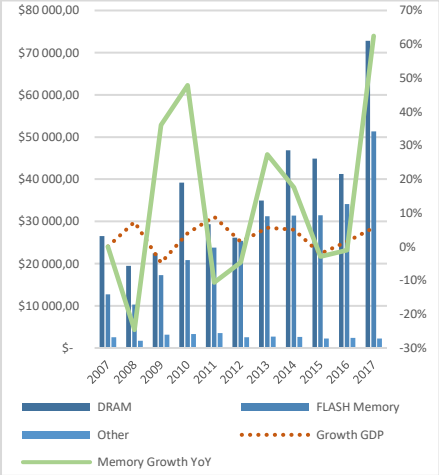
Resource efficiency and social responsibility

Micron strategy for ensuring a healthy and secure workplace consist of establishing a health and safety committees at every manufacturing site. The program involves all parts of the production working collectively to ensure a safe environment. Micron also have a big focus on environmental issues and strive to minimize the climate footprint. However, they have a bigger energy intensity per sales (000s MWh per $/Million) of 365 compared to the industry average of 343.

Micron has a foundation to ensure social responsibility toward communities called Micron Foundation. The foundation has three areas of focus:

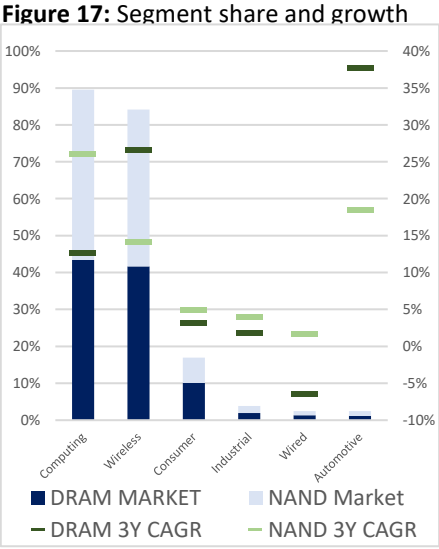
- **Inspiring learning –** Deploys STEM outreach programs and partnerships.
- **Communities –** Distributes $13,5 million to STEM programs and basic human needs in the communities where they operate.
- **Cultivate giving –** A program where employees can do volunteer work for a good cause. Resulted in 150,000 employee hours spent on volunteer work. Micron also match employee donations up to $2 million.

Figure 16: Memory industry revenue



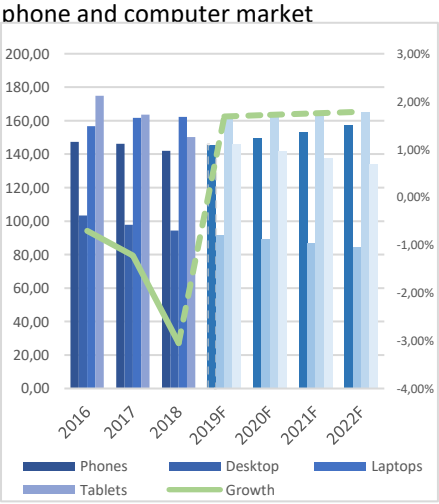
Source: *Data: Bloomberg, graph:*

Figure 17: Segment share and growth



Source: *Bloomberg, Author*

Figure 18: Forecasted G and RV for phone and computer market



Source: *Data: IDC, graph: Author*

Industry overview

A highly cyclical industry

The memory industry is highly cyclical, which is explained by the products sold being commodities. The products are differentiated by different industry standards for speed and power usage. The revenue growth of the memory market goes in cycles around the GDP growth of the overall economy. The memory growth tends to move in cycles with 2years growth followed by 2years decline. The cycles have an upwards going trend (See attached revenue forecast).

Industry size and markets

The memory market of the semiconductor industry had revenues of **$126** billion with a 3Y CAGR of 16%. The memory market consists of the following segments; Computing, Wireless Communication, Consumer, Industrial, Wired Communication and Automotive. In 2017 DRAM accounted for **58%** of the revenues with a 3Y GAGR of **16%**. Computing was the biggest segment accounting for **$31 billion** with a 3Y CAGR of 13%. Wireless communication was close to computing accounting for **$30 billion** but exhibits a much higher growth rate then computing the last three years with a **CAGR of 27%.** The Automotive segment is the least earning segment only generating $833 million. However, the segment had an exceptional strong growth the last three years with a **CAGR of 38%**

The NAND market is still smaller than DRAM, accounting for 40% of the revenues in the memory market, but its growing faster than DRAM with a **3Y CAGR of 18%.** Computing is the most important segment within NAND. It generated **$23 billion** and had a **3Y CAGR of 26%.** Wireless communication is a close second generating **$21 billion**, but the **3Y CAGR is 14%** indicated a weaker growth then the computer segment. As well as for NAND as for DRAM the automotive market is showing an exceptional strong growth with a **3Y CAGR of 18%,** but the market is small, only generating **$675 million**.

Declining growth in familiar markets

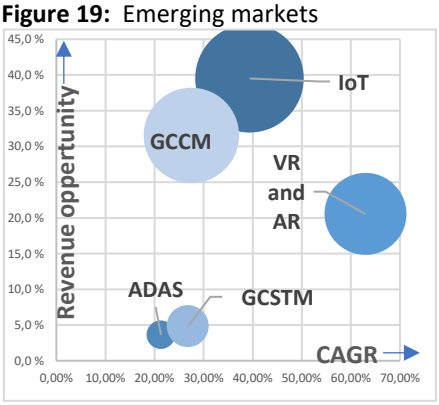
Wireless communication and computing has been one of the biggest growth engines for the memory players in the market. Wireless communication has mainly been driven by exponential growth in the smartphone market with a 7Y CAGR of **16,27%**. However, the growth has been declining fast the previous years and the market is now starting to mature with an expected CAGR to 2020 of **2,6%.** The traditional revenue drivers as PC, laptops and tablets is also expected to continue a slow growth path. The total of smartphones, desktop PC's, laptops and tablets had a 7Y previous CAGR of **10,06%** but are expected to have a CAGR to 2020 of **1,7%.**

Future growth opportunities

A lot of new technological possibilities are emerging. Internet of things (IoT), Advanced Driver Asstive Systems (ASAD), Virtual- and Augmented Reality (VR and AR), Global cloud Computer and Storage (GCCM and GCSTM) are all relatively new emerging markets. All the markets are heavily dependent of memory products.

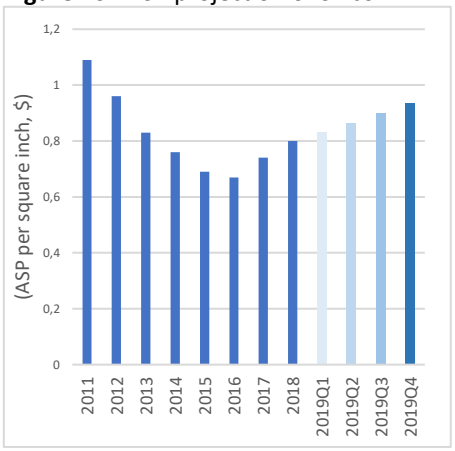
Automotive is the fastest growing segment because of the transition to Advanced Driver Asstive Systems which require a substantial number of sensors and

Figure 19: Emerging markets



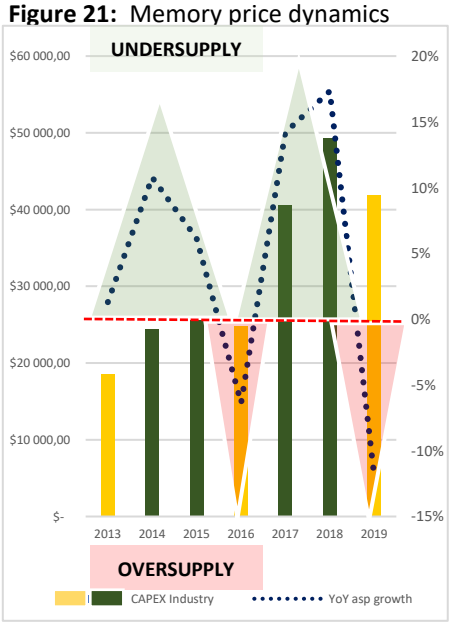
Source: Data: *GGCM -Accuray research LLP, GCSTM – Verified market research, VR/AR – Zion market research, ADAS- Allied market research, IoT – IoT Analytics.* ***Graph****: Author*

Figure 20: ASP projection of Silicon



Source: *Data: SEMI, graph: Author*

Figure 21: Memory price dynamics



Source: *Bloomberg, Author*

computing power. However, the revenue potential [4] is **3,6%**, which is low even with a strong forecasted growth.

Computing had the second highest 3Y past CAGR of **20,4%** and is supported by a market share of **44%** so the growth has a big impact on the overall revenues. VR, AR, GCCM and GCSTM are all expected to impact the future growth of the computing segment. VR and AR have the strongest anticipated growth until 2025 with a CAGR of **63%** followed by a strong earning potential of **20,5%.** GCCM has the second strongest earning potential of **31,5%** supported by a mid-range growth. Wireless communication had a 3Y CAGR of **17,1%** with an overall market share in 2017 of **41,8%**. The segment is heavily dependent of smartphone sales. However, IoT is already starting to affect the market. IoT is the most anticipated new segment in the semiconductor industry and all firms are taking steps to get involved. IoT has an earning potential of **39,5%** combined with a strong CAGR of **39,4%** it can support the growth of the segment, even though smartphones are growing at a slower rate.

Supply side perspective

Market conditions for goods used in production

The most critical component is memory production are Silicon Wafers and photomasks. The ASP of silicon wafers per square inch has gone from $1,4 in 2007 to $0,74 in 2017. The reason the price has declined is overproduction, because wafer companies has been aggressively adding capacity the last years. Now that the semiconductor industry had a peak in their cycle in 2018 there is a constraint on the supply, driving prices to increase. The ASP is forecasted to increase 3-5% each quarter during 2019. However, as the semiconductor industry is expected to have a decline in growth during 2019, the prices of silicon wafer is expected to stabilize if wafer producers don't expand capacity during 2019. All memory producers are in joint venture or are vertically integrated in photomask production, making the prices less critical for the supply of memory chips.

Memory price dynamics

The memory products are viewed as commodities by the market, and the pricing follows a boom-bust cycle. Demand has less pricing power as there is thousands of buyers and only 7 firms controlling the majority of the market shares. By analyzing the capacity expansion[5] and the ASP of the industry [6] we can see how the price is increasing and decreasing as a direct consequence of adding capacity. From 2013-2015 the price is increasing, and manufactures are adding capacity resulting in an oversupply. As the price decrease in 2016 the manufactures reduce capacity resulting in an undersupply and a price increase. The cycles tend to repeat itself every second year.

Constraint on the production

Due to the undersupply of DRAM and NAND and adding of capacity in 2017-2018

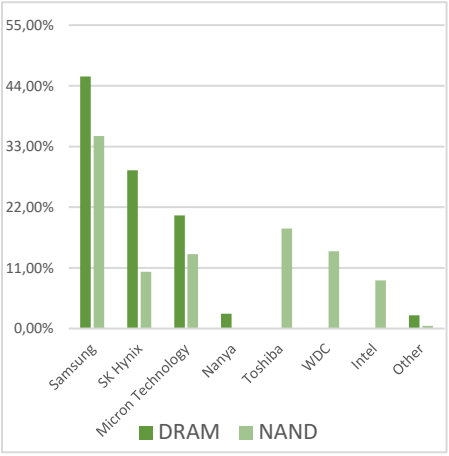
[4] The revenue potential can be read as a market share of all new potential markets in 2025:

$$Revenue\ Potential = \frac{Forecasted\ segment\ value\ 2025}{Total\ forecasted\ market\ value\ 2025}$$

[5] Measured by the CAPEX growth YoY

[6] SIATOTL index – which is a ASP index of all semiconductor products

Figure 22: Memory market shares

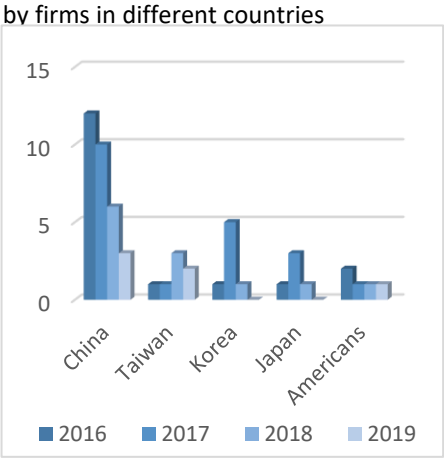


Source: *Statista, Author*

Figure 23: Chinese market revenue

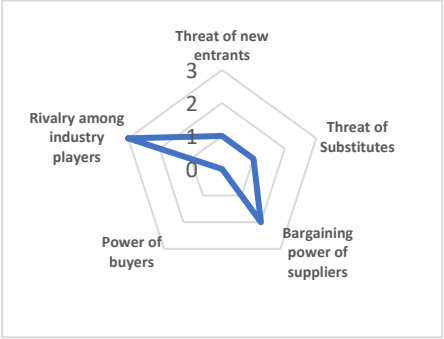
Source: *SEMI, Author*

Figure 24: Investment in new fabs by firms in different countries



Source: *SEMI, Author*

Figure 25: Porters Five Forces



Source: *Author*

the market has reached a new oversupply, which has caused the free fall of the average selling price. Most producers now decided to cut production. The average selling price of Micron's products fell by 20 percent QoQ. As a result, Micron has announced they will cut production by 5% for DRAM and NAND for 2019. Samsung and SK Hynix have also announced a production cut (they have not announced the reduction amount) to try to infuse a price increase.

Competitive positioning

Market positioning of firms

The memory market is a highly competitive oligopolistic market, which is defined by a few large firms with big market shares. However, the products are not differentiated resulting in a price war and competitive strategies based on game-theory. Samsung is the leading player in both DRAM and NAND, controlling over 30% of the market shares in both markets. SK Hynix and Micron is also big players in both markets, while the rest of the players are specialized in either one of the markets.

Chinese market impacts

The Chinese market accounted for **57%** of microns revenues in 2018 and had a 2Y CAGR of **81%**. The second biggest market was the US market, which accounted for 12% of the revenues in 2018 with a 2Y CAGR of **37%**. This proves how extremely important the Chinese market is for the memory industry. The market players face a significant risk of increased competition in the Chinese market. As a result of significant investments in the semiconductor industry by the Chinese government and various state owned or state affiliated firms that intends to advance in the Chinese market. The made in China 2025[7] plan sees the semiconductor industry as a key component. China has a target of producing **40%** of all semiconductors it uses by 2020, and further increase to 70% in 2025. The plan is backed by governmental initiatives including tens of billions of dollars in investments of the country's chip industry, as well as tax cuts for producers.

A strategic diversification away from commodities

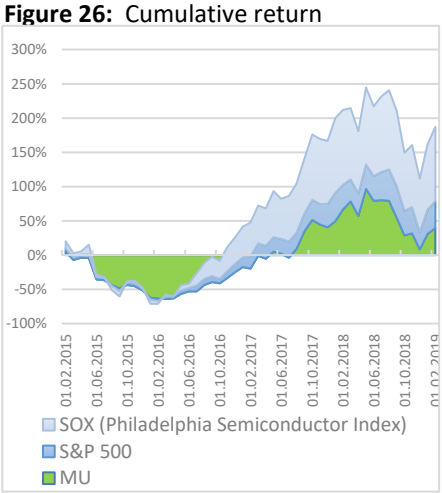
Microns major products are NAND and DRAM which both are categorized as commodities, where they have little to non-price influence. Micron have the possibility to switch capacity on production of the two by analyzing price projections to maximize revenue. To diversify away from the risk of having no other products to rely on in the case of price stagnation in both markets, Micron have had a joint venture with Intel to develop a new memory class product called 3D Xpoint. 3D Xpoint is a non-volatile memory and is characterized by massive in memory data base, fast system recovery, low latency and high endurance. The product has a write speed 1000 times faster than 3D NAND (10x faster according to reviews). The companies made clear in the Intel & Micron 3D Xpoint webcast that the product will not interfere with the 3D NAND roadmap, but target niche markets. The end user possibilities will be gaming, high fidelity pattern recognition and genomics which all require incredible high memory speed.

The cost of producing 3D Xpoint per GB is estimated to be between NAND and DRAM. The CEO of Micron explained in the webcast that the technology will have

[7] A governmental initiative which aims to boost the production of higher-value products in china until 2025.

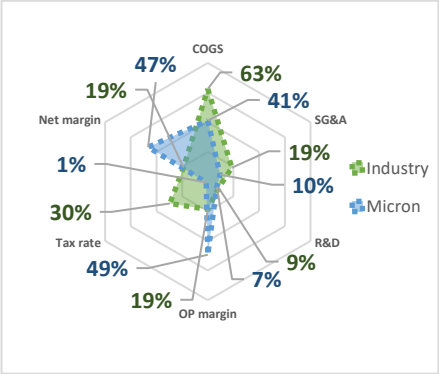
an aggressively scale ability which can give it cost advantages in the future. Market Research Future' have projected the technology to reach revenues of $5 billion in 2022 and is forecasted to have a CAGR of 13,7%.

Figure 26: Cumulative return



Source: *Yahoo finance, Author*

Figure 27: MU metrics VS Peers 2018



Source: *Bloomberg, Author*

Figure 28: DCF summary

EV	$	48 094,77
EV Explicit	*$*	*11 677,96*
EV Fade	*$*	*-1 035,97*
EV Terminal	*$*	*37 452,78*
Net debt	$	2 162,90
Equity value	$	45 931,87
Shares outstanding	$	1 110,00
Target price	$	41,38
Potential		24,19 %

Source: *Author estimates*

Investment summary

The issued recommendation for Micron Technology will be **buy** as a result of the DCF valuation resulting in a **price target of $41,38** and a **upside potential of 24,19%** with medium risk (see **appendix: 15** for investment risk reasoning). The evident start of a new bust-cycle and declining growth in familiar markets is reducing the upside potential for Micron technology. The introduction of 3D Xpoint and the uprising of the new tech markets combined with a better cost structure then its competitors support the evaluation of an upside potential.

The start of a new bust-cycle

The market has evidently started a new bust cycle with 2019 Q1 showing a decline of -6% in revenues Q/Q, Q2 with -26% decline Q/Q and Q3 with a -18% decline Q/Q. The bust cycle is forecasted to flatten out 2020 and go over to a positive growth in 2021. This is a result of the market starting to reduce capacity to shrink the oversupply of DRAM and NAND in the market.

Reducing capacity and cost yields

The cost structure of Micron is forecasted to increase as the capacity is reduced, which causes the "cost per GB of NAND and DRAM" to increase. The main cost driver COGS is forecasted an increase to 65% in 2019F and 68% in 2020F. The introduction of 3D Xpoint is also a factor which result is in a higher cost structure as it takes time to reach maturity yields for the product. The cost per GB of producing 3D Xpoint is estimated to be between DRAM and NAND[8] and will not change the cost structure dramatically. However, as the capacity is increased and 3D Xpoint reaches better cost yields COGS is estimated a decrease to 49% in 2021 and 55% in 2022.

A strong cash flow position should calm investors

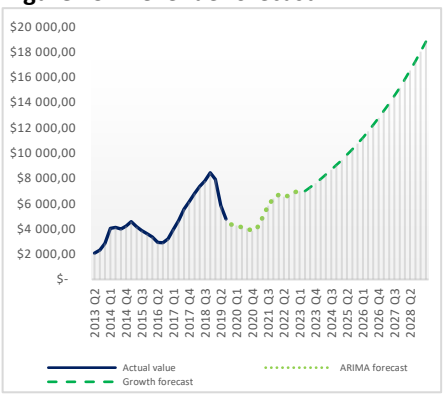
Even though costs are forecasted to increase, and revenues are in a steep decline Micron will still generate sufficient cash flows. Micron currently has a substantially lower cost structure then its competitors. Which results in a positive net income for 2019F, 2020F,2021F and 2022F. The recent years Micron went through a deleveraging process where they reduced their Debt/Equity ratio from 113% in 2017 to 30% in the end of 2018, which substantially decrease the risk arising from unsustainable debt levels. The accumulated FCFF to 2022F is estimated to $11,6 billion which is enough to complete the scheduled share repurchasing program of $10 Billion.

Valuation methods

The target price is calculated with a Discounted Cash Flow (DCF) valuation using the Free Cash Flow to the Firm (FCFF) method. The model computes the Enterprise Value EV) of the firm, which is subtracted from net debt to derive the Equity Value (EQV). The price target of $41,38 is the result from dividing the EQV by the shares outstanding. A complimentary valuation using multiple valuation by

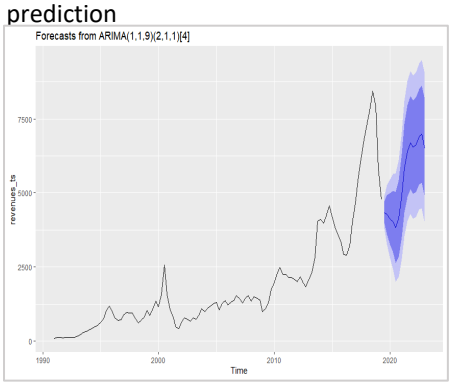
[8] Investor conference between Micron and Intel introducing 3D Xpoint.

Figure 29: Revenue forecast



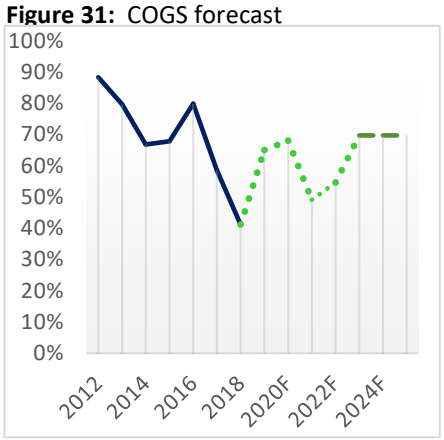
Source: *Author*

Figure 30: ARIMA revenue model prediction



Source: *Author, created in R*

Figure 31: COGS forecast



Source: *Author*

Figure 32: ARIMA COGS model prediction

Source: *Author, created in R*

assessing the P/E, EV/SALES, EV/EBITDA has also been used to investigate the result of the DCF method, resulting in an average target price of $34,10.

Investment risk

Investors should be aware of the high volatility in prices for DRAM and NAND which can substantially affect Microns earning potential. Micron also face regulative risk in their most important market, China. An elaborated risk analysis is detailed in the investment risk section as well as a risk evaluation of the DCF method using sensitivity analysis and a Monte Carlo simulation.

Valuation

The investment recommendation is based on a **DCF** model with **FCFF** as the discounted value. The EV-value of Micron is estimated to be $48,094 billion. Net debt 2019F is estimated to be $2,185billion resulting in an equity value of **$45,93 billion**. Estimated shares outstanding in 2019F is 1110 million shares, resulting in an estimated target price of **$41,38**.

The DCF model is differentiated into three different periods:

- 2019F-2022F: Explicit period (accounts for 24% of the price target)
- 2023F-2028F: Fade period (accounts for -2% of the price target)
- 2028F-Perpetuity: Terminal period (account for 78% of the price target)

The reasoning for using a three-stage model is to ensure credibility in the forecasts. The purpose of the explicit period is to forecast the future values with line-item accuracy. However, as forecasts become less accurate for each time step included, an explicit forecast will not be used after 2022F. The fade period is used to ensure the long-term behavior of the business is reflected in the model. At last a terminal period will be added, which represent all future values after 2028F.

Revenues 2019F-2028F

To predict the revenues for the explicit period the model will be using a time series forecast based on the historical data of the revenues. An ARIMA (1,1,9)(2,1,1) model is selected (See comprehensive revenue forecast document attached). The model has no lags outside the 95% confidence interval indicating it captures all information in the time series. The residuals are normally distributed and follows a white noise process. The model is consistent with the market research and predicts a CAGR (2019-2023) of **12%.** The 3D Xpoint revenues is forecasted using the average of two forecasts estimated by Hardy and Webb (see **Appendix 18:** Revenue forecast).

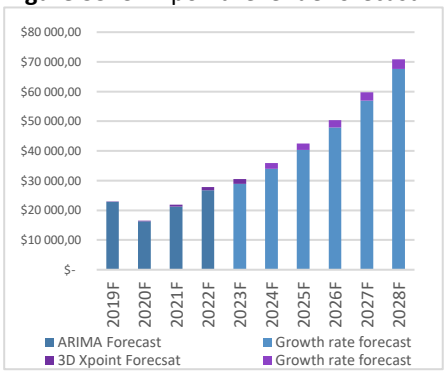
For the fade period a normalized quarterly growth rate of **4,40%** is applied. The normalized growth rate is the average growth rate between two cycles (2013-2019). The terminal growth rate is selected by using economic theory. Economist states to choose a rate between **4,5-5%**, which reflects the economic opportunity created from the combined effect of population growth, inflation and general productivity increase[9].

Cost of goods sold 2019F-2028F

The COGS is assumed to follow the time to maturity yield of new products and

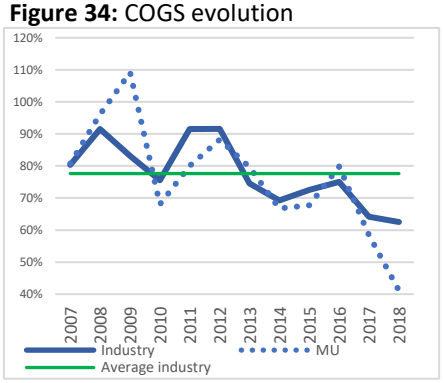
[9] Rees, M. *Financial modelling in practice.* Wiley, 2008.

Figure 33: 3D Xpoint revenue forecast



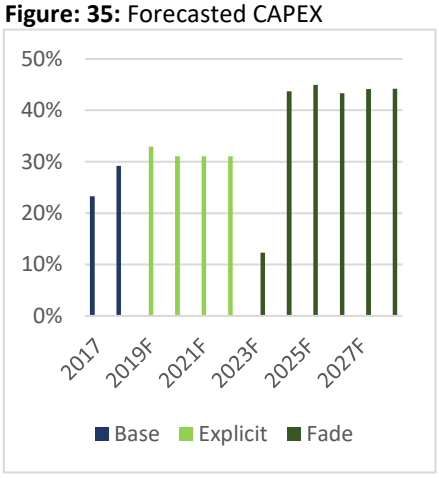
Source: *3D Xpoint: Hardy and Webb*

Figure 34: COGS evolution



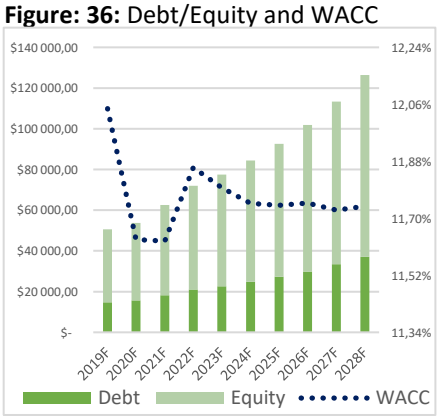
Source: *Bloomberg, Author*

Figure: 35: Forecasted CAPEX



Source: *Authors estimates*

Figure: 36: Debt/Equity and WACC



Source: *Authors estimates*

production capacity. Historically memory firms introduce a new memory chip with increased memory capacity every second year, following the principals of "Moors Law". The COGS for the explicit period are forecasting using a time series forecast. The model used is an ARIMA (2,1,0) model, which had the lowest AIC score of the candidate models. The model predicts an increase in cost for 2019F and 2020F which is consistent with the reduced production capacity and the introduction of the new 3D Xpoint chip. However, the COGS are assumed to decrease as the production ramp up and the products reach yield maturity.
After conducting an industry analysis (**Appendix: 9**), we can see that Micron has a cost advantage over the market. However, for the long-term assumption it is not reasonable to assume that Micron will manage to keep the cost advantage in perpetuity. By analyzing the historical COGS from the industry (**figure 34**) we can conclude that Micron goes over and under the industry in cycles. The model assumes that the COGS for Micron will tend to the normalized industry average of **70%**, which is estimated by taking the average of two full cycles (2013-2018).

Other relevant line-items

SG&A, R&D and other operating (income) or expense shows much less volatility based on historical data. Therefor it is assumed a direct correlation between revenues and the respective line-item. To forecast the future values the model applies the past 3Y average ratio and multiplies it with the forecasted revenue.

CAPEX (Explicit period) and D&A

For CAPEX 2019F Micron has estimated an expenditure of **$9billion.** The estimate includes the expenditures caused by 3D Xpoint, which the previously shared with Intel. To forecast the CAPEX for the explicit period a 2Y average of 2018 and 2019F is used to reflect the most recent capital structure of the firm. The rate is multiplied with the forecasted revenues. For D&A a 3Y average is used resulting in a depreciation rate of **22%** multiplied by the value of fixed assets.

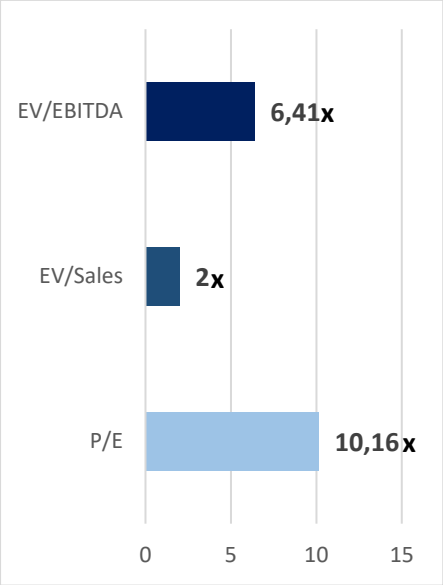
Weighted Average Cost of Capital

To discount the FCFF the WACC is used. The WACC shows small fluctuations YoY depending on several factors. For the cost of equity, the CAPM model has been used. The risk-free rate data is taken from Bloomberg the 02.08.2019 and is equivalent to a long-term governmental bond. The market risk premium is taken from Bloomberg the 02.08.2019 and is equivalent to the expected return of the US market, calculated by using a relevant market index. The beta is calculated by taking the unlevered beta of Microns peers and applying Microns debt structure and tax rate for each respective year. The cost of debt (**Appendix 10:** Debt Schedule) is calculated each year by forecasting the debt repayment of the current notes and loans. The debt/equity ratio is assumed constant and approximately equal to **42%**. The rate is determined by taking the average D/E ratio over the two last cycles (2013-2018).

Fade period

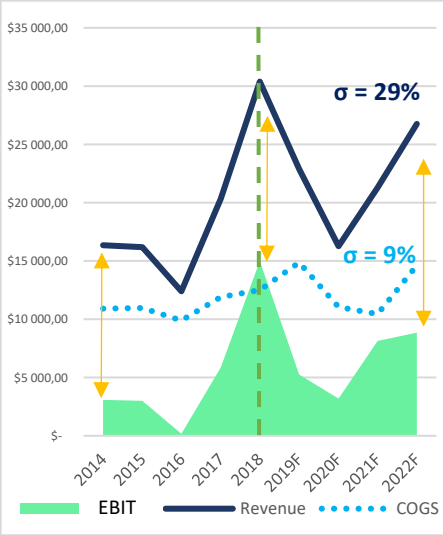
The furthermost important role of the fade period is to ensure that the return on capital employed converges to a reasonable level before a subsequent perpetuity formula is applied to the terminal value. This approach can help with a common problem in valuation models, which is to underestimate the capital expenditure requirements making the FCFF to high.

Figure: 37: Ratio multiples



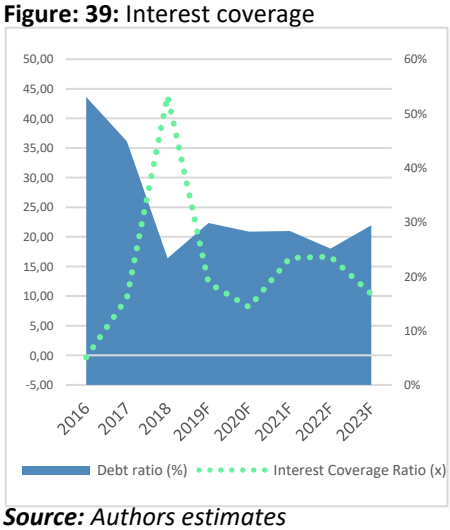
Source: *Authors estimates*

Figure: 38: Revenue volatility



Source: *Authors estimates*

Figure: 39: Interest coverage



Source: *Authors estimates*

To adjust the return-on-capital ratio we can either adjust the costs, so the profit level is set to an appropriate return on capital. However, the DCF model will use a capital base adjustment, which will keep more integrity in the IS, on the expense of a less realistic BS (See **Appendix 8:** ROCE analysis and adjustments)

The appropriate return-on capital at the end of the fade period will typically be some margins over the WACC, which mean that it still will be some positive economic profit. To adjust the capex-to-sales I have used solver, so the return-on-capital is adjusted to a desirable level. This model we will assume an economic profit of 1 % in perpetuity and converge to a ROCE of **12%** in the end of the fade period, which is the industry average over the two past cycles.

Screening process of peers

To better asses the credibility of the DCF valuation a multiple approach will be used to compare the result. The selection process of peers consists of 5 screening stages, where the initial group was selected using the market shares of the industry. Next the group will be evaluated by investigating the similarity of products, growth, capital structure and size. In the end the group consisted of 5 firms consistently displaying similarity in products, growth and capital expenditures (**Appendix 11:** Comparable companies).

Multiple valuation

The estimated price target using the multiple approach is **$34,10**, which supports the theory that Micron is undervalued. The price target is estimated using the EV/Sales (2,00x) and the EV/EBITDA (6,41x). The ratios measure the value of the firm using operational parameters. To account for the cyclical variability in sales and EBITDA the past 3Y average of the ratios have been used.

Financial analysis

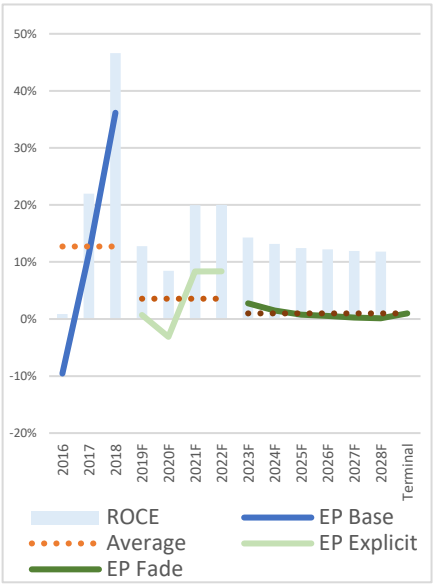
Revenues drives the variation in EBIT

The EBIT margin has grown rapidly from 2016 until 2018, before it is predicted to plummet in 2019F. The EBIT growth has mainly been driven by an increase in the ASP of DRAM and NAND sales volumes, following a boom cycle. The EBIT variation is closely correlated to the revenues and less effected by the costs. The cost structure of Micron exhibits less volatility compared to the volatility of the revenues. The EBIT is predicted to fall as the market is entering a bust-cycle and not increase again before the predicted revenue increase in 2021F. For the fade period the EBIT margin is predicted to be stable around 18-19% as a normalized growth rate is used to forecast the revenues.

Deleveraging before the bust cycle

In 2015 Micron finalized the acquisition of Inotera Memories by acquiring the rest of the outstanding shares, a transaction valued approximately $4billion. This substantially increased Micron debt levels. However, since 2015 Micron has used considerable amount of its cash to repay debt. The debt to equity reached 113% 2016 and ended at 30% in 2018. Micron is dependent on low debt levels as they now enter a new bust-cycle. To capitalize on new opportunities and to maintain the high capex investments Micron must be able to obtain capital from the capital markets at a reasonable rate. After the operational cash flows Micron is estimated to need additional $3,7billion in capital to maintain a positive cash flow. Microns debt levels are estimated to lower as the cycle are starting to turn in 2021F.

Figure: 40: Economic profit analysis



Source: *Authors estimates*

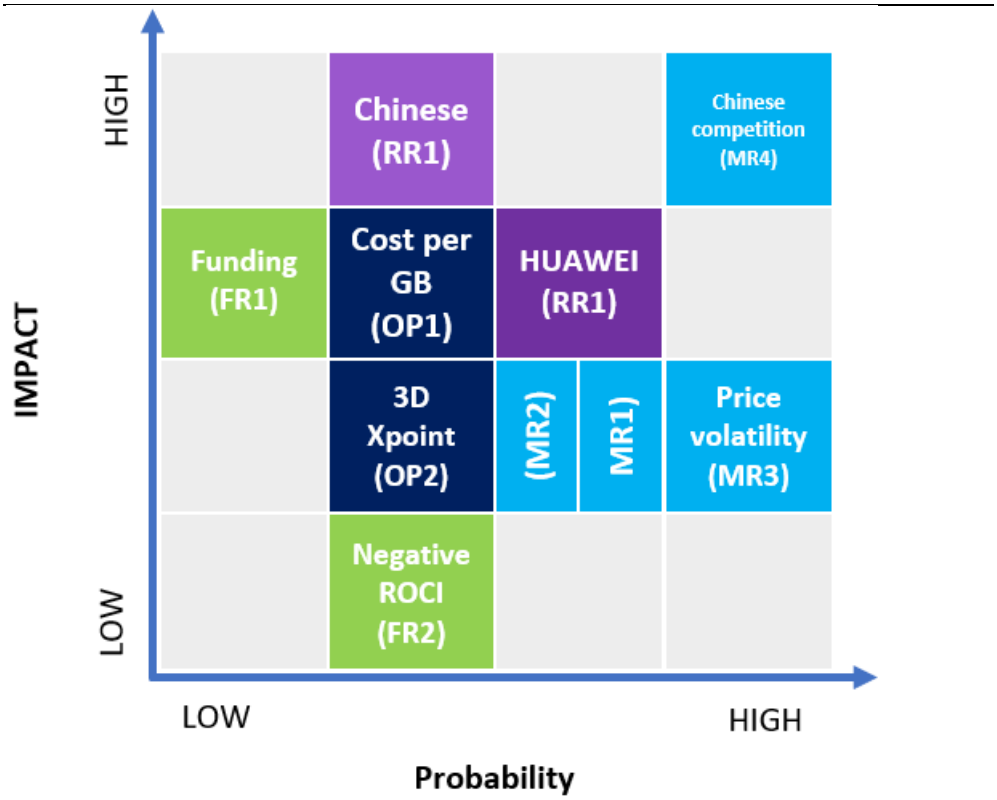
ROCE and Economic profit

Micron have generated a high return on its employed capital the recent years, combined with a moderate cost of capital the economic profit has averaged 13% for the base years 2016 to 2018. For 2019F the decrease in revenue combined with a growth in the capital expenditures lowers the ROCE, but as the ROCE is still higher than the WACC the economic profit will be positive. As for 2020F the capital employed is growing faster than the revenues. The result is a stagnation in ROCE combined with a flat WACC creates an economic loss. However, the economic profit is forecasted to increase again as the revenues increase in 2021F. For the fade period the economic profit averages 1%.

Strategic reward for shareholders

Micron is currently not paying dividends. However, In May 2018 the board of directors authorized and announced that Micron will initiate a stock repurchasing program, starting in 2019. The repurchasing program will aim to repurchase $10billion of outstanding common stock. A buyback fits Micron's business model better than dividends as it provides much more flexibility on the cash usage. From the forecast it is reasonable for Micron to reinvest the FCFF in the firm instead of a buyback in 2019F and continue the buyback plan in 2020F as the cash flows are increasing again. The forecasted cumulative FCFF for 2019F to 2022F is **$11,6 billion,** which is enough to complete the stock repurchasing program.

Investment risks



Operational risk | Unable to improve cost per GB(OP1)

Historically micron have regularly been able to improve their cost per GB by reducing costs and adding more capacity to the chips. Without improving cost per GB Micron will risk losing a significant portion of their operating margin. Micron have already stated a production cut which will affect the cost per GB.

Operational risk | A broader product portfolio (OP2)
Micron will introduce their 3D Xpoint product in 2019. This product class has only existed in the market 1 year through Intel's Optane chip. Intel has already achieved first move advantage and started to capture market shares in the niche. The operational margin will be affected by how the market receives the product and how well the product compares to Intel's Optane. The yield ramp will be slower since Micron don't have experience in scaling the product and the cost per GB will likely increase.

Market risk |Competitors resources (MR 1)
Some of Microns competitors are substantially larger corporations. Many of the competitors have larger resources to invest in technology, capitalize on fast immerging opportunities and withstand future bust cycles. Micron is specialized in the memory market, while most of the competitors are present in several markets within the semiconductor industry. This makes them able to switch capacity between different markets faster dependent on future earning potentials.

Market risk |Decline in familiar markets (MR 2)
Many of microns highest earning segments have declined in growth and future projections support the assumptions of a continuation in declined growth. If new emerging markets cannot generate enough demand to support a higher growth it can adversely affect Microns future revenue earnings.

Market risk |Price volatility (MR 3)
Micron and many of its competitors have the possibility to ramp up production which will have a considerable impact on supply. An increase in the world supply of memory and storage, if not followed by an equal increase in demand would cause a further decrease in the average selling price. A decrease in the ASP will adversely affect microns operating margins, results and financial condition.

Market risk |Chinese governmental market interference (MR 4)
Micron face the risk of increased competition because of the substantial investments by the Chinese government in the IC market. The result can further increase the market shares of Chinese firms in the Chinese market.

Financial risk | Sufficient cash flows for CAPEX (FR1)
The cash flows are primarily dependent on the volume of memory products sold, cost per GB and ASP. Any change in these factors can adversely affect the cash flow holdings. To improving production efficiency, process technology and support future growth opportunities Micron are dependent on heavily CAPEX investments with an estimated CAPEX of 2019 equal to $9 billion.

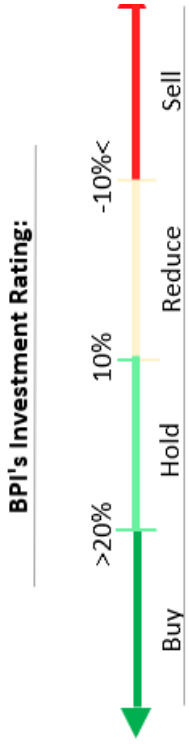
Financial risk |Negative return on capital investments (FR2)
Micron invest a substantial part of their cash flows in CAPEX. Investments in CAPEX may not generate expected returns or enough cash flows. Any delay in the plans of ramping up production or postponements in construction of new facilities will affect Micron's financial position.

Political Risk | Huawei (RR1)
On May 15th, 2019 the US government banned US entities from doing business with Huawei, a major electronics producer based in China. The ban resulted from the Chinese governmental involvement in the firm and claims of espionage. The ban has resulted in a $200 million loss in revenue for Micron, due to sale

restraints. Microns CEO stated in June: *"We determined that we could lawfully resume shipping a subset of current products because they are not subject to export administration regulations and entity list restrictions".* New York Times stated that Micron had found a way to bay pass the ban, because the ban applies to American-made products, where most of Microns products are made outside the US. However, Huawei is Microns top customer and the ban might substantially impact Huawei financial position which might again affect the volume of products purchased from Micron.[10]

Regulatory risk | **Chinese market restrictions (RR 1)**
Micron states in its 10-k report that it risks the Chinese government to implement regulations that can affect how much Micron can participate in the Chinese market. This might be implemented by the Chinese, so they accomplish their stated national policy objectives.

Figure: 41: Recommendation scale



Source: *Author*

Risks to price target

Terminal economic profit: The assumed terminal ROCE will significantly affect the price target. The evaluation changes to a hold recommendation if the economic profit in perpetuity is zero. However, if the economic profit falls under-1,5% the recommendation changes to sell. An economic profit between -1,5% and -0% will result in a reduce recommendation, while an economic profit between 0% and 1% will result in hold recommendation. An economic profit greater than 1% will result in a buy recommendation.

Table 3: Sensitivity evaluation of the terminal ROCE.

			Terminal ROCE		Δ =	1,00 %
9,60 %	10,60 %	11,60 %	12,6 %	13,60 %	14,60 %	15,60 %
-15,8 %	-2,5 %	10,9 %	24,2 %	37,5 %	50,8 %	64,2 %
			Economic profit			
-2,0 %	-1,0 %	0,0 %	1,0 %	2,0 %	3,0 %	4,0 %

Source: Authors estimates

Revenue growth rate and COGS: A 0,25% change in the revenue growth will result in an approximately 1,7% change in the potential. To change the recommendation to hold the revenue growth would have to decrease to 3,65%. For the recommendation to change to reduce the COGS would have to increase 7,07%. The COGS are very volatile and 7,07% is not unlikely to happen. From 2007 to 2018 Micron had a range of COGS from 41% to 109%.

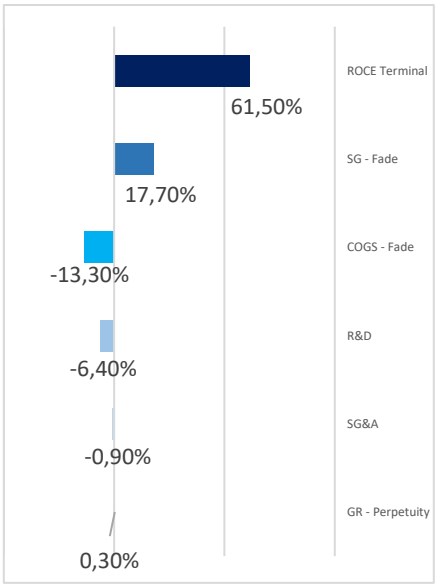
[10] Reuters, article: «Micron resumes some chip shipments to Huawei, boosting stock". Written by Sayanti Chakraborty and Stephen Nellis, June 25.

Table: 4: Sensitivity of revenue growth (fade) and COGS (fade)

		Revenue growth rate				Δ =		0,25 %
		5,15 %	4,90 %	4,65 %	4,40 %	4,15 %	3,90 %	3,65 %
3,70 %	58,57 %	68,4 %	65,4 %	62,4 %	59,5 %	56,8 %	54,1 %	51,5 %
	62,27 %	55,6 %	52,9 %	50,3 %	47,8 %	45,3 %	42,9 %	40,7 %
	65,97 %	42,8 %	40,5 %	38,2 %	36,0 %	33,8 %	31,8 %	29,8 %
Δ =	70 %	30,0 %	28,0 %	26,1 %	24,2 %	22,4 %	20,6 %	18,9 %
	73,37 %	17,2 %	15,6 %	14,0 %	12,4 %	10,9 %	9,5 %	8,1 %
	77,07 %	4,4 %	3,1 %	1,8 %	0,6 %	-0,6 %	-1,7 %	-2,8 %
COGS fade	80,77 %	-8,4 %	-9,4 %	-10,3 %	-11,2 %	-12,1 %	-12,9 %	-13,7 %
	84,47 %	-21,3 %	-21,9 %	-22,4 %	-23,0 %	-23,5 %	-24,1 %	-24,6 %

Source: Authors estimates

Figure: 42: Variable sensitivity

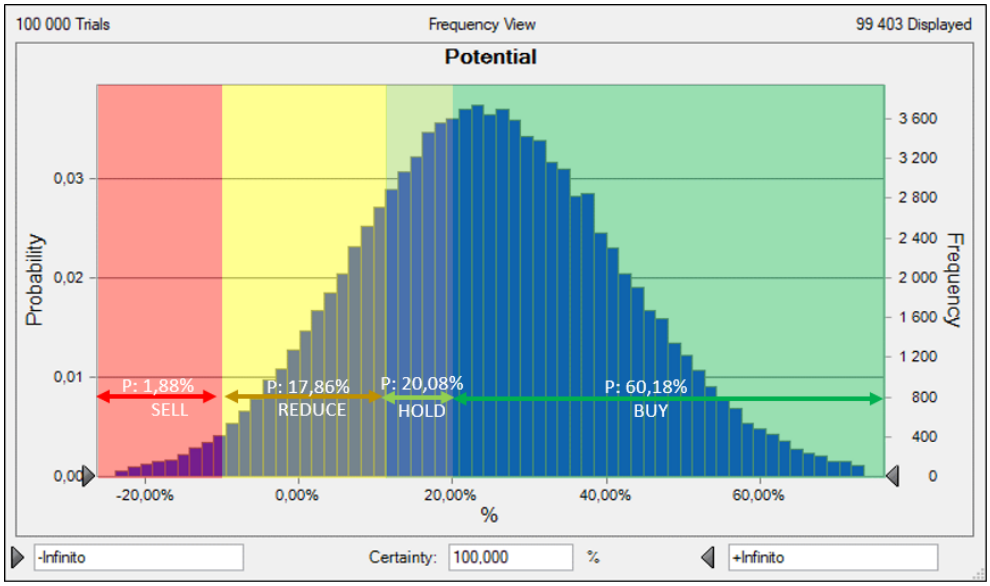


Source: Author

Monte Carlo simulation:

As complimentary analysis of the price target a Monte Carlo simulation was performed. The price target was the output while the inputs where: COGS – fade, Growth Rate (DRAM/NAND/Other), Growth Rate (Perpetuity), SG&A, R&D and ROCE terminal. As it is not one variable controlling the explicit sales it was not possible to model so it was excluded. All variables were assigned a normal distribution.

Table 5: Results Monte Carlo simulation



Source: Software – Oracle Crystal Ball

The Monte Carlo simulation was modelled using 100.000 iterations. The mean from the simulations is 24,81% with a standard deviation of 17,38%. The potential ranges from -48,94% to 104,67%. The simulation results in a 1,88% probability for sell, 17,86% probability for reduce, 20,08% probability for hold and a **60,18% probability for a buy recommendation**. The simulation strengthens the belief of a buy recommendation. The most sensitive variable was the ROCE terminal value which determines the economic profit in perpetuity. The sales growth (fade) and COGS (fade) all had sensitivity above 10%.

Micron as a portfolio asset

Figure: 43: Regression output

Regression Statistics MU	
Multiple R	0,397359
R Square	0,157895
Adjusted R Square	0,143121
Beta	1,706998
Standard Error	0,112071
Observations	59

Regression Statistics - GOOG	
Multiple R	0,504465
R Square	0,254485
Adjusted R Square	0,241406
Beta	0,995236
Standard Error	0,048427
Observations	59

Regression Statistics - APPL	
Multiple R	0,510239
R Square	0,260344
Adjusted R Square	0,247367
Beta	1,178033
Standard Error	0,05645
Observations	59

Source: Data: Yahoo finance
Regression: Author

Regression analysis
To obtain basic information about the stock performance of MU a time series regression has been used from May 2013 to May 2019. The stock has been regressed against the S&P 500, which is assumed to represent the US market. As comparison two of the biggest firms in the technology sector has been included (Apple, Inc. and Alphabet, Inc.).

Beta
From the regression analysis MU has a beta of 1,7 which means that the stock moves 1,7x the market, which is very volatile. In comparison Alphabet and Apple closely follow the market with a beta of 0,99x and 1,17x.

Alpha
All stocks outperformed the market index with an alpha > 0. However, the p-value of the regression is over 0,05 which indicates that the factor is not statistically relevant. Investors should investigate the alpha at different sites which quote risk factors related to stocks.

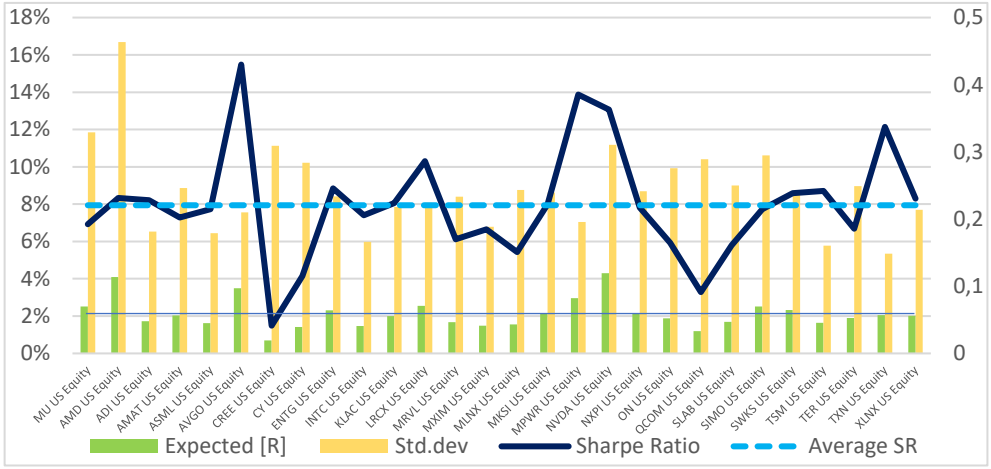
Market influence on the stock
The Micron stock has an R-squared of 0,15, indicating that only a small portion of the stock movement can be explained by market movement. This indicates a lot of risk as the stock movements is harder to predict based on the general market. This implies that the Micron would be hard to Beta-hedge as it would require constant re-balancing, resulting in **low beta hedging efficiency**. In comparison both Alphabet and Apple exhibits higher R-squared values of 0,24. Investors are recommended not to use the Micron stock for beta hedging.

Semiconductor portfolio construction

Selection of firms
The PHLX Semiconductor Sector Index (ticker: SOX) is a market capitalization-weighted index composed of 28 US firms. The firms are primarily involved with the design, distribution, manufacture and sale of semiconductors. The index is very useful for investors which seeks an investment object that fully covers the US semiconductor market. To construct a portfolio which covers the whole US semiconductor industry the SOX index will be decomposed.

Risk and reward

Figure 44: SOX index decomposition; Risk and return.



Source: *Data: Bloomberg, Graph: Author*

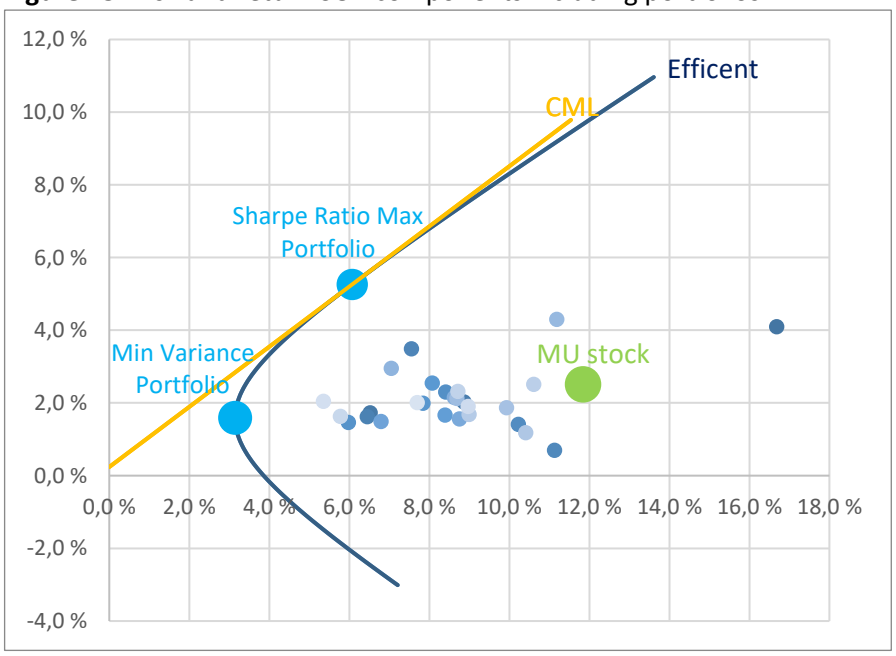
Micron has a favorable expected monthly return of 2,5% (5th highest) compared to the peer's average of 2,1%. However, the returns exhibit a lot of volatility with a std. dev of 12% (2nd highest), 310 basis points over the peer's average. The Sharpe Ratio has been applied to compare the risk over reward for the industry peers. The high volatility does not justify the return and Micron falls right under the industry average of 0,22.

Sharp ratio maximized- and volatility minimized portfolios

To verify weather Microns stock should be bought or sold two hypothetical portfolios will be constructed using Mean Variance Theory (MVT). The first portfolio will seek to create an asset of semiconductor firms in the US that maximize the return over risk, which will be quantified using the Sharpe Ratio. The second portfolio will aim to construct an asset that will cover all the US semiconductor firms, which minimizes the potential risk. The ratio used to quantify risk will be the std. dev of the portfolio.

Portfolio construction

Figure 45: Risk and return SOX components including portfolios.



Source: *Author*

As we can see from figure 45 the Micron stock (**R: 2,5%, σ=12%**) is one of the most volatile stocks. An investor which wish to hold a position in the semiconductor industry is recommended to include several assets as it would greatly reduce the unsystematic risk. By constructing a Minimum Variance Portfolio (MVP) (**R: 1,6%, σ=3,1%**) of all the SOX components an investor can reduce the risk with 8,9% (and give up 0,9% potential return), compared to solely investing in the Micron stock. An investor which seeks to maximize the return given the risk would be recommended to invest in a Sharpe Ratio Maximized Portfolio (SRMP) (**R: 5,3%, σ=6,3%)**. The SRMP asset increases the potential return with **3,1%,** while **simultaneously** reducing the risk with **5,7%** compared to solely investing in the Micron stock.

Both portfolios include a long position in the MU stock
Even though Microns stock exhibits a lot of risk, a big part of the risk can be diversified away due to the correlation between the SOX components. The MVP portfolio includes a 1% weighted long position in Micron. The SRMP includes a 5% weighted position in Micron (**see Appendix: 17** for full analysis).

Limitations of using Mean Variance Theory
The assumptions for using mean variance theory is limiting the use of the model. The model assumes that all returns are normally distributed, which is rarely the case. The model assumes that all expected returns, variances and covariances are known for all investors, which is unrealistic. The model also assumes that it is no transaction costs, which we know is not true. Small input errors can cause completely wrong calculations making the model likely to be estimation biased. An investor which use MVT to construct a portfolio will need to constantly rebalance the portfolio as new daily returns change the E[R], variance and covariances of the components.

Appendices

Appendix 1: Statement of Financial Position (Micron Technology)

BALANCE SHEET	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
IN MILLION $	Historical		Base year	EXPLICITT PERIODE				FADE PERIODE					
Total Fixed assets	$ 16 681,00	$ 22 879,00	$ 27 337,00	$ 30 449,15	$ 29 012,69	$ 29 900,36	$ 32 614,42	$ 28 998,85	$ 37 462,14	$ 47 372,00	$ 57 724,10	$ 70 155,00	$ 84 618,42
cash and equivalents	$ 4 140,00	$ 5 109,00	$ 6 506,00	$ 12 559,80	$ 19 230,41	$ 25 342,06	$ 30 136,81	$ 38 412,76	$ 35 073,90	$ 31 165,16	$ 27 500,56	$ 23 511,93	$ 18 430,86
Receivables	$ 2 068,00	$ 3 759,00	$ 5 478,00	$ 4 203,07	$ 3 022,54	$ 4 007,54	$ 5 083,02	$ 5 581,45	$ 6 550,84	$ 7 764,13	$ 9 203,00	$ 10 909,50	$ 12 933,55
Inventories	$ 2 889,00	$ 3 123,00	$ 3 595,00	$ 3 129,87	$ 2 250,77	$ 2 984,27	$ 3 785,13	$ 4 156,29	$ 4 878,16	$ 5 781,65	$ 6 853,12	$ 8 123,89	$ 9 631,12
Other current assets	$ 140,00	$ 147,00	$ 164,00	$ 124,20	$ 89,32	$ 118,43	$ 150,21	$ 164,94	$ 193,58	$ 229,44	$ 271,96	$ 322,39	$ 382,20
Short-term investments (balancing item)	$ 258,00	$ 296,00	$ 319,00	$ 179,75	$ 156,73	$ 181,65	$ 204,91	$ 215,69	$ 236,65	$ 262,88	$ 293,99	$ 330,89	$ 374,66
Total current assets	$ 9 495,00	$ 12 457,00	$ 16 039,00	$ 20 196,71	$ 24 749,77	$ 32 633,95	$ 39 360,07	$ 48 531,12	$ 46 933,13	$ 45 203,27	$ 44 122,63	$ 43 198,59	$ 41 752,38
Total assets	$ 27 540,00	$ 35 336,00	$ 43 376,00	$ 50 645,85	$ 53 762,46	$ 62 534,31	$ 71 974,49	$ 77 529,97	$ 84 395,27	$ 92 575,27	$ 101 846,73	$ 113 353,59	$ 126 370,80
Accounts payable and accrued expenses	$ 3 879,00	$ 3 664,00	$ 4 611,00	$ 5 062,93	$ 3 811,24	$ 3 644,51	$ 5 144,66	$ 7 209,58	$ 8 461,75	$ 10 028,97	$ 11 887,56	$ 14 091,85	$ 16 706,32
Deferred income	$ 200,00	$ 408,00	$ 284,00	$ 215,09	$ 154,67	$ 205,08	$ 260,12	$ 285,62	$ 335,23	$ 397,32	$ 470,95	$ 558,28	$ 661,86
Current debt	$ 756,00	$ 1 262,00	$ 859,00	$ 509,13	$ 326,20	$ 387,87	$ 196,49	$ -	$ -	$ -	$ -	$ -	$ -
Total current liabilities	$ 4 835,00	$ 5 334,00	$ 5 754,00	$ 5 787,14	$ 4 292,12	$ 4 237,46	$ 5 601,27	$ 7 495,20	$ 8 796,98	$ 10 426,28	$ 12 358,51	$ 14 650,13	$ 17 368,17
Long-term debt	$ 9 154,00	$ 9 872,00	$ 3 777,00	$ 8 354,56	$ 10 771,17	$ 13 420,32	$ 14 850,39	$ 14 597,87	$ 15 385,64	$ 16 293,86	$ 16 961,22	$ 18 256,54	$ 19 170,78
Other noncurrent liabilities	$ 623,00	$ 639,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00	$ 581,00
Total liabilities	$ 14 612,00	$ 15 845,00	$ 10 112,00	$ 14 722,70	$ 15 644,28	$ 18 238,78	$ 21 032,66	$ 22 674,07	$ 24 763,61	$ 27 301,15	$ 29 900,72	$ 33 487,67	$ 37 119,95
Redeemable convertible notes	$ -	$ 21,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00	$ 3,00
Redeemable noncontrolling interest	$ -	$ -	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00	$ 97,00
Common stock	$ 109,00	$ 112,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00	$ 117,00
Additional capital	$ 7 736,00	$ 8 287,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00	$ 8 201,00
Treasury Stock Starting	$ -1 029,00	$ -67,00	$ -429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00	$ -1 429,00
Retained earnings	$ 5 299,00	$ 10 260,00	$ 24 395,00	$ 28 054,15	$ 30 249,18	$ 36 426,53	$ 43 072,83	$ 46 986,89	$ 51 762,66	$ 57 405,12	$ 64 077,00	$ 71 996,92	$ 81 381,84
Accumulated other comprehensive income	$ -35,00	$ 29,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00	$ 10,00
Total Micron shareholders' equity	$ 12 080,00	$ 18 621,00	$ 32 294,00	$ 35 053,15	$ 37 248,18	$ 43 425,53	$ 50 071,83	$ 53 985,89	$ 58 761,66	$ 64 404,12	$ 71 076,00	$ 78 995,92	$ 88 380,84
Noncontrolling interests in subsidiaries	$ 848,00	$ 849,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00	$ 870,00
Total equity	$ 12 928,00	$ 19 470,00	$ 33 164,00	$ 35 923,15	$ 38 118,18	$ 44 295,53	$ 50 941,83	$ 54 855,89	$ 59 631,66	$ 65 274,12	$ 71 946,00	$ 79 865,92	$ 89 250,84
Total liabilities and equity	$ 27 540,00	$ 35 336,00	$ 43 376,00	$ 50 645,85	$ 53 762,46	$ 62 534,31	$ 71 974,49	$ 77 529,97	$ 84 395,27	$ 92 575,27	$ 101 846,73	$ 113 353,59	$ 126 370,80

BALANCE SHEET	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
IN % OF TOTAL ASSETS	Historical		Base year	EXPLICITT PERIODE				FADE PERIODE					
Total Fixed assets	61 %	65 %	63 %	60 %	54 %	48 %	45 %	37 %	44 %	51 %	57 %	62 %	67 %
cash and equivalents	15 %	14 %	15 %	25 %	36 %	41 %	42 %	50 %	42 %	34 %	27 %	21 %	15 %
Receivables	8 %	11 %	13 %	8 %	6 %	6 %	7 %	7 %	8 %	8 %	9 %	10 %	10 %
Inventories	10 %	9 %	8 %	6 %	4 %	5 %	5 %	5 %	6 %	6 %	7 %	7 %	8 %
Other current assets	1 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Short-term investments (balancing item)	1 %	1 %	1 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Total current assets	34 %	35 %	37 %	40 %	46 %	52 %	55 %	63 %	56 %	49 %	43 %	38 %	33 %
Total assets	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Accounts payable and accrued expenses	14 %	10 %	11 %	10 %	7 %	6 %	7 %	9 %	10 %	11 %	12 %	12 %	13 %
Deferred income	1 %	1 %	1 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	1 %
Current debt	3 %	4 %	2 %	1 %	1 %	1 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Total current liabilities	18 %	15 %	13 %	11 %	8 %	7 %	8 %	10 %	10 %	11 %	12 %	13 %	14 %
Long-term debt	33 %	28 %	9 %	16 %	20 %	21 %	21 %	19 %	18 %	18 %	17 %	16 %	15 %
Other noncurrent liabilities	2 %	2 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %	0 %
Total liabilities	53 %	45 %	23 %	29 %	29 %	29 %	29 %	29 %	29 %	29 %	29 %	30 %	29 %
Redeemable convertible notes	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Redeemable noncontrolling interest	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Common stock	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Additional capital	28 %	23 %	19 %	16 %	15 %	13 %	11 %	11 %	10 %	9 %	8 %	7 %	6 %
Treasury Stock Starting	-4 %	0 %	-1 %	-3 %	-3 %	-2 %	-2 %	-2 %	-2 %	-2 %	-1 %	-1 %	-1 %
Retained earnings	19 %	29 %	56 %	55 %	56 %	58 %	60 %	61 %	61 %	62 %	63 %	64 %	64 %
Accumulated other comprehensive income	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Total Micron shareholders' equity	44 %	53 %	74 %	69 %	69 %	69 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %
Noncontrolling interests in subsidiaries	3 %	2 %	2 %	2 %	2 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %
Total equity	47 %	55 %	76 %	71 %	71 %	71 %	71 %	71 %	71 %	71 %	71 %	70 %	71 %
Total liabilities and equity	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

Appendix 2: Income statement (Micron Technology)

INCOME STATEMENT	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F	2028F ->	CAGR	CAGR
IN MILLION $	Historical		BASE YEAR	EXPLICIT PERIOD				FADE PERIODE						Terminal value	2018-2022F	2022F-2028F
Net sales	**$12 399,00**	**$20 322,00**	**$30 391,00**	**$23 016,50**	**$16 551,76**	**$21 945,76**	**$27 835,18**	**$30 564,61**	**$35 873,12**	**$42 517,26**	**$50 396,66**	**$59 741,63**	**$70 825,53**	**$ 74 366,81**	**-2 %**	**17 %**
Cost of goods sold	$ 9 894,00	$11 886,00	$12 500,00	$14 953,82	$11 256,85	$10 764,39	$15 195,22	$21 294,15	$24 992,55	$29 621,46	$35 110,98	$41 621,56	$49 343,63	$ 51 810,82	**5 %**	**22 %**
Gross margin	**$ 2 505,00**	**$ 8 436,00**	**$17 891,00**	**$ 8 062,68**	**$ 5 294,91**	**$11 181,36**	**$12 639,95**	**$ 9 270,47**	**$10 880,58**	**$12 895,79**	**$15 285,67**	**$18 120,07**	**$21 481,90**	**$ 22 555,99**	**-8 %**	**9 %**
Selling, general and administrative	$ 659,00	$ 743,00	$ 813,00	$ 313,00	205,5520883	434,0685142	$ 490,69	$ 359,89	$ 422,39	$ 500,62	$ 593,40	$ 703,43	$ 833,94	875,6397407	**-12 %**	**9 %**
Research and development	$ 1 617,00	$ 1 824,00	$ 2 141,00	$ 2 436,00	$ 1 809,74	$ 2 332,27	$ 2 902,79	$ 3 167,20	$ 3 681,45	$ 4 325,08	$ 5 088,38	$ 5 993,65	$ 7 067,37	$ 7 410,42	**8 %**	**16 %**
Other operating (income) expense, net	$ 61,00	$ 1,00	$ -57,00	$ 23,73	$ 17,07	$ 22,63	$ 28,70	$ 31,52	$ 36,99	$ 43,84	$ 51,97	$ 61,60	$ 73,03	$ 76,68		**17 %**
Operating income	**$ 168,00**	**$ 5 868,00**	**$ 14 994,00**	**$ 5 289,95**	**$ 3 262,55**	**$ 8 392,39**	**$ 9 217,77**	**$ 5 711,87**	**$ 6 739,75**	**$ 8 026,25**	**$ 9 551,93**	**$ 11 361,39**	**$ 13 507,55**	**$ 14 193,25**	**-11 %**	**7 %**
Interest income	$ 42,00	$ 41,00	$ 120,00	$ 96,06	$ 185,44	$ 283,93	$ 374,16	$ 444,95	$ 567,14	$ 517,84	$ 460,13	$ 406,03	$ 347,14	$ 406,03	**33 %**	**-1 %**
Interest expense	$ -437,00	$ -601,00	$ -342,00	$ -402,00	$ -416,23	$ -521,09	$ -752,99	$ -734,66	$ -712,73	$ -751,20	$ -795,54	$ -828,12	$ -891,37	$ -828,12	**22 %**	**3 %**
Other non-operating income (expense)	$ -54,00	$ -112,00	$ -465,00	$ -352,17	$ -253,25	$ -335,78	$ -425,89	$ -467,66	$ -548,88	$ -650,54	$ -771,10	$ -914,08	$ -1 083,67	$ -1 137,86	**-2 %**	**17 %**
EBT	**$ -281,00**	**$ 5 196,00**	**$14 307,00**	**$ 4 631,84**	**$ 2 778,51**	**$ 7 819,44**	**$ 8 413,04**	**$ 4 954,50**	**$ 6 045,27**	**$ 7 142,35**	**$ 8 445,42**	**$10 025,21**	**$11 879,65**	**$ 12 633,30**	**-12 %**	**6 %**
Income tax provision	$ -19,00	$ -114,00	$ -168,00	$ -972,69	$ -583,49	$ -1 642,08	$ -1 766,74	$ -1 040,45	$ -1 269,51	$ -1 499,89	$ -1 773,54	$ -2 105,29	$ -2 494,73	$ -2 652,99		
Net income (- loss)	$ -275,00	$ 5 090,00	$ 14 138,00	$ 3 659,15	$ 2 195,02	$ 6 177,36	$ 6 646,30	$ 3 914,06	$ 4 775,77	$ 5 642,46	$ 6 671,88	$ 7 919,92	$ 9 384,92	$ 9 980,30	-17 %	6 %

INCOME STATEMENT	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F	2028F ->
IN % OF REVENUE	Historical		BASE YEAR	EXPLICIT PERIOD				FADE PERIODE						Terminal value
Net sales	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**
Cost of goods sold	80 %	58 %	41 %	65 %	68 %	49 %	55 %	70 %	70 %	70 %	70 %	70 %	70 %	70 %
Gross margin	**20 %**	**42 %**	**59 %**	**35 %**	**32 %**	**51 %**	**45 %**	**30 %**	**30 %**	**30 %**	**30 %**	**30 %**	**30 %**	**30 %**
Selling, general and administrative	5 %	4 %	3 %	1 %	1 %	2 %	2 %	1 %	1 %	1 %	1 %	1 %	1 %	1 %
Research and development	13 %	9 %	7 %	11 %	11 %	11 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %	10 %
Other operating (income) expense, net	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Operating income	**1 %**	**29 %**	**49 %**	**23 %**	**20 %**	**38 %**	**33 %**	**19 %**	**19 %**	**19 %**	**19 %**	**19 %**	**19 %**	**19 %**
Interest income	0 %	0 %	0 %	0 %	1 %	1 %	1 %	1 %	2 %	1 %	1 %	1 %	0 %	1 %
Interest expense	-4 %	-3 %	-1 %	-2 %	-3 %	-2 %	-3 %	-2 %	-2 %	-2 %	-2 %	-1 %	-1 %	-1 %
Other non-operating income (expense)	0 %	-1 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %	-2 %
EBT	**-2 %**	**26 %**	**47 %**	**20 %**	**17 %**	**36 %**	**30 %**	**16 %**	**17 %**	**17 %**	**17 %**	**17 %**	**17 %**	**17 %**
Income tax provision	0 %	-1 %	-1 %	-4 %	-4 %	-7 %	-6 %	-3 %	-4 %	-4 %	-4 %	-4 %	-4 %	-4 %
Net income (- loss)	**-2 %**	**25 %**	**47 %**	**16 %**	**13 %**	**28 %**	**24 %**	**13 %**	**13 %**	**13 %**	**13 %**	**13 %**	**13 %**	**13 %**

Appendix 3: Cash flow statement (Micron Technology)

Cash flow	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
IN MILLION $	Historical		BASE YEAR	EXPLICIT PERIOD				FADE PERIODE					
Net income (loss)	$ -275,00	$ 5 090,00	$ 14 138,00	$ 3 659,15	$ 2 195,02	$ 6 177,36	$ 6 646,30	$ 3 914,06	$ 4 775,77	$ 5 642,46	$ 6 671,88	$ 7 919,92	$ 9 384,92
Depreciation expense and amortization of intagble assets	$ 2 980,00	$ 3 861,00	$ 4 759,00	$ 6 006,87	$ 6 690,72	$ 6 375,08	$ 6 570,13	$ 7 166,50	$ 6 372,04	$ 8 231,71	$ 10 409,25	$ 12 683,96	$ 15 415,45
Change in operating assets and liabilities													
Receivables	$ 465,00	$ -1 651,00	$ -1 734,00	$ 1 274,93	$ 1 180,54	$ -985,01	$ -1 075,48	$ -498,43	$ -969,39	$ -1 213,29	$ -1 438,87	$ -1 706,50	$ -2 024,05
Inventories	$ -549,00	$ 50,00	$ -472,00	$ 465,13	$ 879,10	$ -733,50	$ -800,87	$ -371,16	$ -721,87	$ -903,49	$ -1 071,47	$ -1 270,76	$ -1 507,23
Accounts payable and accrued expenses	$ 272,00	$ 564,00	$ 549,00	$ 451,93	$ -1 251,69	$ -166,73	$ 1 500,15	$ 2 064,92	$ 1 252,17	$ 1 567,22	$ 1 858,59	$ 2 204,29	$ 2 614,47
Net cash provided by operating activities	$ 3 168,00	$ 8 153,00	$ 17 400,00	$ 11 858,01	$ 9 693,69	$ 10 667,21	$ 12 840,24	$ 12 275,89	$ 10 708,71	$ 13 324,60	$ 16 429,38	$ 19 830,90	$ 23 883,57
Expenditures for property, plant, and equipment	$ -5 817,00	$ -4 734,00	$ -8 879,00	$ -9 000,00	$ -5 142,49	$ -6 818,36	$ -8 648,15	$ -3 550,93	$ -14 835,33	$ -18 141,57	$ -20 761,34	$ -25 114,86	$ -29 878,87
Net cash provided by (used for) investing activites	$ -3 044,00	$ -7 537,00	$ -8 216,00	$ -9 000,00	$ -5 142,49	$ -6 818,36	$ -8 648,15	$ -3 550,93	$ -14 835,33	$ -18 141,57	$ -20 761,34	$ -25 114,86	$ -29 878,87
Repayments of debt	$ -870,00	$ -2 558,00	$ -10 194,00	$ -2 719,74	$ -3 285,54	$ -6 191,20	$ -15 568,44	$ -2 729,51	$ -2 206,84	$ -2 325,93	$ -2 463,23	$ -2 564,12	$ -2 759,94
Proceeds from issuance of stock	$ 48,00	$ 142,00	$ 1 655,00	$ -1 000,00									
Proceeds from issuance of debt	$ 2 199,00	$ 3 311,00	$ 1 009,00	$ 6 834,53	$ 5 404,95	$ 8 454,00	$ 16 171,10	$ 2 280,50	$ 2 994,60	$ 3 234,16	$ 3 130,59	$ 3 859,45	$ 3 674,18
Net cash provided by (used for) financing activities	$ 1 745,00	$ 349,00	$ -7 776,00	$ 3 114,79	$ 2 119,41	$ 2 262,80	$ 602,66	$ -449,01	$ 787,76	$ 908,23	$ 667,35	$ 1 295,33	$ 914,24
Net increase in cash, cash equivalents, restricted cash	$ 1 888,00	$ 953,00	$ 1 371,00	$ 5 972,80	$ 6 670,61	$ 6 111,65	$ 4 794,75	$ 8 275,95	$ -3 338,86	$ -3 908,74	$ -3 664,60	$ -3 988,63	$ -5 081,06
Cash, cash equivalents, and restricted cash at beginning of period	$ 2 375,00	$ 4 263,00	$ 5 216,00	$6 587,00	$12 559,80	$19 230,41	$25 342,06	$30 136,81	$38 412,76	$35 073,90	$31 165,16	$27 500,56	$23 511,93
Cash, cash equivalents, and restricted cash at end of period	$ 4 263,00	$ 5 216,00	$ 6 587,00	$ 12 559,80	$ 19 230,41	$ 25 342,06	$ 30 136,81	$ 38 412,76	$ 35 073,90	$ 31 165,16	$ 27 500,56	$ 23 511,93	$ 18 430,86

Cash flow	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
IN % OF CASH AND CASH EQUIVALENTS	Historical		BASE YEAR	EXPLICIT PERIOD				FADE PERIODE					
Net income (loss)	**-9 %**	**62 %**	**81 %**	**31 %**	**23 %**	**58 %**	**52 %**	**32 %**	**45 %**	**42 %**	**41 %**	**40 %**	**39 %**
Depreciation expense and amortization of intagble assets	94 %	47 %	27 %	51 %	69 %	60 %	51 %	58 %	60 %	62 %	63 %	64 %	65 %
Change in operating assets and liabilities													
Receivables	15 %	-20 %	-10 %	11 %	12 %	-9 %	-8 %	-4 %	-9 %	-9 %	-9 %	-9 %	-8 %
Inventories	-17 %	1 %	-3 %	4 %	9 %	-7 %	-6 %	-3 %	-7 %	-7 %	-7 %	-6 %	-6 %
Accounts payable and accrued expenses	9 %	7 %	3 %	4 %	-13 %	-2 %	12 %	17 %	12 %	12 %	11 %	11 %	11 %
Net cash provided by operating activities	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**
Expenditures for property, plant, and equipment	-184 %	-58 %	-51 %	-76 %	-53 %	-64 %	-67 %	-29 %	-139 %	-136 %	-126 %	-127 %	-125 %
Net cash provided by (used for) investing activites	**-96 %**	**-92 %**	**-47 %**	**-76 %**	**-53 %**	**-64 %**	**-67 %**	**-29 %**	**-139 %**	**-136 %**	**-126 %**	**-127 %**	**-125 %**
Repayments of debt	-27 %	-31 %	-59 %	-23 %	-34 %	-58 %	-121 %	-22 %	-21 %	-17 %	-15 %	-13 %	-12 %
Proceeds from issuance of stock	2 %	2 %	10 %	-8 %									
Proceeds from issuance of debt	69 %	41 %	6 %	58 %	56 %	79 %	126 %	19 %	28 %	24 %	19 %	19 %	15 %
Net cash provided by (used for) financing activities	**55 %**	**4 %**	**-45 %**	**26 %**	**22 %**	**21 %**	**5 %**	**-4 %**	**7 %**	**7 %**	**4 %**	**7 %**	**4 %**
Net increase in cash, cash equivalents, restricted cash	60 %	12 %	8 %	50 %	69 %	57 %	37 %	67 %	-31 %	-29 %	-22 %	-20 %	-21 %
Cash, cash equivalents, and restricted cash at beginning of period	75 %	52 %	30 %	56 %	130 %	180 %	197 %	245 %	359 %	263 %	190 %	139 %	98 %
Cash, cash equivalents, and restricted cash at end of period	**135 %**	**64 %**	**38 %**	**106 %**	**198 %**	**238 %**	**235 %**	**313 %**	**328 %**	**234 %**	**167 %**	**119 %**	**77 %**

Appendix 4: Key Financial Ratios (Micron Technology)

Key Financial Ratios	2016	2017	2018	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
Liquidity Ratios													
Current Ratio (x)	2,0	2,2	3,0	3,5	4,3	7,6	9,3	8,7	6,3	5,1	4,2	3,5	2,8
Quick Ratio (x)	0,9	1,0	1,3	2,2	3,4	6,0	7,2	6,9	4,7	3,6	2,7	2,0	1,3
Cash Ratio (x)	0,9	0,9	1,2	2,2	3,3	5,9	7,1	6,9	4,7	3,5	2,6	1,9	1,3
Efficiency Ratios													
Total Assets Turnover (x)	-	0,65	0,77	0,49	0,32	0,38	0,41	0,41	0,44	0,48	0,52	0,56	0,59
Accounts Receivables Turnover (x)	-	5,39	6,58	4,75	4,58	6,24	6,12	5,73	5,91	5,94	5,94	5,94	5,94
Collection Period (days)	-	67,77	55,47	76,76	79,67	58,46	59,60	63,68	61,72	61,45	61,44	61,44	61,44
Inventory Turnover (x)	-	6,76	9,05	6,85	6,15	8,38	8,22	7,70	7,94	7,98	7,98	7,98	7,98
Days in Inventory (days)	-	53,99	40,34	53,32	59,33	43,53	44,38	47,42	45,96	45,76	45,75	45,75	45,75
Payables Turnover (x)	-	3,15	3,02	3,09	2,54	2,89	3,46	3,45	3,19	3,20	3,20	3,20	3,20
Payables Period (days)	-	115,82	120,82	118,06	143,87	126,41	105,56	105,88	114,43	113,92	113,92	113,91	113,91
Operating Cycle (days)	-	121,76	95,81	130,08	139,00	102,00	103,99	111,09	107,68	107,20	107,20	107,19	107,19
Cash Cycle (days)	-	5,94	-25,00	12,02	-4,87	-24,41	-1,58	5,21	-6,75	-6,72	-6,72	-6,72	-6,72
Profitability Ratios													
Gross Profit Margin (%)	20,20 %	41,51 %	58,87 %	35,03 %	31,99 %	50,95 %	45,41 %	30,33 %	30,33 %	30,33 %	30,33 %	30,33 %	30,33 %
EBIT Margin (%)	1,35 %	28,88 %	49,34 %	22,98 %	19,71 %	38,24 %	33,12 %	18,69 %	18,79 %	18,88 %	18,95 %	19,02 %	19,07 %
Net Profit Margin (%)	-2,22 %	25,05 %	46,52 %	15,90 %	13,26 %	28,15 %	23,88 %	12,81 %	13,31 %	13,27 %	13,24 %	13,26 %	13,25 %
ROA (%)	-1 %	14 %	33 %	7 %	4 %	10 %	9 %	5 %	6 %	6 %	7 %	7 %	7 %
ROE (%)	-2 %	27 %	44 %	10 %	6 %	14 %	13 %	7 %	8 %	9 %	9 %	10 %	11 %
EPS				3,30	1,98	5,57	5,99	3,53	4,30	5,08	6,01	7,14	8,45
Solvency Ratios													
Debt ratio (%)	53 %	45 %	23 %	29 %	29 %	29 %	29 %	29 %	29 %	29 %	29 %	30 %	29 %
Long-term Debt Ratio (%)	33 %	28 %	9 %	16 %	20 %	21 %	21 %	19 %	18 %	18 %	17 %	16 %	15 %
Debt to Equity Ratio (x)	1,13	0,81	0,30	0,41	0,41	0,41	0,41	0,41	0,42	0,42	0,42	0,42	0,42
Equity Multiplier (x)	2,13	1,81	1,31	1,41	1,41	1,41	1,41	1,41	1,42	1,42	1,42	1,42	1,42
Debt to EBITDA	86,98	2,70	0,67	2,78	4,80	2,17	2,28	3,97	3,67	3,40	3,13	2,95	2,75
Interest Coverage Ratio (x)	-0,38	9,76	43,84	13,16	7,84	16,11	12,24	7,77	9,46	10,68	12,01	13,72	15,15
Credability of forecast check													
Fixed assets	$ 16 681,00	$ 22 879,00	$ 27 337,00	$ 30 449,15	$ 29 012,69	$ 29 900,36	$ 32 614,42	$ 28 998,85	$ 37 462,14	$ 47 372,00	$ 57 724,10	$ 70 155,00	$ 84 618,42
Operating working capital	$ 1 078,00	$ 3 218,00	$ 4 462,00	$ 2 270,01	$ 1 462,07	$ 3 347,30	$ 3 723,49	$ 2 528,16	$ 2 967,25	$ 3 516,82	$ 4 168,57	$ 4 941,54	$ 5 858,34
Operating Assets **(Capital employed)**		$ -2 140,00	$ -1 244,00	$ 2 191,99	$ 807,95	$ -1 885,23	$ -376,19	$ 1 195,33	$ -439,09	$ -549,57	$ -651,75	$ -772,97	$ -916,81
Sales/Operating assets **(Asset turnover)**	17759,00	26097,00	31799,00	32719,16	30474,76	33247,66	36337,91	31527,01	40429,39	50888,82	61892,66	75096,54	90476,76
Net Operating Profit After Tax **(NOPAT)**	$ 0,70	$ 0,78	$ 0,96	$ 0,70	$ 0,54	$ 0,66	$ 0,77	$ 0,97	$ 0,89	$ 0,84	$ 0,81	$ 0,80	$ 0,78
NOPAT/Capital employed **(ROCE)**	1 %	22 %	47 %	13 %	8 %	20 %	20 %	14,3 %	13,2 %	12,5 %	12,2 %	12,0 %	11,8 %
WACC	10 %	10 %	10 %	12 %	12 %	12 %	12 %	11,8 %	11,7 %	11,7 %	11,7 %	11,7 %	11,7 %
Economic profit	**-10 %**	**12 %**	**36 %**	**1 %**	**-3 %**	**8 %**	**8 %**	**2,5 %**	**1,4 %**	**0,7 %**	**0,4 %**	**0,2 %**	**0,1 %**

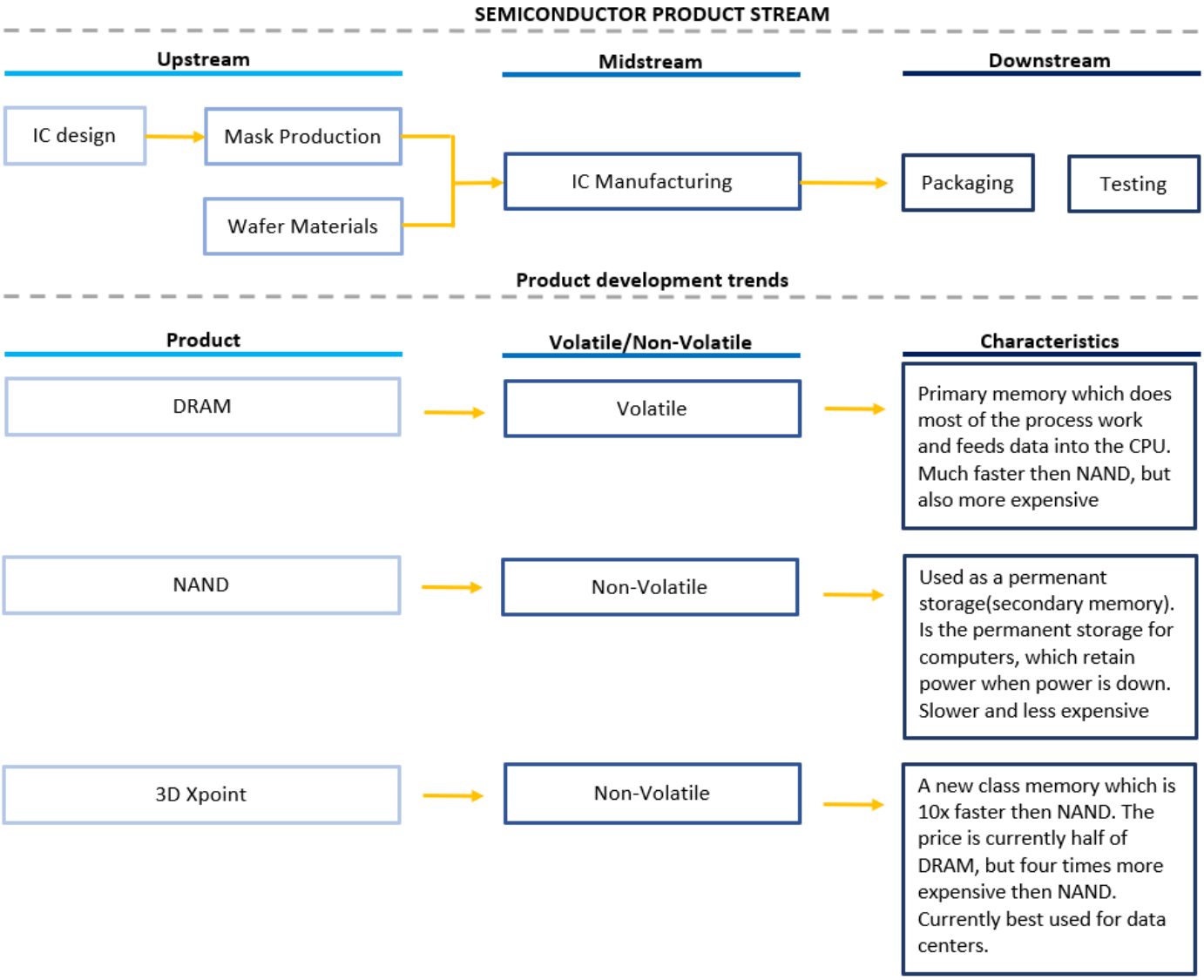
Appendix 5: Income statement assumptions

Income Statement - Assumptions						
Line item	**BASE VALUE**	**2019F 2020F 2021F 2022F** **EXPLICIT PERIOD**	**BASE VALUE**	**2023F 2024F 2025F 2026F 2027F 2028F** **FADE PERIODE**	**BASE VALUE**	**2028F ->** **Terminal value**
Net sales		See sales forecast support document	4,40 %	After the forecast of the explicit period its not possible to accurate predict the future revenues. So I assume the revenues will grow at the historical average growth rate from from 2013Q2-2019Q2	5 %	Economical theory states to choose a rate between 4.5% and 5%, which should reflect the economic oppertunity created from the combined effect of population growth, inflation and general productivity increase. Source: Financial Modelling in Practice By Michael Rees
COGS		See COGS forecast appendix	70 %	advantage over its competitors in longer period. Therefore, I assume the COGS for the fade period and terminal period will tend to the average COGS for the industry between two full cycles (2013-2018).	70 %	Assumed to follow the same cost relationship as the fade period.
SG&A	4 %	Assumed to follow the same cost structure as the present business model. Calculated as the average of the three past fiscal years.				
R&D	10 %	Assumed to follow the same cost structure as the present business model. Calculated as the average of the three past operating years + $206 Million. The R&D is also expexted to increase now that Micron buys out Intel of the IMFT joint venture where they shared R&D costs. On average Micron recieved $206Million the past three years from Intel, which they have to pay themself in the future for the devlopment of 3D Xpoint				
Other operating income	0,10 %	Assumed to follow the same cost structure as the present business model. Calculated as the average of the three past operating years.				
Interest income	1,5 %	Calculated the interest recieved the previous year on the cash holdings. On average Micron has recieved 1,5% interest on their cash holdings, which is the rate assumed for the future. The interest rate is calculated by multiplaying the interest rate with the starting balance of the cash&equivelent account the same fiscal year to aviod circular references.				
Interest expenses		See debt structure for calcuations	4,64 %	As the current credit facility agreement will be disolved in 2023. I assume all new debt will be aquired through a new loan agreement where the interest rate = average interest rate between 2019-2023(4,46%), with a term of 5 years.		
Non-operating income	-2 %	Assumed flat lined for every year.				
Tax rate	-21 %	The tax structure of micron is extremely complex due to operations in several countries with different tax policies where they have aquired tax benefits from different agreements. Micron does not disclose enough intormation to accurate calculate the real tax rate. I will assume a flat US corporate tax rate of 21%.				

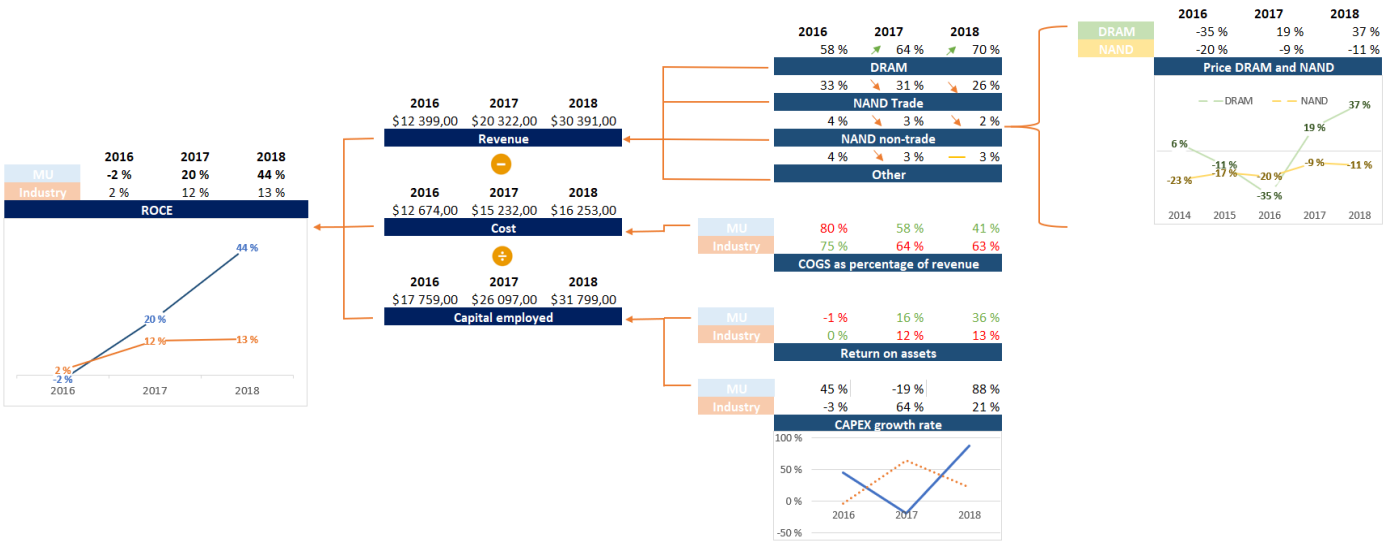
Appendix 6: Statement of Financial Position assumptions

Balance sheet - Assumptions			
Line item	BASE VALUE		Explanation
CAPEX-TO-SALES	31 %		Assumed to be the average between 2018-2019 for the explicit period. CAPEX for 2019 is already known, stated in the Q2 investor report. For the fade period capex-to-sales is used to adjust the economic profit and is found by using goal seek: Change economic profit to desired level by changing capex-to-sales
Depreciation	22 %		Assumed to be the average of 2016,2017 and 2018
Capital lease increase			From the debt structure
Recivables	66,65	Days	Assumed to be the average of 2017 and 2018. Calcuated using the beginning balance of recivables to aviod circular references
Inventory	49,63	Days	Assumed to be the average of 2017 and 2018. Calcuated using the beginning balance of inventory to aviod circular references
Other current assets			Assumed to follow the growth rate of revenues
Account payable	123,58	Days	Assumed to be the average of 2017 and 2018. Calcuated using the beginning balance of account payable to aviod circular references
Deferred income			Assumed to follow the growth rate of revenues
Current debt			Form the debt schedule
Long-term debt			Form the debt schedule
Other noncurrent liabilites	$ 581,00		Assumed straight lined
Redeemable convertible notes	$ 3,00		Assumed straight lined
Redeemable noncontrolling interest	$ 97,00		Assumed straight lined
Common stock	$ 117,00		Assumed straight lined
Additional capital	$ 8 201,00		Assumed straight lined
Treasuary stock	$ -1 000,00		Micron states in their 10-k report that they will initiate a stock repurchase plan to repurchase $10Billion worth of stocks, within 2023. For 2019F Micron has already stated they will repurchase $1 billion shares to the WASP of it stock between 04.08.2018-28.11.2018
Accumulated other comprehensive income	$ 10,00		Assumed straight lined
Noncontrolling interests in subsidiaries	$ 870,00		Assumed straight lined

Appendix 7: Semiconductor production group and memory products characteristics:



Appendix 8: ROCE analysis

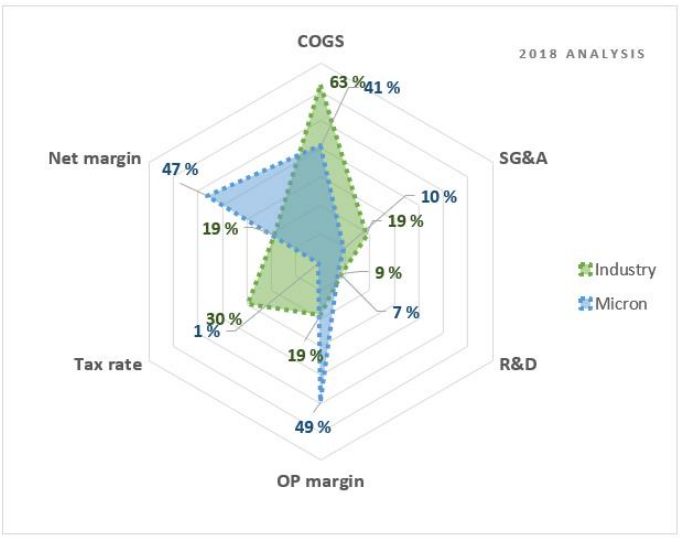


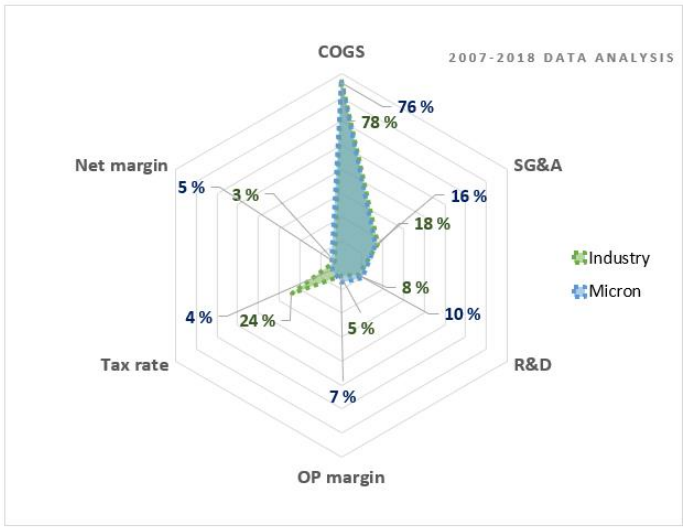
In the past Micron has achieved a considerable higher ROCE as its competitors. For 2017 and 2018 Micron realized a ROCE of 20% and 44%, while the industry on average realized 12% and 13%. The ROCE has been decomposed to identify efficiency drivers. The main ROCE drivers has been DRAM the past years. DRAM has gone from a revenue share of 58% in 2016 to 70% in 2018. The main reason is the increase in ASP for DRAM, while the ASP has stagnated for NAND. Micron also displays a better cost structure then the industry realizing a COGS/Revenue of 58% and 41% while the industry average was at 64% and 63% for 2017 and 2018. The capex declined in 2017 while heavily increasing again in 2018 as the industry peaked in the boom-cycle. Micron also managed to sustain a higher ROA for 2017 and 2018 compared to the industry.

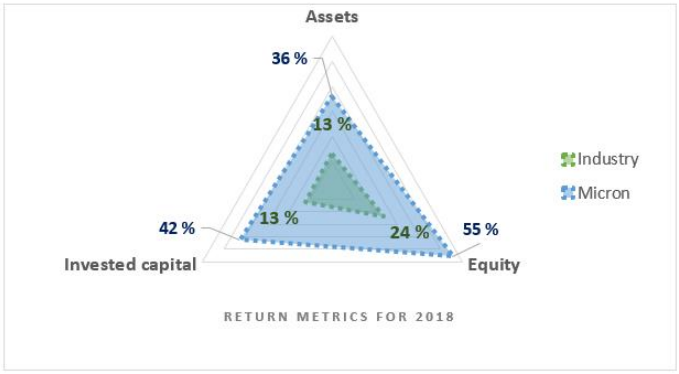
Capital employed model adjustments:

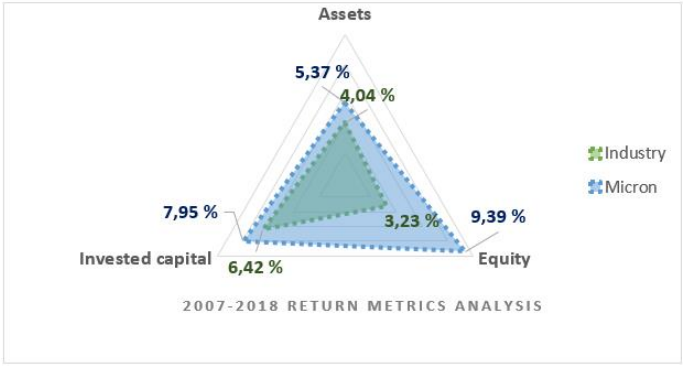
Capital employed/Working Capital is commonly calculated as **total assets – current liabilities**. The DCF model will use an adjusted capital employed = **Total fixed assets + Operating Working Capital**. Where operating working capital excludes non-operating items. The biggest effect of the adjustment will be the exclusion of Cash & Equivalents. The reasoning for excluding Cash & Equivalents is that the account is usually invested in fixed income products which results in a stable risk-free return. By excluding non-operating items in CE the ROCE will better reflect the return created by assets engaged in operating activities, which is the true value drivers of Micron. The implication of the adjustment is that the ROCE and in turn economic profit will be higher than if an investor used the non-adjusted working capital to calculate ROCE or economic profit. From the ratio analysis we can see that the economic profit for the fade period is positive, while the FCFF is negative. However, by using a non-adjusted ROCE the economic profit would also be negative. A positive implication is that model adjust the true value drivers of the company to a reasonable level.

Appendix 9: Metrics comparison between Micron and the memory market









Micron outperform the industry in most areas for 2018. However, by analyzing the data for a longer time horizon, Microns metrics are closely related to the industry averages. For 2018 micron exhibits a lower COGS, SG&A, R&D and tax rate relative to revenues. The COGS to revenue advantage can be influenced by Microns revenues which is more influenced by DRAM then other memory. Micron is also constantly improving the DRAM maturity yields, which mean that they reach cost optimization faster for each new product they start producing. Micron also used considerably less on SG&A then its competitors. For R&D Micron spent 7%, while the industry averaged at 9%. Intel and Micron had a strategic collaboration through IMFT to research and develop 3D Xpoint, resulting in R&D costs cut in half for 3D Xpoint.

For the period 2007-2018, Micron have had a slightly competitive advantage in the cost structure. Realizing a 2% advantage for COGS and SG&A compared to the rest of the industry players. Micron had an average of 10% in R&D, which is 2% over the industry average. One of the main targets of R&D expenses for Micron is to reduce the yield to maturity of new products. The higher R&D expenditures might be an explanation to why Micron today have a much better cost structure then the average.

For 2018, Microns return metrics is much better than the industry average. The ROE is 55%, which is exceptionally good considering the low leverage. Micron had leverage multiplier of 1,30x, while the industry had an average of 1,80x. By analyzing the time period 2007-2018, Microns return metrics are more related to the industry averages. However, micron still realizes a 1,52% higher return on invested capital, which is the most important factor considering the capital requirements in the industry.

Appendix 10: Debt schedule

Debt information		2018		2019		2020		2021		2022	
Loan type	Rate	Current	Long Term	Current	Long Term	Current	Long Term	Current	Long Term	Current	Long Term
IMFT memeber debt		$ -	$ 1 009,00	$ -	$ 1 009,00	$ -	$ 1 009,00	$ -	$ 1 009,00	$ -	$ 1 009,00
Capital lease obligations	3,86 %	$ 310,00	$ 535,00	$ 147,74	$ 662,13	$ 141,18	$ 632,72	$ 196,49	$ 880,62	$ 196,49	$ 1 320,16
MMJ creditor payments	9,76 %	$ 309,00	$ 183,00	$ 183,00	0						
2022 Term loan B	3,83 %	$ 5,00	$ 720,00	$ 178,39	$ 370,27	$ 185,02	$ 187,75	$ 191,38	$ -	$ -	$ -
2025 Notes	5,50 %	$ -	$ 515,00	$ -	$ -	$ -	$ -		$ -	$ -	$ -
2032D Notes	3,13 %	$ -	$ 132,00	$ -	$ 132,00	$ -	$ 132,00	$ -	$ 132,00	$ -	$ 132,00
2033F Notes	2,13 %	$ 235,00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2043G Notes	3 %	$ -	$ 682,00	$ -	$ 682,00	$ -	$ 682,00	$ -	$ 682,00	$ -	$ 682,00
Other notes	2,5 %	$ -	$ 1,00	$ -	$ 1,00	$ -	$ 1,00	$ -	$ 1,00	$ -	$ 1,00
New credit facility	Libor +1,25%-2%	$ -	$ -	$ -	$ 6 133,94	$ -	$ 7 583,08	$ -	$ 10 070,96	$ -	$ 7 867,91
Total		**$ 859,00**	**$ 3 777,00**	**$ 509,13**	**$ 8 990,33**	**$ 326,20**	**$ 10 227,54**	**$ 387,87**	**$ 12 775,58**	**$ 196,49**	**$ 11 012,06**
Total debt		**$ 4 636,00**		**$ 9 499,46**		**$ 10 553,74**		**$ 13 163,45**		**$ 11 208,56**	

The debt information is collected from the 10-k 2018 report, with the rate reflecting the effective rate for each instrument. The rest of the table shows the calculated balance for the current and long-term obligations for each loan during the explicit period. All new capital is assumed required through the new credit facility agreement which Micron entered in the end of 2018.

Assumptions for debt instruments:

2022 term loan		2025 Notes		2033F Notes		2043G Notes	
Principle	750	Principle	515	Principle	235	Principle	682
Interest	Libor + 1,75%	Interest	5,50 %	Interest	2,13 %	Interest	3,00 %
Paid	Quarterly	Paid	Semi annual	Paid	Semi annual	Paid	Semi annual
Terms	16	Maturity	01.02.2025	Maturity	01.02.2033	Maturity	01.11.2043
Assumed to continue until 2022 as an amortization loan with floating interest. LIBOR forwards used in calculation		Micron states in the 10-k report that they will payout these notes before 1.august.2019. (page 57)		The closing price of Microns common stock met the threshold for conversion and the 2033 Notes were convertible by their holders as of August 30, 2018 and		Assumed to continue during the forecast periode.	

Capital Lease Obligations		MMJ Creditor payments		New credit facility		Financing fade periode	
Principle	$ 845,00	Principle	$ 492,00	Principle	$ -	Principle	$ -
Interest	4,60 %	Interest	9,76 %	Interest	LIBOR + 1,5%	Interest	4,64 %
Paid	Anually	Paid	Installments	Paid	Quarterly	Paid	Yearly
Term	Weighted average 5year	Term		Terms	16	Term	5, rolled over each year
Maturity	Follow sales growth	Maturity		Maturity	2022F	Maturity	Continous
Growth	-	Growth		Growth			
weigthed average interest paid of 4,6% with a weigthed expected term of 5years		From the 10-k statement it follows that micron will pay the rest in two installments in 2019 and 2020.		New credit facility wich Micron entered into in the end of 2018. All new debt will be assumed to be aquired through this credit facility		From 2022F all debt will be assumed to be taken through a hypotetical credit facility. Interest rates = average interest rate paid 2019-2022F.	

Debt schedule explicit period snapshot:

DEBT SCHEDULE		2019Q1	2019Q2	2019Q3	2019Q4	2019 TOT	2020Q1	2020Q2	2020Q3	2020Q4	2020 TOT	2021Q1	2021Q2	2021Q3	2021Q4	2021 TOT	2022Q1	2022Q2	2022Q3	2022Q4	2022 TOT
2022 term loan	Term	1	2	3	4		5	6	7	8		9	10	11	12		13	14	15	16	
	Float interest	2,25 %	2,48 %	2,48 %	2,35 %		2,02 %	1,85 %	1,74 %	1,69 %		1,65 %	1,64 %	1,57 %	1,71 %		1,68 %	1,66 %	1,64 %	1,78 %	
	Fixed interest	1,75 %	1,75 %	1,75 %	1,75 %		1,75 %	1,75 %	1,75 %	1,75 %		1,75 %	1,75 %	1,75 %	1,75 %		1,75 %	1,75 %	1,75 %	1,75 %	
	Tot.Quarterly Int	**1,00 %**	**1,06 %**	**1,06 %**	**1,02 %**	**4,14 %**	**0,94 %**	**0,90 %**	**0,87 %**	**0,86 %**	**3,58 %**	**0,85 %**	**0,85 %**	**0,83 %**	**0,86 %**	**3,39 %**	**0,86 %**	**0,85 %**	**0,85 %**	**0,88 %**	**3,44 %**
	Beg. Outstanding	725	$ 682,99	$ 640,73	$ 598,02	$ 725,00	$ 554,78	$ 510,90	$ 466,51	$421,66	$ 554,78	$ 376,40	$ 330,73	$ 284,67	$ 238,20	$ 376,40	$ 191,38	$ 144,14	$ 96,50	$ 48,45	$ 191,38
	Interest paid	$ 7,24	$ 7,22	$ 6,77	$ 6,13	$ 27,36	$ 5,23	$ 4,60	$ 4,07	$ 3,63	$ 17,53	$ 3,20	$ 2,80	$ 2,36	$ 2,06	$ 10,42	$ 1,64	$ 1,23	$ 0,82	$ 0,43	$ 4,12
	Principle	$ 42,01	$ 42,26	$ 42,71	$ 43,24	$ 170,22	$ 43,88	$ 44,39	$ 44,85	$ 45,26	$ 178,39	$ 45,67	$ 46,06	$ 46,47	$ 46,82	$ 185,02	$ 47,23	$ 47,64	$ 48,05	$ 48,45	$ 191,38
	PMT	$ 49,26	$ 49,48	$ 49,48	$ 49,37	$ 197,58	$ 49,11	$ 48,99	$ 48,92	$ 48,89	$ 195,91	$ 48,86	$ 48,86	$ 48,83	$ 48,88	$ 195,44	$ 48,88	$ 48,87	$ 48,86	$ 48,88	$ 195,49
	End. Outstanding	**$ 675,74**	**$ 633,51**	**$ 591,25**	**$ 548,65**	**$ 548,65**	**$ 505,67**	**$ 461,91**	**$ 417,59**	**$372,77**	**$ 372,77**	**$ 327,53**	**$ 281,87**	**$ 235,84**	**$ 189,31**	**$ 189,31**	**$ 142,50**	**$ 95,27**	**$ 47,64**	$ -	$ -
2025 Notes	Beg.outstanding	$ 515,00																			
	Interest		$ 14,16		$ 14,16	$ 28,33															
	Principle				$ 515,00	$ 515,00															
	PMT					$ 543,33															
	End. Outstanding				$ -	$ -															
2032D Notes	Beg.outstanding	$ 132,00		$ 132,00		$ 132,00	$ 132,00		$ 132,00		$ 132,00	$ 132,00		$ 132,00		$ 132,00	$ 132,00		$ 132,00		$ 132,00
	Interest	$ 1,41		$ 1,41		$ 2,81	$ 1,41		$ 1,41		$ 2,81	$ 1,41		$ 1,41		$ 2,81	$ 1,41		$ 1,41		$ 2,81
	Principle					$ -					$ -					$ -					$ -
	PMT					$ 2,81					$ 2,81					$ 2,81					$ 2,81
	End. Outstanding	$ 132,00		$ 132,00		**$ 132,00**	$ 132,00		$ 132,00		**$ 132,00**	$ 132,00		$ 132,00		**$ 132,00**	$ 132,00		$ 132,00		**$ 132,00**

Debt schedule fade period:

In million $	2023F	2024F	2025F	2026F	2027F	2028F
Beg debt	$ 15 046,88	$ 14 597,87	$ 15 385,64	$ 16 293,86	$ 16 961,22	$ 18 256,54
Interest	$ 734,66	$ 712,73	$ 751,20	$ 795,54	$ 828,12	$ 891,37
Principle	$ 2 729,51	$ 2 206,84	$ 2 325,93	$ 2 463,23	$ 2 564,12	$ 2 759,94
New debt	$ 2 280,50	$ 2 994,60	$ 3 234,16	$ 3 130,59	$ 3 859,45	$ 3 674,18
PMT	$ 3 464,16	$ 2 919,57	$ 3 077,13	$ 3 258,77	$ 3 392,24	$ 3 651,31
End debt	**$ 14 597,87**	**$ 15 385,64**	**$ 16 293,86**	**$ 16 961,22**	**$ 18 256,54**	**$ 19 170,78**

Control of debt schedule:

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Debt repayment	$ 2 719,74	$ 3 285,54	$ 6 191,20	$ 15 568,44	$ 2 729,51	$ 2 206,84	$ 2 325,93	$ 2 463,23	$ 2 564,12	$ 2 759,94
Interest expense	$ 402,00	$ 416,23	$ 521,09	$ 752,99	$ 734,66	$ 712,73	$ 751,20	$ 795,54	$ 828,12	$ 891,37
PMT	$ 3 121,74	$ 3 701,76	$ 6 712,29	$ 16 321,43	$ 3 464,16	$ 2 919,57	$ 3 077,13	$ 3 258,77	$ 3 392,24	$ 3 651,31
Cost of debt	5,96 %	4,17 %	4,18 %	5,22 %	5,0 %	4,8 %	4,7 %	4,8 %	4,7 %	4,8 %
New debt	$ 6 834,53	$ 5 404,95	$ 8 454,00	$ 16 171,10	$ 2 280,50	$ 2 994,60	$ 3 234,16	$ 3 130,59	$ 3 859,45	$ 3 674,18
New Capital Lease	$ 119,02	$ 111,77	$ 444,39	$ 636,03	0	0	0	0	0	0
Total new debt	$ 6 953,55	$ 5 516,72	$ 8 898,39	$ 16 807,13	$ 2 280,50	$ 2 994,60	$ 3 234,16	$ 3 130,59	$ 3 859,45	$ 3 674,18
CONTROL										
Beginning debt	$ 4 636,00	$ 8 869,81	$ 11 101,00	$ 13 808,19	$ 15 046,88	$ 14 597,87	$ 15 385,64	$ 16 293,86	$ 16 961,22	$ 18 256,54
(-) Repayment	$ -2 719,74	$ -3 285,54	$ -6 191,20	$ -15 568,44	$ -2 729,51	$ -2 206,84	$ -2 325,93	$ -2 463,23	$ -2 564,12	$ -2 759,94
(+) total new debt	$ 6 953,55	$ 5 516,72	$ 8 898,39	$ 16 807,13	$ 2 280,50	$ 2 994,60	$ 3 234,16	$ 3 130,59	$ 3 859,45	$ 3 674,18
(=) Ending. Bal	$ 8 869,81	$ 11 101,00	$ 13 808,19	$ 15 046,88	$ 14 597,87	$ 15 385,64	$ 16 293,86	$ 16 961,22	$ 18 256,54	$ 19 170,78

Appendix 11: Comparable companies

Microns revenue is mostly driven by DRAM and NAND chips which account for 96% of the revenue. The rest of the revenue is shared by memory storage (memory cards and SSD) and advanced data solutions (3D xpoint). Therefore, DRAM and NAND producers will be used as comparable companies. The DRAM/NAND markets is an oligopoly consisting of few suppliers so the amount of comparable businesses is limited, which can make the analysis biased due to lack of comparable companies. However, since the industry is unique due to the immense capital requirement the use of an index would not be appropriate. The selection of peers will consist of a 5-stage screening process where the companies will be evaluated for: Industry, similar products, growth, capital expenditures and size.

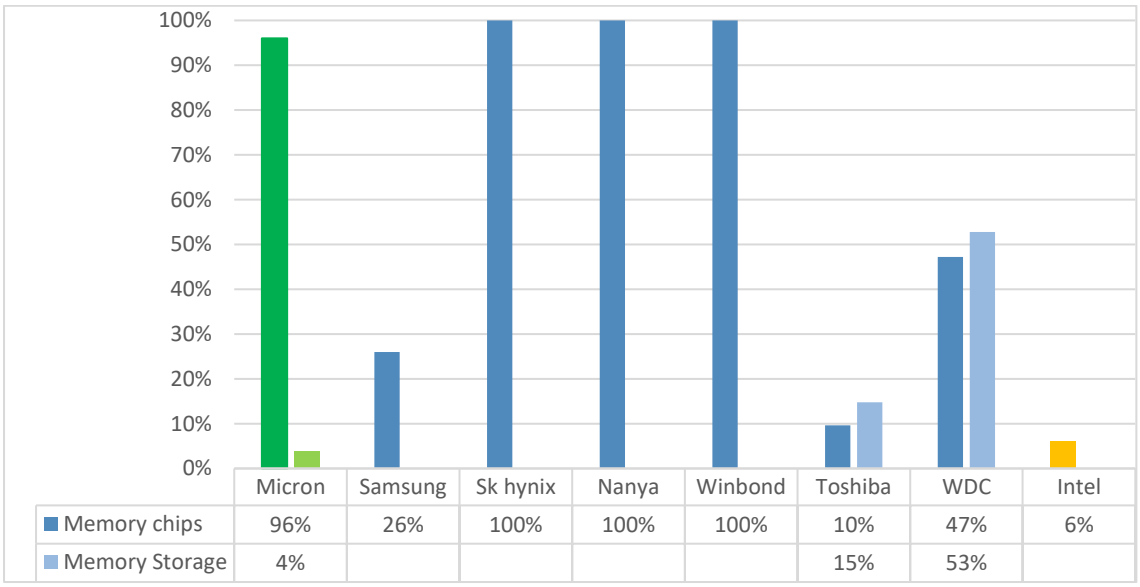
1st step: Selecting peers based on the DRAM/NAND industry

The peers selected for evaluation as peer is the all the firms with a market share in the DRAM/NAND markets (Figure 22 – competitive positioning). By participating in the DRAM/NAND market the firms should have relatively similar products and capital expenditures as Micron. The selected companies include Samsung (005930.KS), SK Hynix (000660.KS), Nanya (2408.TW), Winbond (2344.TW), Toshiba (TOSBF), WDC (WDC) and Intel (INTC).

2st step: Screening based on revenue generation

To check if the core business of the peer's match Microns business structure a product/revenue ratio is used. The threshold for deeper investigation is set at 20%.

- **Intel:** Intel only generate 6% of its revenue from memory chips, which may indicate that the core business does not match Micron. However, 100% of intel's revenue is from the semiconductor industry which share similar capital requirements and growth outlooks. Intel's revenue is more diversified in the industry where the main product is microprocessors which consist of a similar production process as DRAM and NAND. Intel will not be excluded after the 2nd screening.

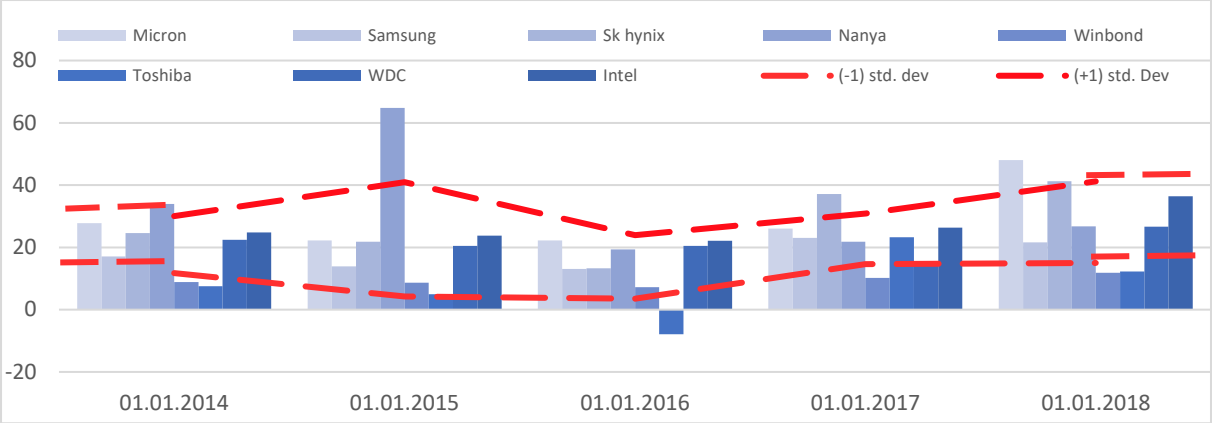


	Micron	Samsung	Sk hynix	Nanya	Winbond	Toshiba	WDC	Intel
Memory chips	96%	26%	100%	100%	100%	10%	47%	6%
Memory Storage	4%					15%	53%	

Source: *Data: Bloomberg, graph: Author.*

3rd step: Screening based on growth:

The ratio used to measure growth opportunity is past ROCE. The reasoning for choosing ROCE is that it also accounts for the capital efficiency, which is crucial for growth in the semiconductor industry. The analysis will consist of past historical data from 2014-2018 to measure consistency in ROCE, as the industry moves in cycles. To identify outliers the std. dev will be used to measure consistency, where each year consist of an average and +- 1 std. dev as inner and outer bounce.

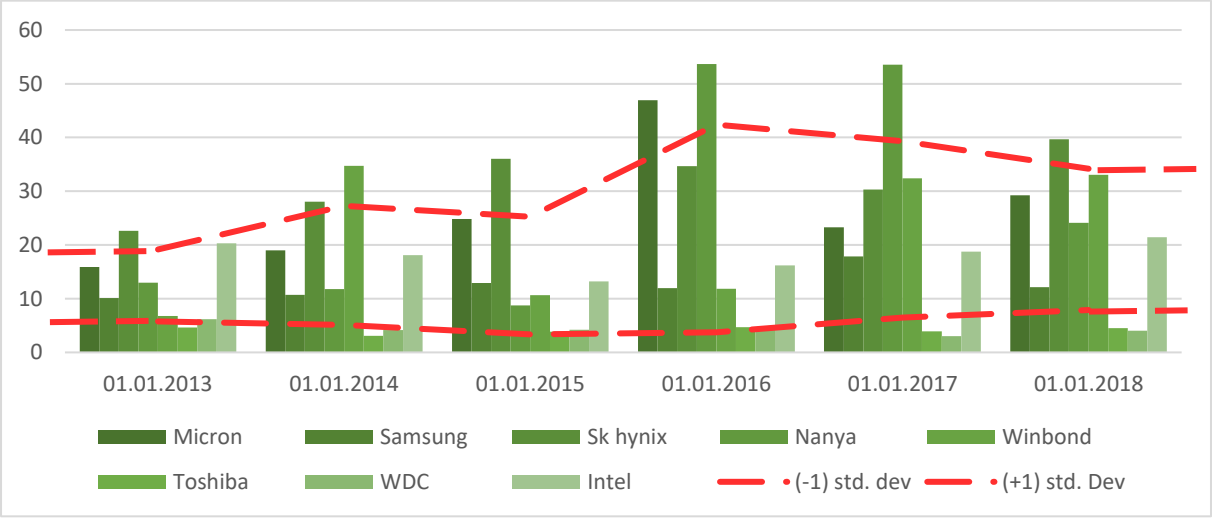


Source: *Data: Bloomberg, graph: Author.*

From the analysis **Winbond** and **Toshiba** is consistently out of the interval. **Toshiba** have a 3Y average ROCE of 9,23% and Winbond have a 3Y average ROCE of 9,73% while the peer average 3Y ROCE is 20%. Similar growth possibilities are one of the most important factors for evaluating businesses based on peers. However, the firms will still be included in the rest of the screening process.

4th step: Screening based capital expenditures:

One of the most important characteristics for the semiconductor industry is the extreme capital requirements. To be certain the peers consistently display the same capital structure as Micron the same methodology for the growth screening will be applied. Capex-to-sales will be the determining factor.



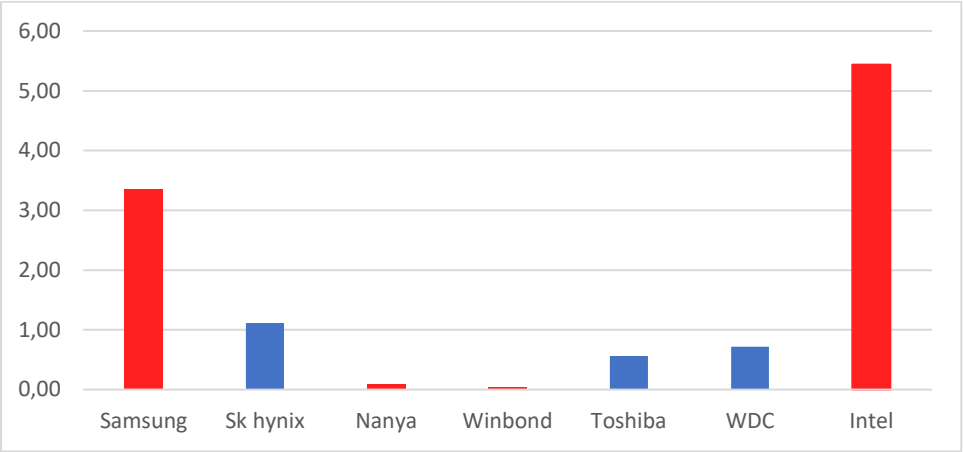
Source: *Data: Bloomberg, Source: Author*

Based on the analysis the consistent outliers are **Toshiba** and **Winbond**. **Toshiba** had an 3Y average capex-to-sales ratio of 4,39% and Winbond had an 3Y average of 3,86%, while the peers had an 3y average of 20,77%. The reason Toshiba and Winbond has a lower capex-to-sales is the strong diversification into memory storage segment which require lower capital expenditures then producing the memory chips. However, Micron is also involved in the memory storage segment and including a competitor from this segment would not be unreasonable.

5th step: Screening based on size:

A similar size support the credibility of the multiple valuation. Size influences revenues, growth opportunities and strategic decisions. The ratio used to evaluate the size of the firms is EV-peer/EV-Micron. The peers display a lot of variability regarding size compared to Micron. It would be impossible to disregard every peer that shows a significant size difference, due to the lack of similar peers. However, the size screening will be compared against the other screenings to see a broader picture. Samsung, Intel and Nanya is all significant different in size then Micron, but they

all produce similar products, display a reasonable growth rate and tends to have the same capital structure as Micron.



Source: *Data: Bloomberg, Graph: Author.*

Results peer selection:

The criteria for being selected as a peer is that the peer can pass 3 out of 5 screenings. The result of the screenings is represented below:

PEER selection									
	INDUSTRY		Similar products		Growth	Similar capital structure		Size	
	MS DRAM	MS NAND	Memory chips	Memory Stor	3Y average ROCE	Fabs	CAPEX to Sales	EV value	PEER
Micron	**21 %**	**14 %**	**96 %**	**4 %**	**32,09**	**16**	**29 %**	**40835,34**	
Samsung	46 %	35 %	26 %		19,25	11	13,98	3,35	YES
Sk hynix	29 %	10 %	100 %		30,53	12	34,87	1,11	YES
Nanya	3 %		100 %		22,63	3	43,76	0,09	YES
Winbond	3 %		100 %		9,73	4	25,77	0,04	NO
Toshiba		18 %	10 %	15 %	9,23	12	4,39	0,56	NO
WDC		14 %	47 %	53 %	20,45	1	3,86	0,72	YES
Intel		9 %	6 %		28,29	16	18,80	5,44	YES

Source: *Author.*

Appendix 12: Multiple valuation:

To value Microns target value through multiples three ratios have been considered: Price over earnings per share (**P/E**), enterprise value over sales (**EV/Sales**) and enterprise value over EBITDA(**EV/EBITDA**). The memory industry moves in cycles which must be accounted for when valuating using a multiple approach. In 2018 the industry reached the peak of a boom cycle resulting in record sales and EBITDA, which is reflected in the ratios selected. In the 2019F the industry is entering a bust cycle, which mean comparing the 2018 ratios with the forecasted 2019F values would result into a pessimistic valuation. To adjust the ratios the for cyclicality the ratios used in the calculations are estimated as an average of the three past years.

Ratio results

P/E		
Peer group	Value	2019F
Micron (EPS)		3,296536019
Samsung	8,631433333	28,45383088
Sk Hynix	6,159133333	20,30380488
Nanya	5,058066667	16,67409895
Winbond	11,59396667	Excluded peer
Toshiba	20,36403333	Excluded peer
WDC	16,56916667	54,62085471
Intel	14,3875	47,42891197
Average	10,16106	33,49630028
Median	8,631433333	28,45383088
Enterprise value		$ 35 018,00
Net debt		$ 2 162,90
Shares outstanding		1110
Stock price 30.05.2019		$ 33,32
Target price 2019F		$ 33,50
Downside potential		0,53 %

EV/Sales		
Peer group	Value	2019F
Micron (Sales)		23016,50277
Samsung	0,896233333	20628,157
Sk Hynix	1,540433333	35455,38809
Nanya	2,793133333	64288,16111
Winbond	1,2403	Excluded peer
Toshiba	0,4823	Excluded peer
WDC	1,599233333	36808,75845
Intel	3,190466667	73433,38487
Average	2,0039	46122,7699
Median	1,599233333	36808,75845
Enterprise value		$ 43 959,87
Net debt		$ 2 162,90
Shares outstanding		1110
Stock price 30.05.2019		$ 33,32
Target price 2019F		$ 39,60
Upside potential		18,86 %

EV/EBITDA		
Peer group	Value	2019F
Micron (EBITDA)		5289,951738
Samsung	2,720166667	14389,55038
Sk Hynix	2,725433333	14417,4108
Nanya	6,410233333	33909,82496
Winbond	4,683266667	Excluded peer
Toshiba	8,5518	Excluded peer
WDC	6,951266667	36771,86518
Intel	7,6446	40439,56505
Average	5,29034	27985,64328
Median	6,410233333	33909,82496
Enterprise value		$ 31 746,93
Net debt		$ 2 162,90
Shares outstanding		1110
Stock price 30.05.2019		$ 33,32
Target price 2019F		$ 28,60
Downside potential		-14,16 %

Summary

The P/E ratio is easy to read and simply shows the price divided by the earning per share and is commonly used in valuation. However, the P/E ratio is sensitive to the leverage of the company. In the memory industry firms show an extremely volatile debt structure, where they are more leveraged in bust-cycles and deleveraged in boom-cycles. Micron went from a D/E ratio of 113% to 30% in 2018. As a result, the P/E ratio will not be considered for the final price target.

EV/Sales and EV/EBITDA are operational ratios which compares operations result between firms and does not depend on the leverage. By applying the EV/Sales ratio the price target is estimated to be $39,60 with a upside potential of 18,86%. The sales are forecasted to decrease in 2019F, however by taking the average of the cycle the sales indicate a upside potential. Applying the EV/EBITDA ratio implies a price target of $28,60, which is a downside potential of -14,16%. The EV/EBITDA ratio also takes into account the operational costs, which is forecasted to increase during 2019F. The accumulated effect of decreased sales and higher operational costs indicates a downside potential.

The price target of Micron using the multiple approach will be **$34,10**, which is derived by taking the average of the EV/Sales- and EV/EBITDA ratio. The multiple valuation supports the DCF valuation that Micron is undervalued, however the analysis results in a reduce recommendation based on multiples.

Appendix 13: DCF assumptions

Valuation - Assumptions			
Line item	**BASE VALUE**		**Explanation**
Risk-free rate	2,02 %		The risk free rate is the hypotetical rate of return an investor can obtain without taking any risk. The rate used in valuations are usually the risk free rate of the governmental bond where the business operates in. The RF is obtained from bloomberg 2.08.2019
Expected market return	9,32 %		The expected market return is the return an investor can expect by investing in a market. The ususal rate in valuation is the return of an index which captures the biggest investment objects in the market. The expected retun is taken from
Terminal Growth rate	5,00 %		Many economist choose a figure between 4.5% and 5%, which should reflect the economic oppertunity created from the combined effect of population growth, inflation and general productivity increase. Source: Financial Modelling in
Unlevered industry beta	1,34076		The unlevered industry beta is estimated by unlevering the equity beta based on their capital structure. The unlevered industry beta is multiplied with the capital structure at Micron for each year to find the equity beta.
Terminal ROCE	12,60 %		See apendix for fade period
WACC terminal	11,6 %		WACC terminal is equal to the WACC calculated for 2028.
FCFF 2019			The model assumes linearity for the FCFF for 2019. Q4 is derived from 2019FCFF/4.

Unlevered beta calculations:

Industry Beta						
Company	Equity beta	Tax	Net debt	Equity	debt/equity	Unlevered beta
Samsung (KRW)	1,11	0,274936	-₩ 83 093 357 000,00	₩ 240 068 993 000,00	-35 %	1,48
SK hynix	1,04	0,271826	-₩ 3 088 142 000,00	₩ 46 845 719 000,00	-7 %	1,09
Intel (USD)	0,6	0,097097	$ 24 613 000,00	$ 74 563 000,00	33 %	0,46
WDC (USD)	1,95	0,676259	$ 7 066 000,00	$ 11 531 000,00	61 %	1,63
Micron (USD)	1,67	0,011743	$ -5 927 000,00	$ 32 294 000,00	-18 %	2,04
Industry beta	**1,274**				**0,06946054**	**1,34**

WACC calculations:

	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
Unlevered beta	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**	**1,34**
Tax	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*	*21 %*
Debt	*$ 15 358,48*	*$ 15 100,66*	*$ 17 594,04*	*$ 17 194,34*	*$ 23 120,08*	*$ 25 105,25*	*$ 27 552,51*	*$ 30 460,37*	*$ 33 919,68*	*$ 38 031,15*
Equity	*$ 35 030,66*	*$ 37 250,23*	*$ 43 442,75*	*$ 50 256,85*	*$ 54 298,10*	*$ 59 094,70*	*$ 64 762,36*	*$ 71 463,77*	*$ 79 407,14*	*$ 88 821,50*
Debt/Equity	*44 %*	*41 %*	*40 %*	*34 %*	*43 %*	*42 %*	*43 %*	*43 %*	*43 %*	*43 %*
Equity beta	**1,81**	**1,77**	**1,77**	**1,70**	**1,79**	**1,79**	**1,79**	**1,79**	**1,79**	**1,79**
Rf	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %	2,02 %
Market risk premium	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %	9,32 %
Cost of equity	**15,20 %**	**14,94 %**	**14,94 %**	**14,45 %**	**15,10 %**	**15,09 %**	**15,10 %**	**15,10 %**	**15,11 %**	**15,12 %**
Equity financing	70 %	72 %	72 %	75 %	70 %	70 %	70 %	70 %	70 %	70 %
Cost of debt	**6,09 %**	**3,93 %**	**4,16 %**	**4,36 %**	**3,96 %**	**4,53 %**	**4,52 %**	**4,50 %**	**4,49 %**	**4,47 %**
Debt financing	30 %	28 %	28 %	25 %	30 %	30 %	30 %	30 %	30 %	30 %
WACC	**12,09 %**	**11,58 %**	**11,63 %**	**11,68 %**	**11,56 %**	**11,70 %**	**11,69 %**	**11,68 %**	**11,68 %**	**11,67 %**
Quarterly Rate 2019 Q4:	**2,89 %**									

The WACC variation YoY is influenced by the different D/E and the cost of debt. See the debt schedule for computations regarding cost of debt. For 2019F a quarterly discount rate will be applied, since only 2019 Q4 needs to be discounted to the present value.

Appendix 14: DCF model

DCF Valuation

	30.05.2019 Q4F	31.08.2020F	31.08.2021F	31.08.2022F	31.08.2023F	31.08.2024F	31.08.2025F	31.08.2026F	31.08.2027F	31.08.2028F	Terminal value
NOPAT	$ 4 179,06	$ 2 577,41	$ 6 629,99	$ 7 282,04	$ 4 512,37	$ 5 324,40	$ 6 340,73	$ 7 546,02	$ 8 975,49	$ 10 670,97	
(+)Deprciation	$ 6 006,87	$ 6 690,72	$ 6 375,08	$ 6 570,13	$ 7 166,50	$ 6 372,04	$ 8 231,71	$ 10 409,25	$ 12 683,96	$ 15 415,45	
(-) CAPEX	$ -9 000,00	$ -5 142,49	$ -6 818,36	$ -8 648,15	$ -3 550,93	$ -14 835,33	$ -18 141,57	$ -20 761,34	$ -25 114,86	$ -29 878,87	
(+-)Change NWC	$ 2 140,00	$ 1 244,00	$ -2 191,99	$ -807,95	$ 1 885,23	$ 376,19	$ -1 195,33	$ 439,09	$ 549,57	$ 651,75	
FCFF	$ 831,48	$ 5 369,64	$ 3 994,73	$ 4 396,06	$ 10 013,18	$ -2 762,70	$ -4 764,46	$ -2 366,98	$ -2 905,83	$ -3 140,71	$ 104 555,18
Time factor	0,25	1,25	2,25	3,25	4,25	5,25	6,25	7,25	8,25	9,25	9,25
Discount factor	1,01	1,15	1,28	1,44	1,61	1,79	2,00	2,24	2,50	2,79	2,79
Present value	$ 825,59	$ 4 679,56	$ 3 118,86	$ 3 053,95	$ 6 233,62	$ -1 542,02	$ -2 380,55	$ -1 057,89	$ -1 164,10	$ -1 125,04	$ 37 452,78
Value in percentage	*2 %*	*10 %*	*6 %*	*6 %*	*13 %*	*-3 %*	*-5 %*	*-2 %*	*-2 %*	*-2 %*	*78 %*

EV	$	48 094,77
EV Explicit	$	*11 677,96*
EV Fade	$	*-1 035,97*
EV Terminal	$	*37 452,78*
Net debt	$	2 162,90
Equity value	$	45 931,87
Shares outstanding	$	1 110,00
Target price	$	41,38
Potential		24,19 %

Stock buyback			Terminal parameters		Model analysis	
Current	Share price 30.05.2019	33,32	Terminal ROCE	12,6 %	Cummulative FCFF until 2022F	$ 11 677,96
	Stocks outstanding 30.08.2018	1134	WACC	11,6 %	Target price - Explicit Weight	24 %
First buyback	Buyback financial intermediary	$ -1 000,00	Perpetuity g	5,0 %	Taget price - Fade Weight	-2 %
	WASP 05.09-29.11.2019	41,83126971			Target price - Terminal weight	78 %
	Number of stock bought	$ 24,00				

Appendix 15: Recommendation table

BPI's investment rating and risk classification

RISK	Buy	Hold	Reduce	Sell
Low risk	>15%	>5% and 15%<	> -10% and 5%<	< -10%
Medium	**>20%**	**>10% and 20%<**	**> -10% and 10%<**	**< -10%**
High	>30%	>15% and 30%<	> -10% and 15% <	< -10%

Source: BPI investment classification

The investment recommendation is based on BPI's investment rating and risk classification. The recommendation will vary depending on which scale the investor use to classify assets. This analysis of Micron classifies Micron as a medium risk based on several factors.

Fundamental factors:

The main revenue driver DRAM is very volatile. The ASP went from +6% in 2014 to -35% in 2016 to +36% in 2018, which is signs of a high-risk investment. However, Micron has a better cost structure combined with better return efficiencies then its competitors. Micron is also able to efficiently gear between leverage in different cycles, which makes them able to generate stable cash flows. The fundamental analysis tends towards a medium risk assessment.

Stock factors:

The stock has a high volatility compared with its peers in the SOX index. However, the stock also generates sufficient returns resulting in a Sharpe Ratio only slightly lower than the SOX average. From the regression analysis Micron has an alpha > 0, meaning that the stock has slightly overperformed over the market in the past. The risk rising from the volatility can be efficiently reduced by including Microns stock in a well-diversified portfolio (**see appendix: 17**). The risk assessment from the stock factors tends to a medium risk assessment.

Conclusion

The upside potential result from the DCF analysis results in a **Buy recommendation** as Micron is classified as medium risk. However, an investor should identify their own risk metrics and risk willingness to the assess the potential. An investor which classify Micron as high risk would change the recommendation to **hold,** based on BPI's recommendation scale**.**

Appendix 16: Sensitivity analysis

Risk free rate (RF) vs Expected Market Return:

Market return	Δ = 1,00 %	Risk free rate				Δ =		0,50 %
		0,52 %	1,02 %	1,52 %	2,02 %	2,52 %	3,02 %	3,52 %
	6,32 %	52,3 %	55,4 %	58,5 %	61,7 %	65,0 %	68,4 %	71,8 %
	7,32 %	39,4 %	42,1 %	44,9 %	47,8 %	50,7 %	53,7 %	56,8 %
	8,32 %	27,8 %	30,3 %	32,8 %	35,3 %	37,9 %	40,6 %	43,4 %
	9,32 %	17,5 %	19,7 %	21,9 %	24,2 %	26,5 %	28,9 %	31,4 %
	10,32 %	8,2 %	10,2 %	12,2 %	14,2 %	16,3 %	18,5 %	20,7 %
	11,32 %	-0,2 %	1,6 %	3,4 %	5,3 %	7,1 %	9,1 %	11,1 %
	12,32 %	-7,7 %	-6,1 %	-4,5 %	-2,8 %	-1,1 %	0,6 %	2,4 %
	13,32 %	-14,5 %	-13,0 %	-11,6 %	-10,1 %	-8,5 %	-7,0 %	-5,4 %

CAPEX-to-Sales vs Depreciation:

Depreciation	Δ = 6,00 %	CAPEX-TO-SALES - Explicit				Δ =		7,00 %
		9,55 %	16,55 %	23,55 %	31 %	37,55 %	44,55 %	51,55 %
	3,97 %	6,3 %	2,2 %	-2,0 %	-6,1 %	-10,2 %	-14,3 %	-18,4 %
	9,97 %	16,9 %	13,2 %	9,5 %	5,9 %	2,2 %	-1,5 %	-5,2 %
	15,97 %	25,8 %	22,5 %	19,2 %	15,9 %	12,6 %	9,4 %	6,1 %
	22 %	33,2 %	30,3 %	27,3 %	24,4 %	21,5 %	18,5 %	15,6 %
	27,97 %	39,5 %	36,9 %	34,3 %	31,6 %	29,0 %	26,4 %	23,7 %
	33,97 %	44,9 %	42,5 %	40,2 %	37,8 %	35,4 %	33,1 %	30,7 %
	39,97 %	49,6 %	47,4 %	45,3 %	43,2 %	41,0 %	38,9 %	36,8 %
	45,97 %	53,7 %	51,7 %	49,8 %	47,9 %	45,9 %	44,0 %	42,0 %

Terminal growth vs Terminal WACC:

Change in WACC	Δ = 1,00 %	Change in terminal growth rate				Δ =		1,00 %
		2,00 %	3,00 %	4,00 %	5,00 %	6,00 %	7,00 %	8,00 %
	14,6 %	-7,5 %	-7,5 %	-7,5 %	-7,5 %	-7,5 %	-7,5 %	-7,5 %
	13,6 %	0,6 %	0,6 %	0,6 %	0,6 %	0,6 %	0,6 %	0,6 %
	12,6 %	10,8 %	10,8 %	10,8 %	10,8 %	10,8 %	10,8 %	10,8 %
	11,6 %	24,2 %	24,2 %	24,2 %	24,2 %	24,2 %	24,2 %	24,2 %
	10,6 %	42,3 %	42,3 %	42,3 %	42,3 %	42,3 %	42,3 %	42,3 %
	9,6 %	68,4 %	68,4 %	68,4 %	68,4 %	68,4 %	68,4 %	68,4 %
	8,6 %	109,1 %	109,1 %	109,1 %	109,1 %	109,1 %	109,1 %	109,1 %
	7,6 %	181,4 %	181,4 %	181,4 %	181,4 %	181,4 %	181,4 %	181,4 %

Appendix 17: Porters five forces

Threat of new entrants: Low

The threats of new entrants in the market is extremely low because of the intense CAPEX requirement to operate in the industry. The average CAPEX for firms in the memory industry in 2018 were $4,4 billion including non-fab firms. However, it exists firms in the semiconductor which operates “fab-less”, meaning they outsource the production or focus strictly on R&D. This will radically reduce the capex exposure. But there are no fab-less firms in the memory market, and it is highly unlikely to occur. The biggest threat of new entrants in the memory market is if one of the already existing semiconductor producers decides to enter the memory market. These firms will already have facilities and experience in producing chips, which makes it easier to enter the market.

Threat of Substitutes: Low

There is no immediate available substitute for DRAM or NAND. However, there is new emerging memory products like: 3D Xpoint, MRAM, ReRAM Etc. Which can act as a substitute for traditional memory. But the process of making new memory products is slow and it allows competitors time to closely monitor the evolution, and continuously assess if they want to invest in the technology as well.

Bargaining power of suppliers: Moderate

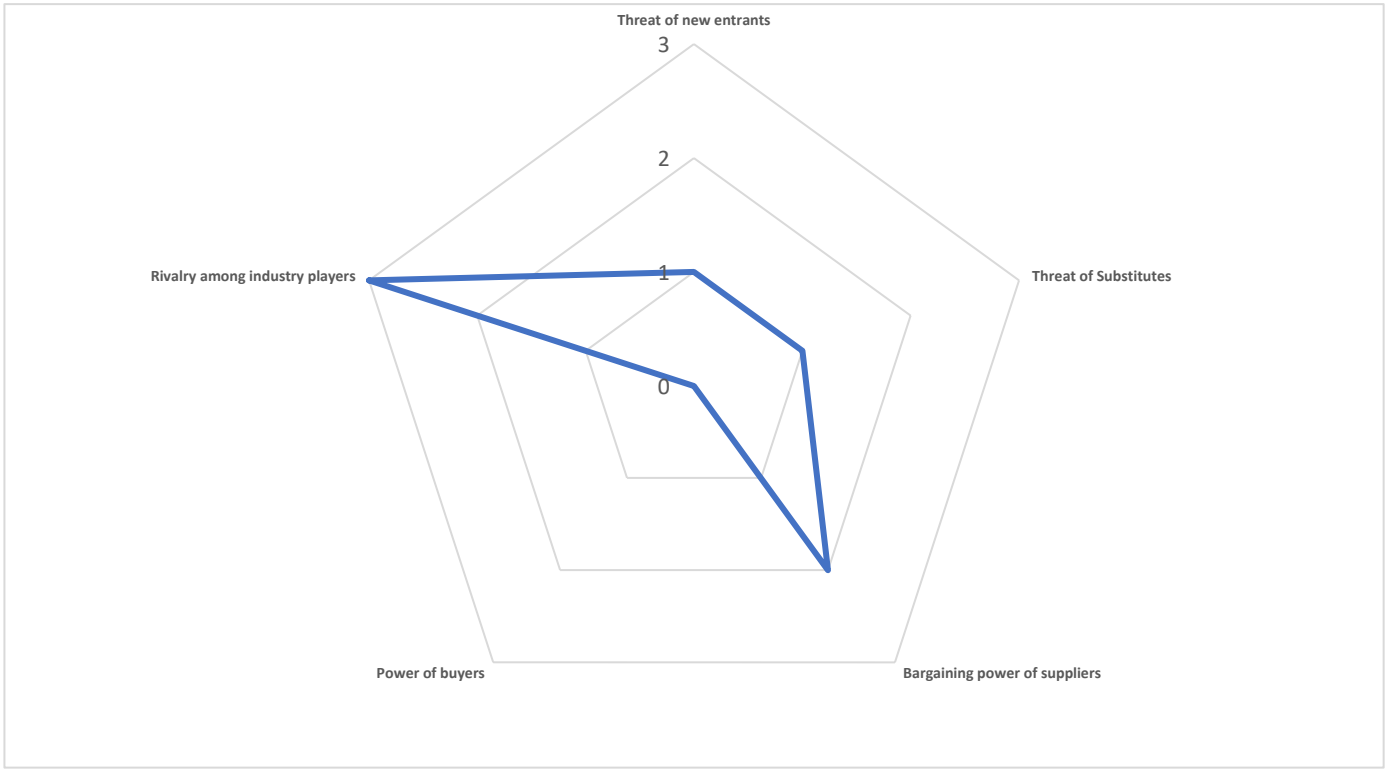
The main components of memory chips are: Silicon wafers, photomasks, chemicals, gases, photoresist, lead frames and molding compound. Silicon wafers have over 20+ manufacturing companies where no player has a dominant market share position. Most memory producers have vertically integrated the production of photomasks or went into a joint venture with a producer. The rest of the raw goods are more commodities and does not require as much customization. The bargain power of suppliers over Micron is moderate.

Power of buyers: Insignificant

Customers of DRAM/NAND are highly price sensitive and their switching costs are quite low, as the products are commodities. However, the number of buyers is in thousands while there is only 4 DRAM producers and 6 NAND producers. The imbalance of the number of buyers and sellers push the market power over to the suppliers.

Rivalry among industry players: High

The memory industry is highly competitive. DRAM and NAND can be bought from either one of the suppliers with small switching costs. The dominant factor is mostly price, because the performance between chips with the same number of layers and transmitters tend to be the same. This creates a fierce competitive oligopolistic market.



Appendix 18: Portfolio construction

Methodology:

Mean Variance Theory (MVT) has been used to construct the two portfolios. The data is collected using Bloomberg. The assets are the decomposition of the SOX index, which amounts to 28 firms. The time horizon for the data is two cycles 2013 to 2018 using monthly data.

1st step: Returns

All the monthly returns are collected between 2013-2018. After collecting the returns the Expected return (E[R]) is calculated using the average function. The Std. dev is calculated as the square root from the variance function.

2nd step: Excess returns

The excess returns are calculated for each stock. The excess returns = array (all returns)-E[R], for all stocks.

3rd step: Variance-Covariance matrix

The variance-covariance matrix is calculated using the excess returns. The formula consists of matrix algebra and uses built in excel functions. The variance-covariance matrix = MMULT(TRANSPOSE(excess return matrix);(excess return matrix))/(COUNT(Rows: excess return matric)-1)

4th step: Portfolio calculations

The portfolio is constructed by first giving each assets an equal weight. The portfolio return = =MMULT(TRANSPOSE(weight vector);(expected return vector). The std.dev of the portfolio = SQRT(MMULT(TRANSPOSE(weight vector);MMULT(variance-covariance matrix; weight vector))).The Sharpe Ratio = (E[R]-Rf)/(Std.dev). The SRMP was constructed using the following parameters in solver: Max the Sharpe Ratio, by changing the weights of the assets, with the constraint that the sum of all weights = 100%. The MVP was constructed using the following parameters: Min std. dev, by changing the weights of the assets, with the constraint that the sum of all weights = 100%. For both portfolios' solver was allowed to make non-constraints variables negative, which means that the model allows for short selling.

Sharp Ratio Maximization Portfolio		
Ticker	Weight	Return
MU US Equity	5 %	2,5 %
AMD US Equity	4 %	4,1 %
ADI US Equity	-38 %	1,7 %
AMAT US Equity	-63 %	2,0 %
ASML US Equity	-19 %	1,6 %
AVGO US Equity	63 %	3,5 %
CREE US Equity	-12 %	0,7 %
CY US Equity	4 %	1,4 %
ENTG US Equity	40 %	2,3 %
INTC US Equity	-26 %	1,5 %
KLAC US Equity	-1 %	2,0 %
LRCX US Equity	61 %	2,5 %
MRVL US Equity	16 %	1,7 %
MXIM US Equity	-17 %	1,5 %
MLNX US Equity	28 %	1,6 %
MKSI US Equity	-36 %	2,2 %
MPWR US Equity	43 %	3,0 %
NVDA US Equity	33 %	4,3 %
NXPI US Equity	11 %	2,1 %
ON US Equity	-26 %	1,9 %
QCOM US Equity	-27 %	1,2 %
SLAB US Equity	-18 %	1,7 %
SIMO US Equity	3 %	2,5 %
SWKS US Equity	-17 %	2,3 %
TSM US Equity	-1 %	1,6 %
TER US Equity	3 %	1,9 %
TXN US Equity	68 %	2,0 %
XLNX US Equity	20 %	2,0 %
Sum Weights	**100 %**	
Output		
Portfolio return	**5,3 %**	
Portfolio Std.dev	**6,1 %**	
Sharpe ratio	**0,83**	

Minimum Variance portfolio		
Ticker	Weight	Return
MU US Equity	1 %	2,5 %
AMD US Equity	1 %	4,1 %
ADI US Equity	1 %	1,7 %
AMAT US Equity	-20 %	2,0 %
ASML US Equity	10 %	1,6 %
AVGO US Equity	13 %	3,5 %
CREE US Equity	1 %	0,7 %
CY US Equity	1 %	1,4 %
ENTG US Equity	3 %	2,3 %
INTC US Equity	26 %	1,5 %
KLAC US Equity	1 %	2,0 %
LRCX US Equity	-5 %	2,5 %
MRVL US Equity	14 %	1,7 %
MXIM US Equity	23 %	1,5 %
MLNX US Equity	11 %	1,6 %
MKSI US Equity	9 %	2,2 %
MPWR US Equity	-4 %	3,0 %
NVDA US Equity	-6 %	4,3 %
NXPI US Equity	13 %	2,1 %
ON US Equity	-28 %	1,9 %
QCOM US Equity	1 %	1,2 %
SLAB US Equity	3 %	1,7 %
SIMO US Equity	-1 %	2,5 %
SWKS US Equity	-1 %	2,3 %
TSM US Equity	23 %	1,6 %
TER US Equity	-16 %	1,9 %
TXN US Equity	8 %	2,0 %
XLNX US Equity	17 %	2,0 %
Sum Weights	**100 %**	
Output		
Portfolio return	**1,6 %**	
Portfolio Std.dev	**3,1 %**	
Sharpe ratio	**0,43**	

Appendix 19: Revenue forecast

IN MILLION $	2019F	2020F	2021F	2022F	2023F	2024F	2025F	2026F	2027F	2028F
DRAM/NAND/Other										
ARIMA Forecast	$22 881,50	$16 256,76	$21 289,51	$26 766,43						
Growth rate forecast					$28 883,36	$33 961,54	$40 343,79	$47 925,42	$56 931,84	$67 630,80
3D Xpoint revenue										
3D Xpoint Forecsat	$ 135,00	$ 295,00	$ 656,25	$ 1 068,75	$ 1 681,25					
Growth rate forecast						$ 1 911,58	$ 2 173,47	$ 2 471,23	$ 2 809,79	$ 3 194,73
Total Revenue	**$23 016,50**	**$16 551,76**	**$21 945,76**	**$27 835,18**	**$30 564,61**	**$33 961,54**	**$40 343,79**	**$47 925,42**	**$56 931,84**	**$67 630,80**

The revenue forecast is split into four different forecasts. An ARIMA forecast has been used to forecast the explicit period for all revenues except 3D Xpoint. The reasoning behind using an ARIMA model (See attached support document for the ARIMA forecasting) is the lack of specific data regarding pricing and production of DRAM and NAND. After forecasting to 2022F a normalized growth rate has been applied to reflect the revenue in the fade period.

3D Xpoint revenues

3D Xpoint revenue											CAGR	Source:
Handy Forecast	$ -	$ 125,00	$ 625,00	$ 1 625,00	$ 3 600,00							Jim Handy, Memory guy at Objective Analysis
Webb Forecast	$ 900,00	$ 1 350,00	$ 2 000,00	$ 2 650,00	$ 3 125,00							Mark Webb of Ventures Consulting
Average	$ 450,00	$ 737,50	$ 1 312,50	$ 2 137,50	$ 3 362,50							http://tiny.cc/ilu3dz
Growth forecast						$ 3 823,16	$ 4 346,94	$ 4 942,47	$ 5 619,58	$ 6 389,47	**13,70 %**	MRFR analysis
Intel marketshare	70 %	60 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %		Assumption
Micron marketshare	30 %	40 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %	50 %		Assumption
Micron revenue	**$ 135,00**	**$ 295,00**	**$ 656,25**	**$ 1 068,75**	**$ 1 681,25**	**$ 1 911,58**	**$ 2 173,47**	**$ 2 471,23**	**$ 2 809,79**	**$ 3 194,73**		Calc

Micron expects to lunch its 3D Xpoint product in late 2019F. Currently Intel is the only competitor which produces 3D Xpoint through its Optane product. Two forecasts where available for 3D Xpoint revenues until 2023. To derive Microns portion of the revenue an average has been applied to the two forecasts, then the revenue has been calculated from the market shares. I have assumed Intel will retain a stronger market share position due to first movers' advantage. I assume Micron will obtain 50% of the market shares 2 years after the launch. From 2023F to 2028F a CAGR of 13,7% has been used estimated by MRFR Analyst.

Time Series Revenue Forecast: Support document

1. Forecasting: Micron Technologies revenues

The objective of this forecast is to forecast the quarterly revenues of Micron Technologies from 2019Q2 until 2022Q4. The forecast will be used to conduct an investment recommendation on Micron Technology.

1.2 Data used for forecasting

The data set used for the forecast contains the quarterly revenues of MU from 1991Q1 until 2019Q2. The data is downloaded from the Bloomberg terminal the 28.06.2019.

2. Decomposition of the data set

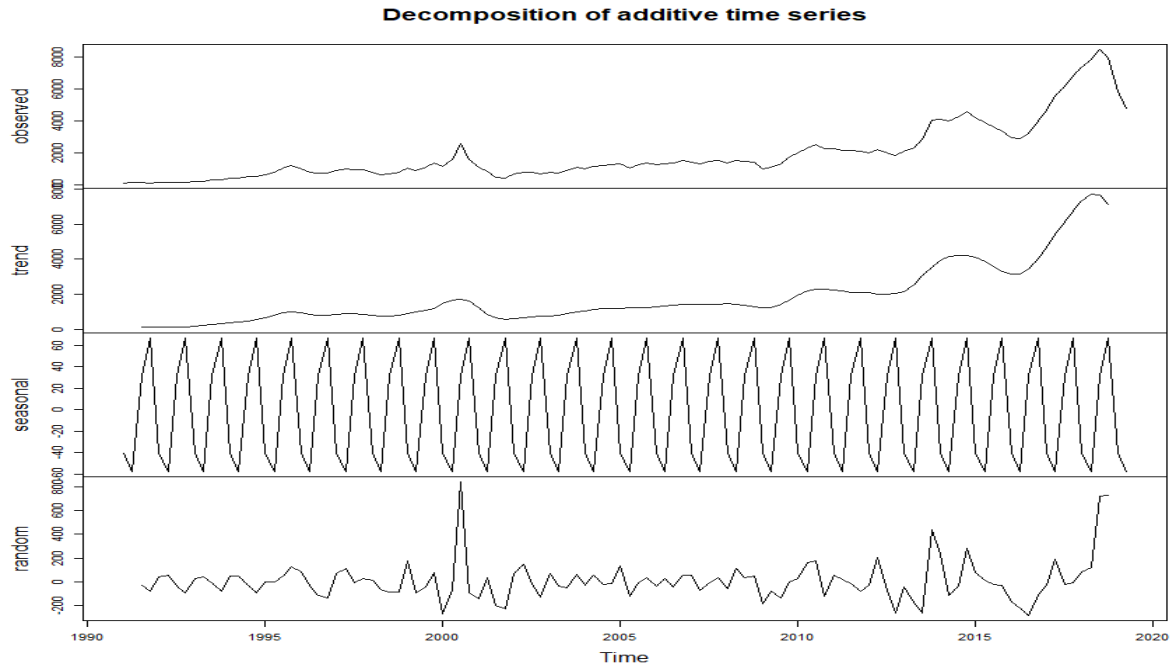


Figure 1: Decomposition of the quarterly revenue time series.

We can decompose the time series in three different components. The data exhibits an upward sloping trend. A seasonal component and a random component.

To create a model the time-series need to be stationary (at least weakly stationarity). This assumptions require that all random variables have the same mean, variance and that the covariances should not depend on time (second order stationarity).

Graphically (Figure 1), we can see that data is not stationarity, because for different time frames the time series have different means. To apply a model to the time series it needs to also account for the trend and seasonal component.

3. Data transformations

3.1 First difference:

$$DY = Yt - Yt - 1$$

Using the formula for first difference we can create a differentiated time series. The time series is created in R using the following code: DY <- diff(Y). We can run a diagnostic on the time series using the autoplot() function:

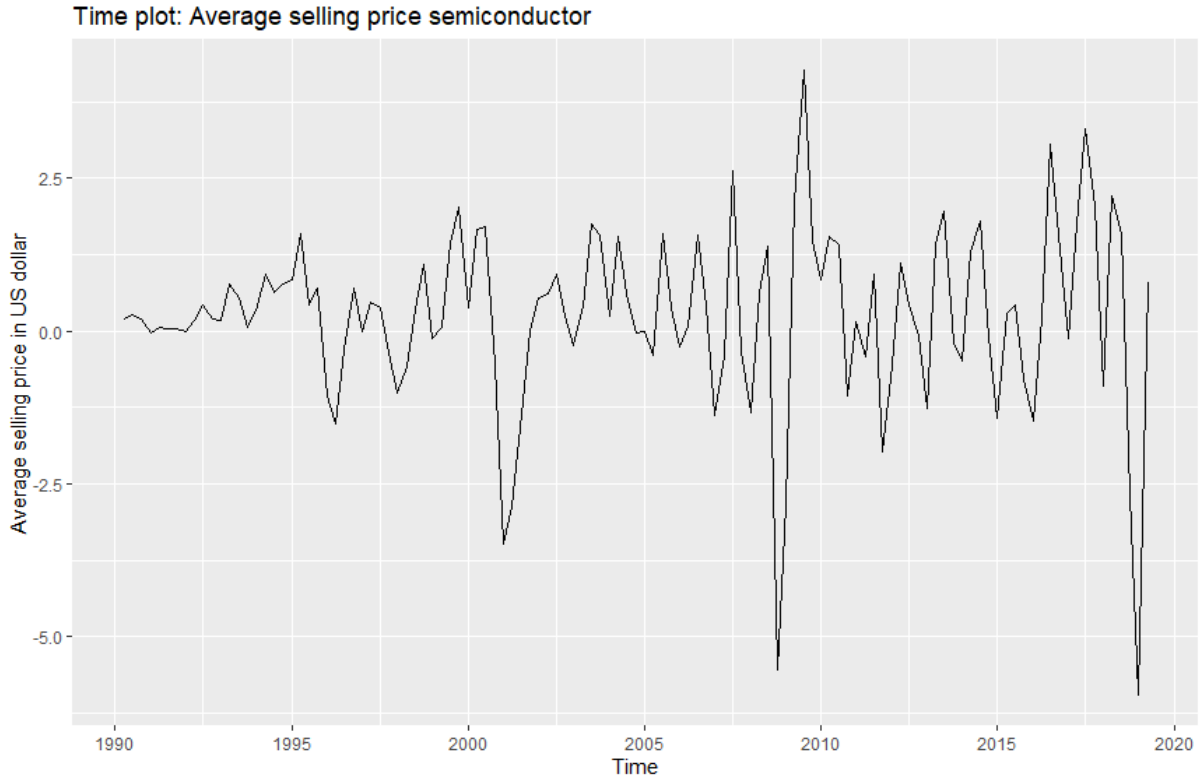


Figure 2: time plot of the first difference

Visually examination of the plot shows that the time series exhibits more stationary traits. The mean is now mean reverting around 0. The variance is still not stationary and seem to increase over time. This might be removed by using a model which includes a seasonal component. We can use an Augmented Dickey-Fuller test to test the differentiated series for stationarity using the adf() function in R:

```
        Augmented Dickey-Fuller Test

data:  DY
Dickey-Fuller = -4.8761, Lag order = 4, p-value = 0.01
alternative hypothesis: stationary
```

as the P-value is lower than 0.05 we can reject the null hypothesis that the time series is not stationary with 95% probability.

3.1.2 Seasonality

By using the ggseasonplot() function we can also investigate the seasonality in the time series:

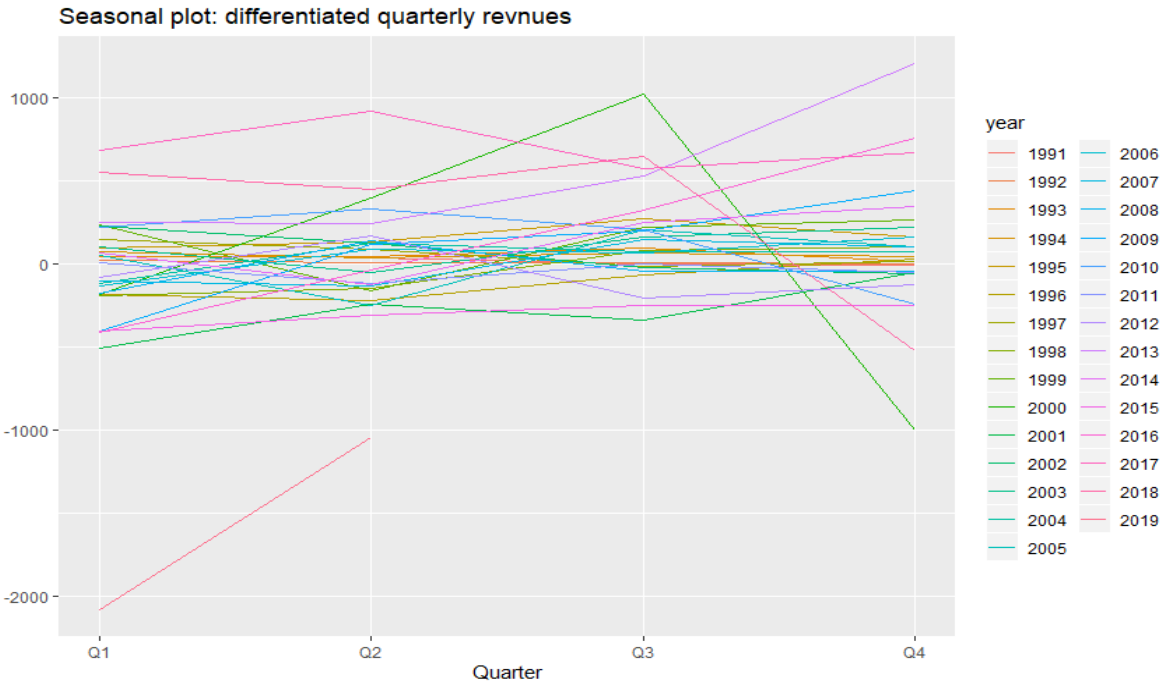


Figure 3: seasonal plot for DY series. Q1, Q2, Q3 and Q4 at each year.

From the graph (figure 3) it's hard to detect any clear seasonal pattern in the time series. To further investigate the seasonality we can use the ggsubseriesplot() function:

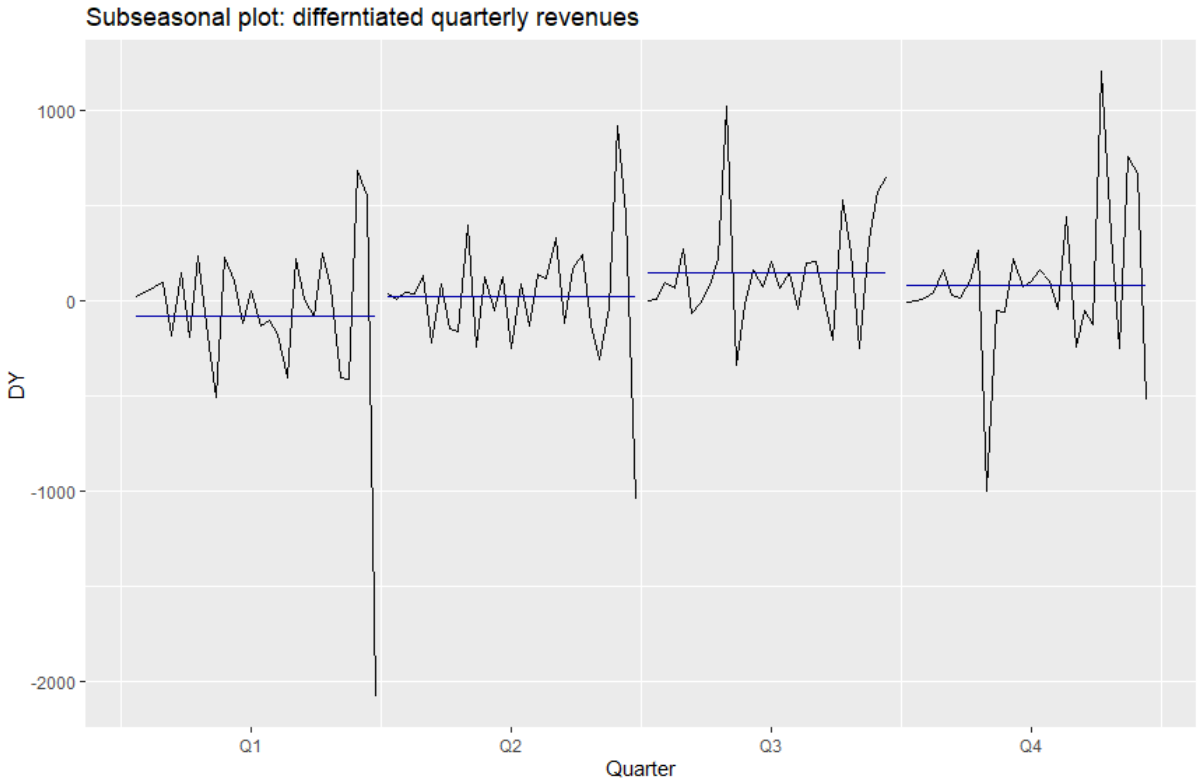


Figure 4: Sub seasonal plot with mean for each quarter across the observed time.

The graph shows all Q1, Q2, Q3, Q4 values from the different years and the mean value (blue line). We can see from the graph that the price tends to increase from Q1 to Q3 and then drop some points in Q4.

3.2 Box-Cox transformation

Another way to transform the data is using a Box Cox transformation. The main properties of a Box Cox transformation are to make the data more normal distributed and stabilizing the variance. As we can see from the preliminary analysis the variance tends to increase as time increase creating a heteroskedastic problem.

$$Wt = \begin{cases} \log yt, & if\ \lambda = 0 \\ \dfrac{(Yt^{\lambda} - 1)}{\lambda}, & otherwise \end{cases}$$

To find the lambda that minimize the variation in the time series we can use the function BoxCox.lambda(). Code:

```
lambda <- BoxCox.lambda(revenues_ts)
print(lambda) #-0.01672169
```

The function returns -0.01672169. To transform the time series using a Box-Cox transformation into a new time series called Y_box we can use the following code in R:

```
Y_box <- BoxCox(Y, lambda = lambda), where boxcox() is the function with parameter, Y(original time series).
```

To check if Y_box is stationary we can use the adf() function. The time series is not stationary with the chosen lambda = -0.01672169, p-value = 0.06199. We can decrease the lamda little by little until we find a stationary time series. Lambda = -0,10 returns a stationary transformed time series, with p-value = 0,04958.

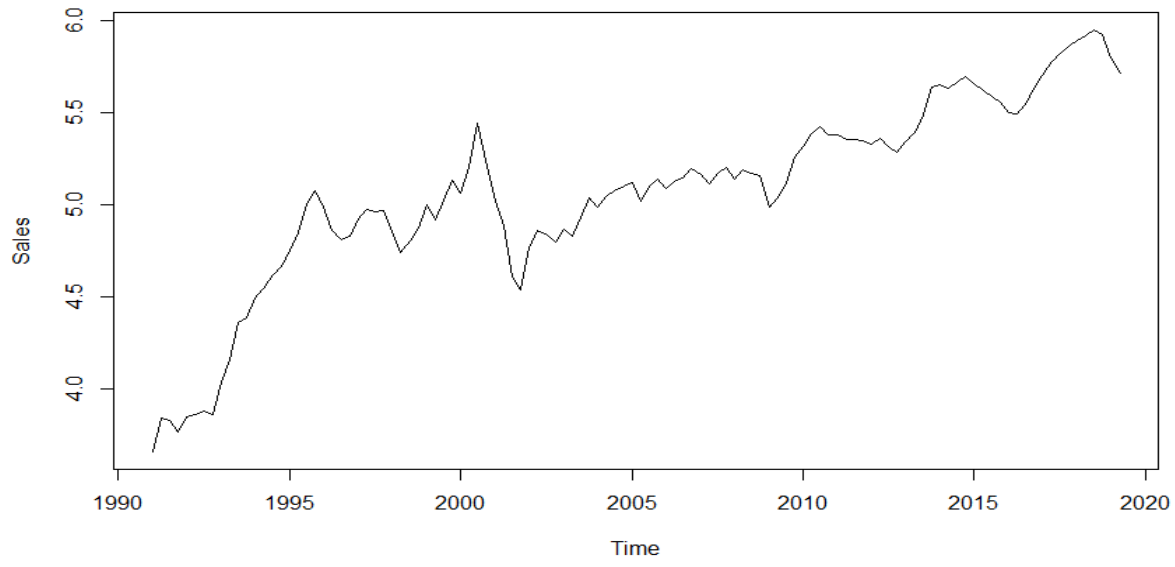


Figure 5: Box-Cox transformed time series using lambda = -0,10.

3.2.1 Seasonality

To investigate seasonal pattern, we can once again apply the seasonal plots:

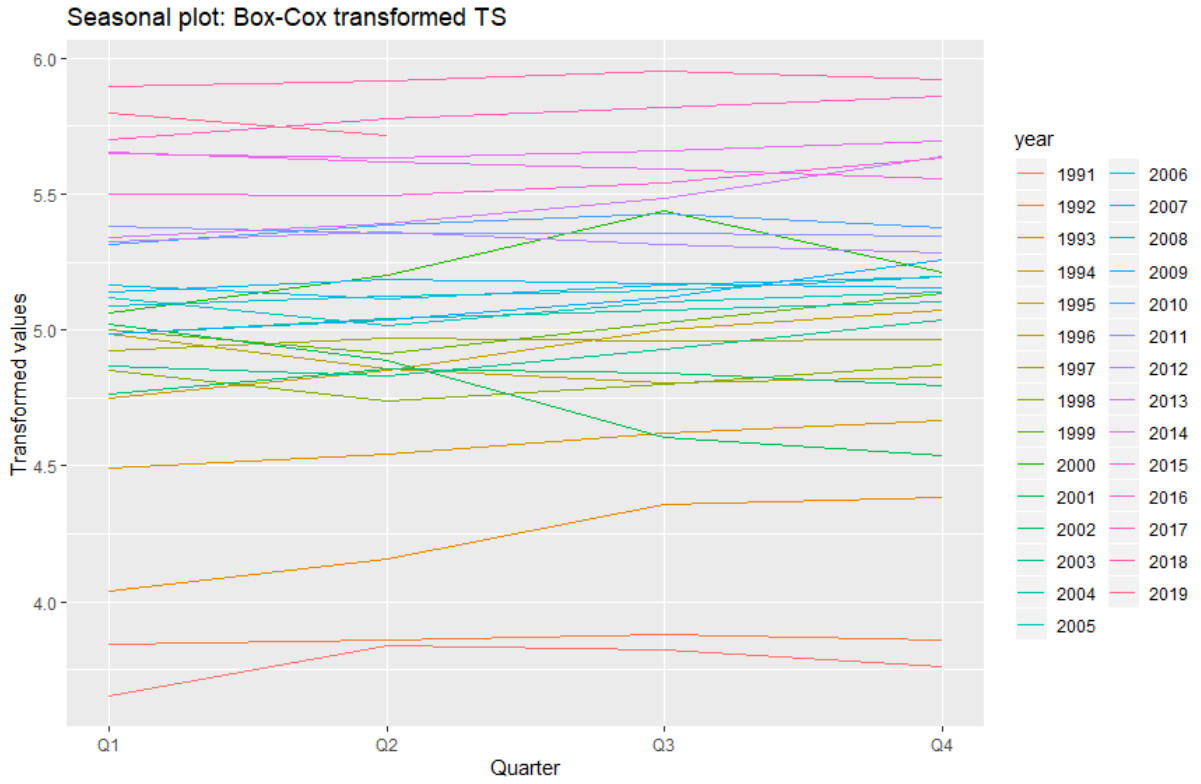


Figure 6: seasonal plot for Y_box series. Q1, Q2, Q3 and Q4 at each year.

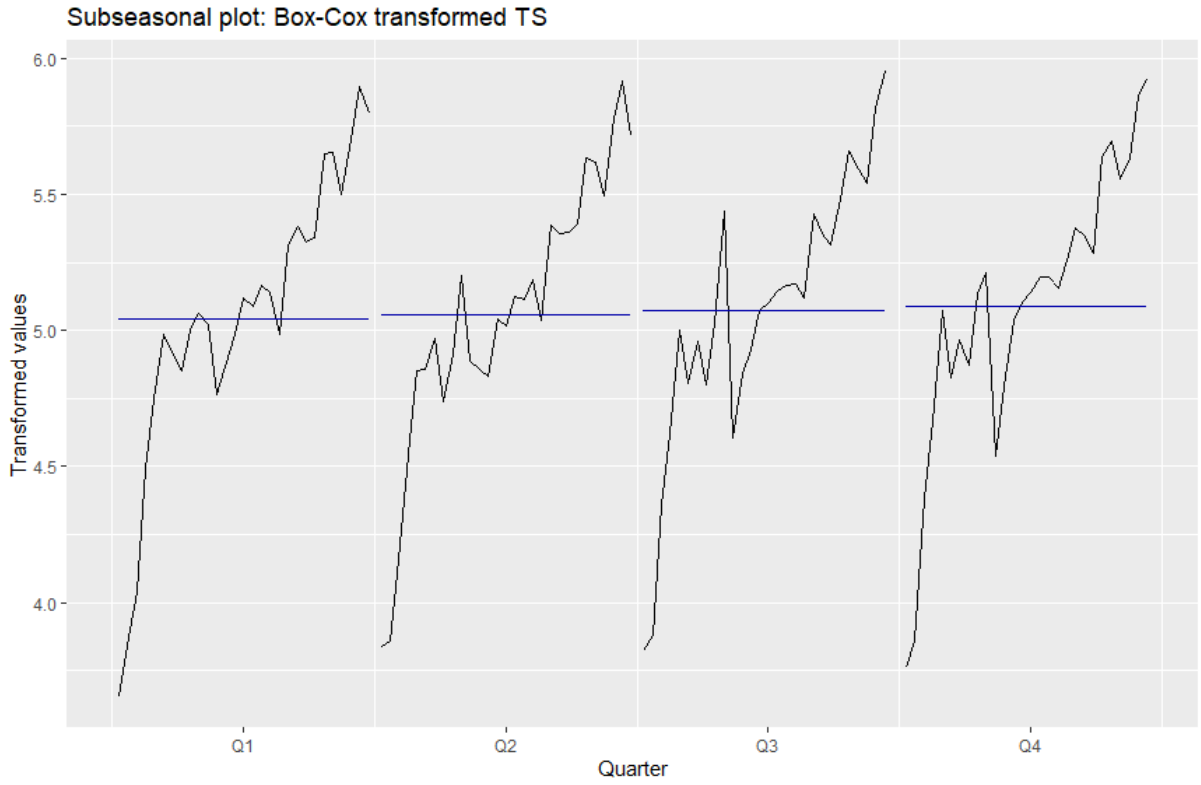


Figure 7: sub seasonal plot with mean for each quarter across the observed time.

By doing a graphically comparison between the first differentiated (DY) series and Box-Cox transformed (Y_box) series we can see that the Y_box series displays much less seasonal variance and a flatter pattern. When we create the model for forecasting, we might not need the seasonal component for the Y_box time series.

4. Creating models

4.1. Method for choosing models

From the preliminary analysis we have discovered that we need models that can account for transformed data, seasonality and trend. Models which can account for the parameters are Exponential Smoothing and ARIMA. To choose ARIMA models we will investigate the autocorrelation function and partial-autocorrelation functions for the transformed time series. We can also use the auto.arima() function which automatically choose the best fitted ARIMA model based on the AIC criterion.

4.2. Choosing candidate models

4.2.1 Using first differenced data

Using the acf() and pacf() functions we can obtain the ACF and PACF for the time series. The ACF and PACF for the first differenced series is:

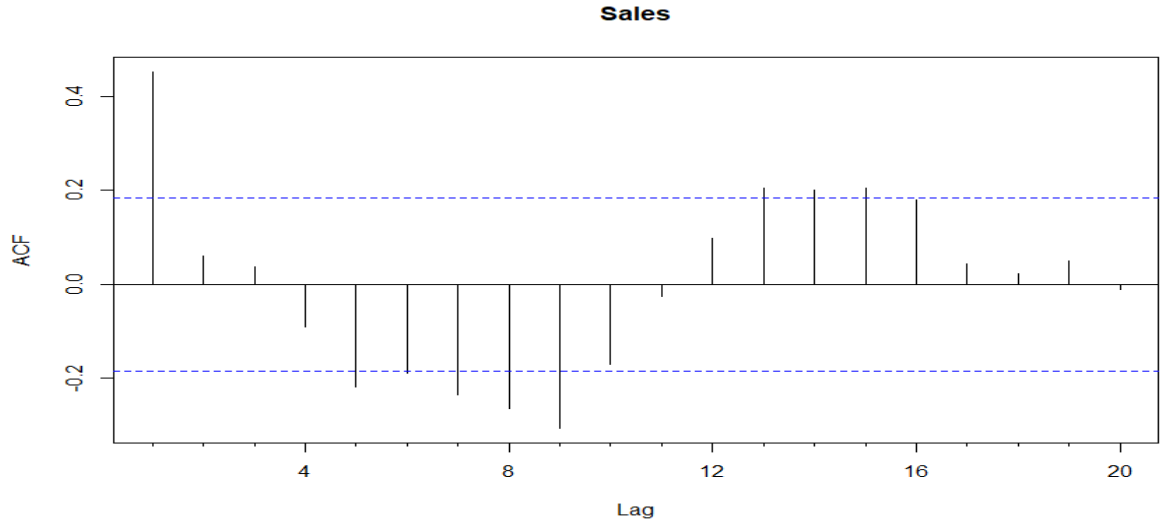


Figure 8: ACF for DY series

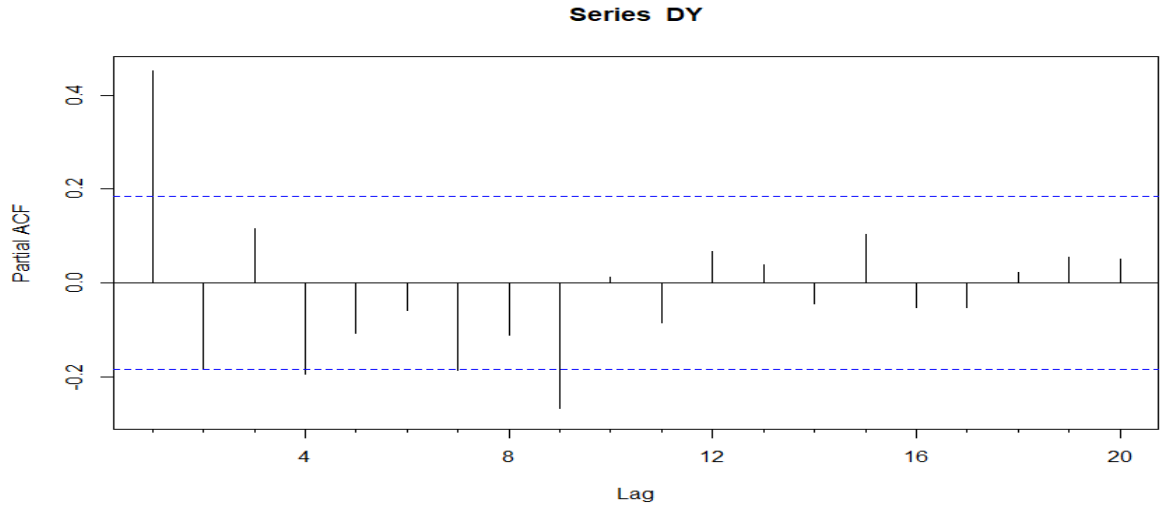


Figure 9: PACF for DY series

Fitting an ARIMA model consist of determining the order of AR and MA processes needed to correct any autocorrelation that remains in the series. If the PACF shows a sharp cut off while the ACF decays more slowly it can be a sign of an AR signature. Meaning that the autocorrelation pattern can be more easily be explained by adding AR orders rather than MA. The lag where the cut off accurse should be the order of AR. As we can see from the PACF the cutoff happens at lag 9. While we still have lag 1,4 and 7 also outside the 95% confidence interval. To test I will include AR models at these lags:

ARIMA(1,1,0), ARIMA(2,1,0), ARIMA(4,1,0), ARIMA(7,1,0), ARIMA(9,1,0)

We will also test for the possibility that the model is a mix of AR and MA. Lag 1 and 5 is over the 95% confidence interval in the PACF. Since the series has an AR signature, we will not include more MA orders then AR and only use the first two lags that are outside of the 95% interval. Models chosen:

ARIMA(1,1,1), ARIMA(2,1,1), ARIMA (4,1,1) ARIMA (7,1,5)

As we saw from the preliminary analysis it is likely that the model will need a seasonal component. The ACF moves in a wave like pattern slowly decaying which may be a sign of seasonality. We will also try a model consisting of a seasonal AR component. Models chosen:

ARIMA(1,1,1)(1,0,0), ARIMA(2,1,1) (1,0,0), ARIMA (4,1,1) (1,0,0) ARIMA (7,1,5) (1,0,0)

4.2.2 Using the auto.arima() function

In R we can call an auto.arima function to choose the best fitted ARIMA model according to AIC. We can use the auto.arima function on the first differenced- and the Box-Cox transformed time series. Code used to obtain model:

```
fit_auto_arima <- auto.arima(revenues_ts,d=1,D=1,stepwise = FALSE, approximation = FALSE, trace = TRUE)
fit_autobx_arima <- auto.arima(Y_box,d=1,D=1,stepwise = FALSE,approximation = FALSE,trace = TRUE )
```

Parameters for the function:
d = how many times we allow the function to differentiate the time series
D = how many times we allow for differentiating in the seasonal component
Stepwise = Is used if we have several time series to test
Approximation = Is used to save time computing. Set false du compute exact values.
Trace= prints all the models tested (see appendix for the print)

The auto.arima function used on the quarterly revenues time series calculated the best fitted ARIMA model to be (0,1,1)(2,1,1)[4], which is an MA(1) process differentiated 1 time, with a seasonal AR(1) and MA(2) component differentiated 1 time. The auto.arima function used on the Box-Cox transformed time series returned an ARIMA(0,1,1)(0,1,1)[4], which is an MA(1) process differentiated 1 time with a SMA(1) process differentiated 1 time.

4.2.3 Using the ets() function.

Since the time series consist of a trend and seasonality, we can also investigate exponential smoothing. The ETS() function returns the parameters for the most fitted model, according to the AIC criterion. The parameters returned are error-, trend- and seasonal component. The components are categorized by the letter's "A","M" or "N", which stands for additive, multiplicative and none. The function returned a model (M,A,N) with the smoothing parameters alpha = 0,9999 and beta= 1e-04.

4.3 Choosing from the candidate models

	Model		Parameters for choosing model			
Method	**ARIMA**	**Season**	**AIC**	**R-squared**	**lags outside 95%**	**Ljung-Box**
ETS			1769		lag 1,5 and 9	0,00
	110	0	1639	334	lag 9	0,166
	210	0	1639	329	lag 9	0,096
	410	0	1636	321	lag 9	0,189
	710	0	1634	310	lag 9	0,006
	111	0	1637	329	lag 5 and 9	0,150
ACF PACF	211	0	1639	329	lag 5 and 9	0,110
DY	411	0	1629	308	lag 9	0,164
	715	0	1629	279	none	0,035
	111	100	1639	329	lag 5 and 9	0,087
	211	100	1641	328	lag 5 and 9	0,056
	411	100	1631	308	lag 9	0,015
	715	**100**	**1626**	**275**	**none**	**0,084**
Auto arima	**(0,1,1)**	**(2,1,1)**	**1587**	**330**	**lag 9**	**0,140**
Auto arima	**(0,1,1)**	**(0,1,1)**	**-234**	**0**	**lag 5 and 9**	**0,140**

Figure 11: candidate models and selection criteria

The main selection criteria will be the Akaike Information Criterion (AIC). The AIC measures the information loss by specified model, so the lower AIC the better the model is fitted to the data. Since the ARIMA models using the auto.arima() function is based on different transformed time series it is not comparable. From the model generated we can see that the ARIMA(0,1,1)(2,1,1) has the lowest AIC score. However, the ARIMA(7,1,5)(1,0,0) has a better sigma which mean less variance in the data. This model also has no residual lags outside the 95% confidence interval in the ACF. The ARIMA(0,1,1)(0,1,1) is not directly comparable to the rest. The models chosen for further testing is:

- ARIMA(0,1,1)(2,1,1), ARIMA(7,1,5)(1,0,0) and ARIMA (0,1,1)(0,1,1)

5. Checking performance on historical data and qualitative analysis

To check the fit on historical data we need to create two new time series. The first time series will be called revenues_train and contains observations from 1991 to 2015. The time series will be used to fit the models. The second time series will be called revenues_test and will contain the observations from 2015 until 2019. This time series is what we will forecast by applying the models on our training set and then compare with the actual values.

5.1 Checking performance on ARIMA(0,1,1)(2,1,1)

```
#Creating a data set of values until the 100th observation but no more

revenues_train <- window(revenues_ts, end=2015)

#Creating a data set of values from the 100th observation and to the end

revenues_test <- window(revenues_ts, start=2015)

#number of observations

n_test <- length(revenues_test)
```

To compare the performance, we can conduct two tests. The first is a multistep forecast where we forecast the one step ahead value, then we feed the **forecasted** one step ahead value to predict the two step ahead forecast, and so on. Starting with the ARIMA(0,1,1)(2,1,1):

```
revenues_auto_model <- arima(revenues_train, order = c(0, 1, 1), seasonal = c(2,1,1))
revnues_multi_forecast <- forecast(revenues_auto_model, h=n_test)
revnues_multi_forecast %>%
autoplot() +
 geom_line(
   aes(
     x = as.numeric(time(revenues_test)),
     y = as.numeric(revenues_test)
   ),
   col = "red"
 )
```

Figure 12: code to produce a multistep forecast and graph

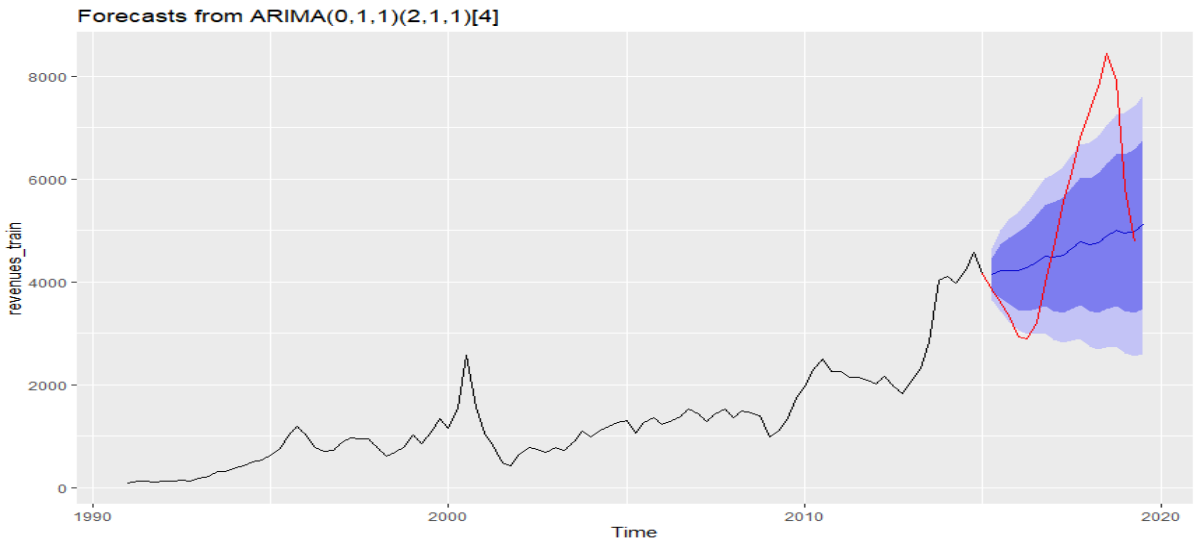


Figure 13: Multistep forecast graphed

The forecast does not represent the future that well. It forecasts some cycles, but they are not big enough to capture the significant variances in the revenues that occurs between 2015-2019.

To further investigate the accuracy of the model we will use another forecasting method: one step ahead forecast. Where we instead of feeding the model the **forecasted** one step ahead value, we return the **actual observed** value to forecast the next.

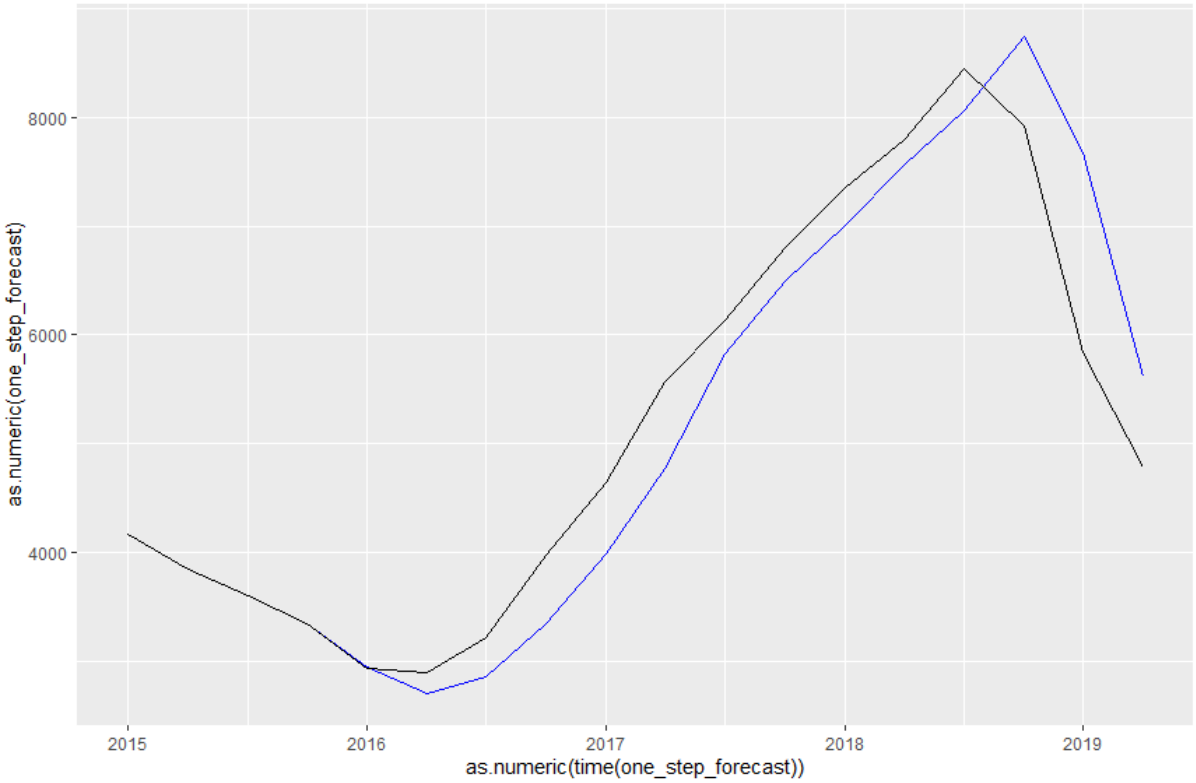


Figure 14: One step ahead forecast compared to actual observed values

As we can see from the graph the model is very accurate, only showing a small variance from the observed values.

We can conclude that the ARIMA(0,1,1)(2,1,1) model can predict accurately for a short time frame where we update the model with the observed values, but struggles to forecast accurately for a larger horizon.

5.2 Checking performance on ARIMA(0,1,1)(0,1,1)

We will again plot the multistep forecast and 1 step ahead forecast for the model:

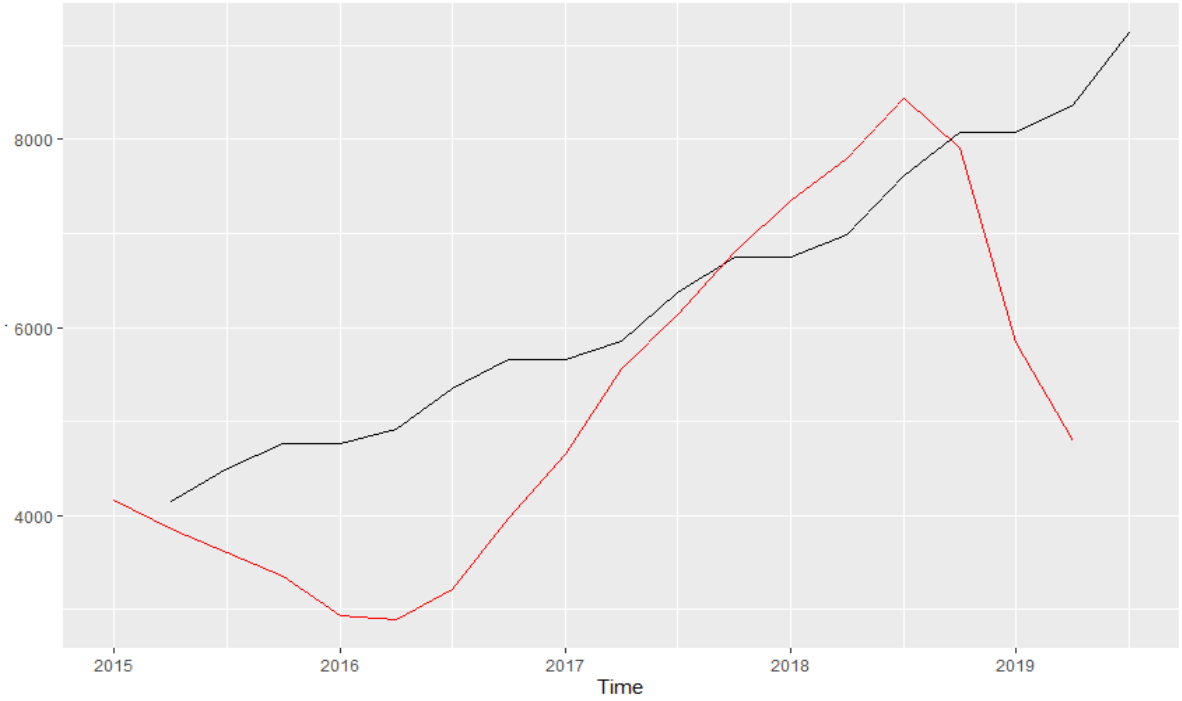


Figure 15: Multistep forecast for ARIMA(0,1,1)(0,1,1) graphed

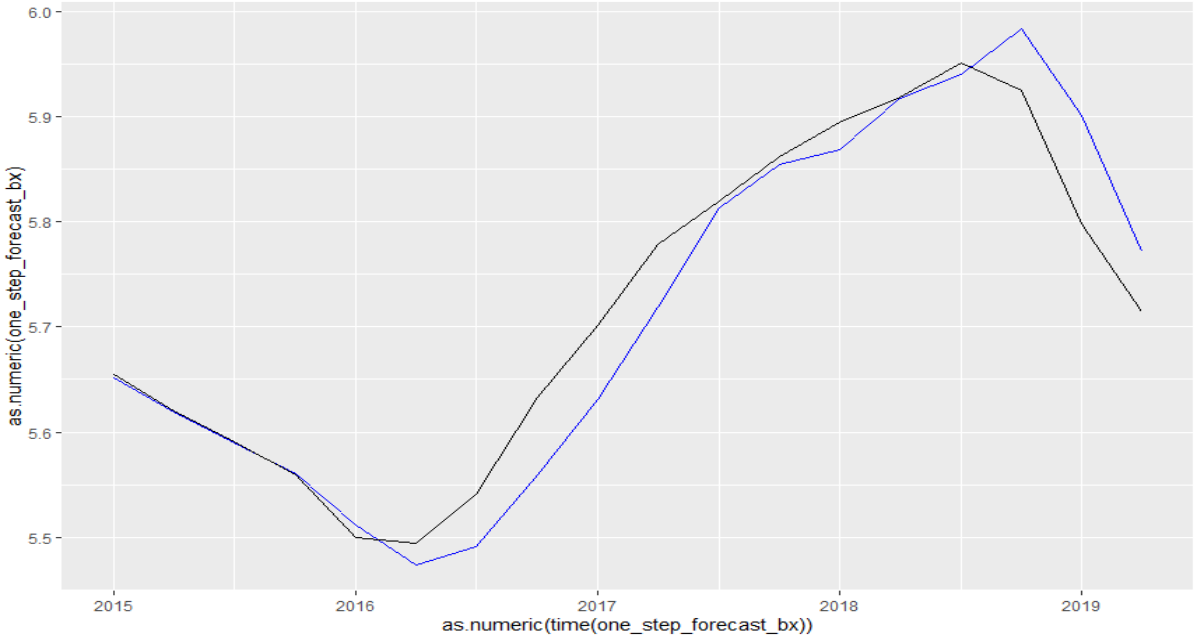


Figure 16: 1 step ahead forecast for ARIMA(0,1,1)(0,1,1) graphed

Visually inspecting the graphs, we can see the same tendency as with the previous ARIMA model. The model struggles to forecast the big cycles that occurs between 2015-2019. However, if we to a 1 step ahead forecast the model is fairly accurate.

The last model is not stationary using the training set.

5.3 Reevaluating the models

By checking the performance on the two models we can conclude that it has high variance between observed values and predicted values. To investigate the possibility of a better fitted model we must examine the residuals in the models:

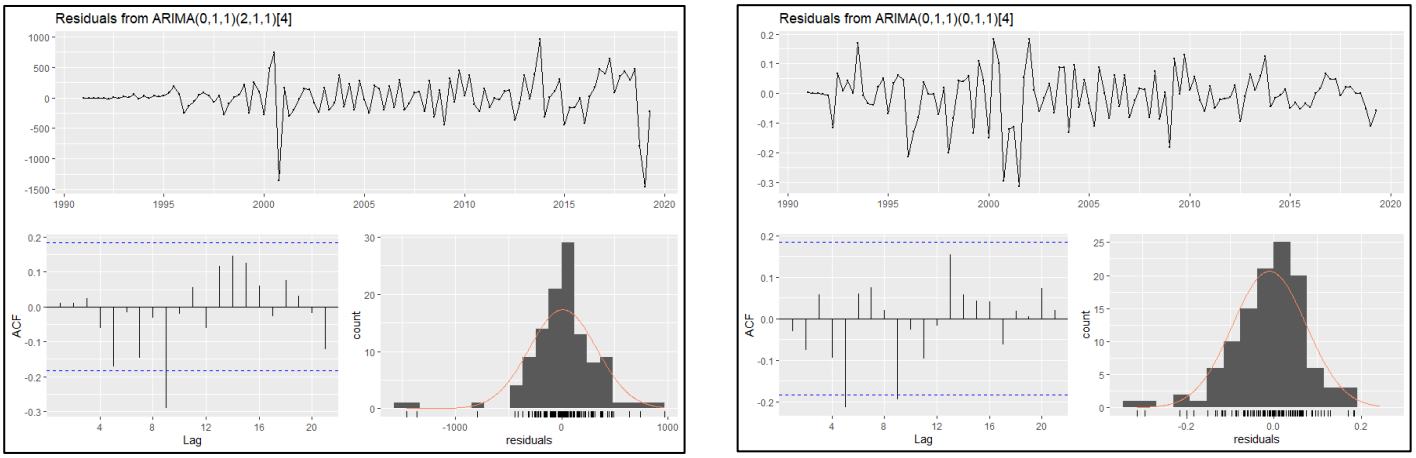


Figure 17: Residuals from ARIMA(0,1,1)(2,1,1) and ARIMA(0,1,1)(0,1,1).

We can see that for both models lag 9 exceeds the 95% confidence interval. To find a better fit we can try to fit lag 9 as an AR order in both models. Creating model:

- Auto_arima_DY_2 : (1,1,9)(2,1,1)
- Auto_arima_BX_2: (9,1,1)(0,1,1)

None of the new models has any lags exceeding the 95% confidence interval, which implies that they capture more of the information in the time series.

Using the same procedure on the models we obtain the following results:

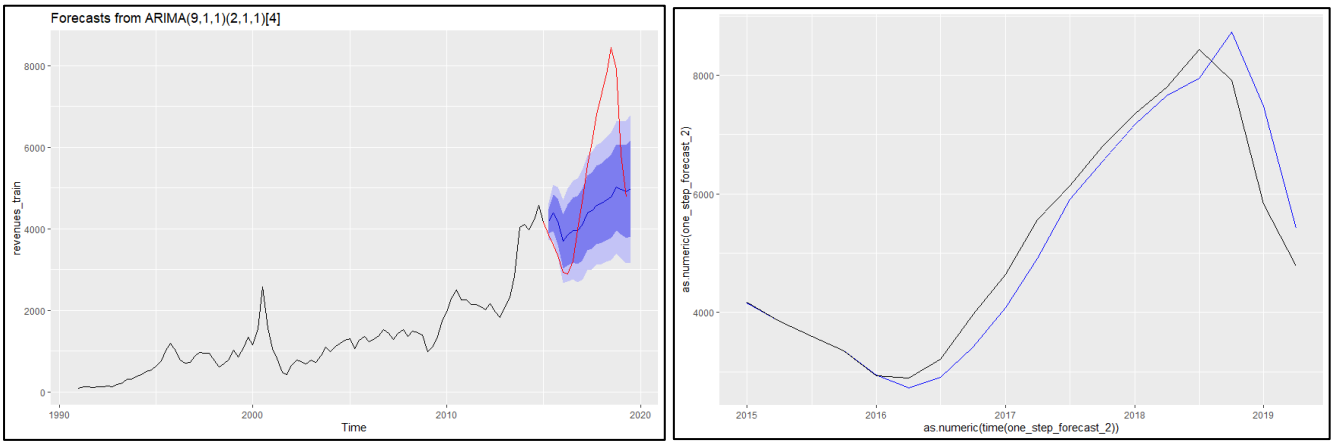


Figure 18: Multistep and 1-step ahead forecast for ARIMA(1,1,9)(2,11)

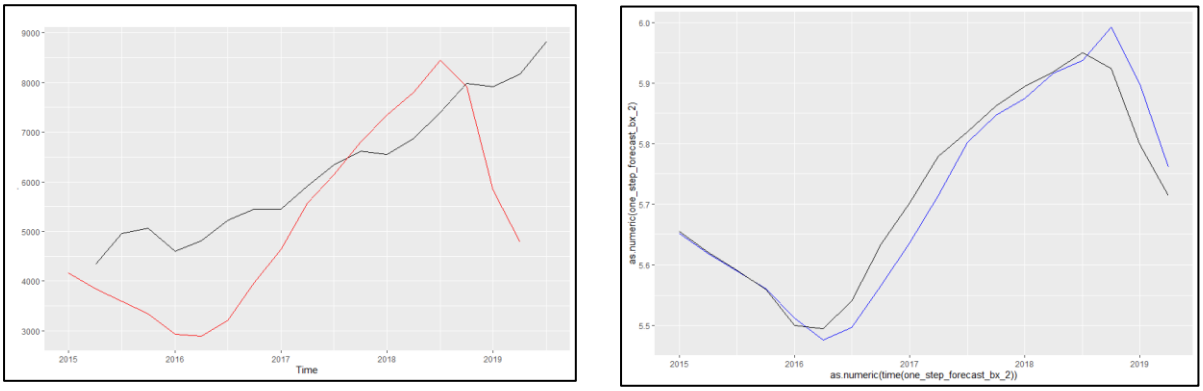


Figure 18: Multistep and 1-step ahead forecast for ARIMA(1,1,9)(0,11)

To evaluate which model performed the best on the training set we can calculate the Mean Squared Error. The model that minimizes MSE is the one who predicts the closest to the observed values overall.

Model	Parameters	Multistep MSE	1-step MSE
Auto ARIMA DY	(0,1,1)(2,1,1)	2 457 430	382 643
Auto ARIMA BX	(0,1,1)(0,1,1)	2 812 282	360 182
Auto ARIMA DY 2	(9,1,1)(2,1,1)	2 724 966	296 727
Auto ARIMA BX 2	(9,1,1)(0,1,1)	2 544 087	360 182

The selected models for forecasting are Auto ARIMA DY which minimize errors for long term forecasting. Auto ARIMA DY 2 minimize errors for short term forecasts and ARIMA(7,1,5)(1,0,0), which we could not analyze using a past performance are also selected.

5.4 Quantitative analysis of forecasts

By running a forecast until 2023 Q4 for the selected models we can produce the following graph:

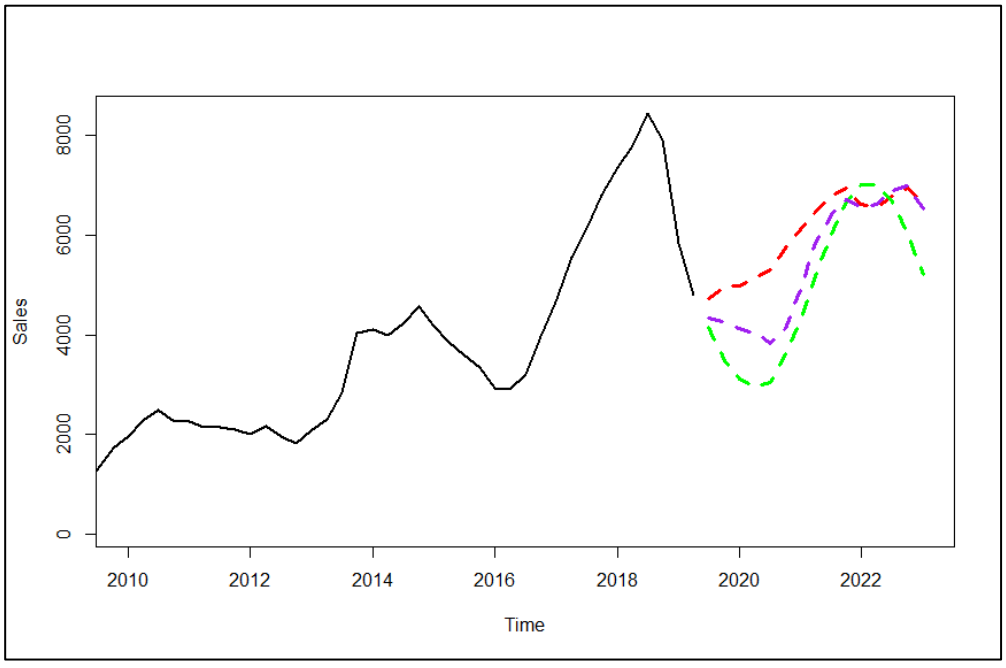


Figure 19: forecast of ARIMA(0,1,1)(2,1,1), ARIMA(1,1,9)(2,1,1) and ARIMA(7,1,5)(1,0,0)

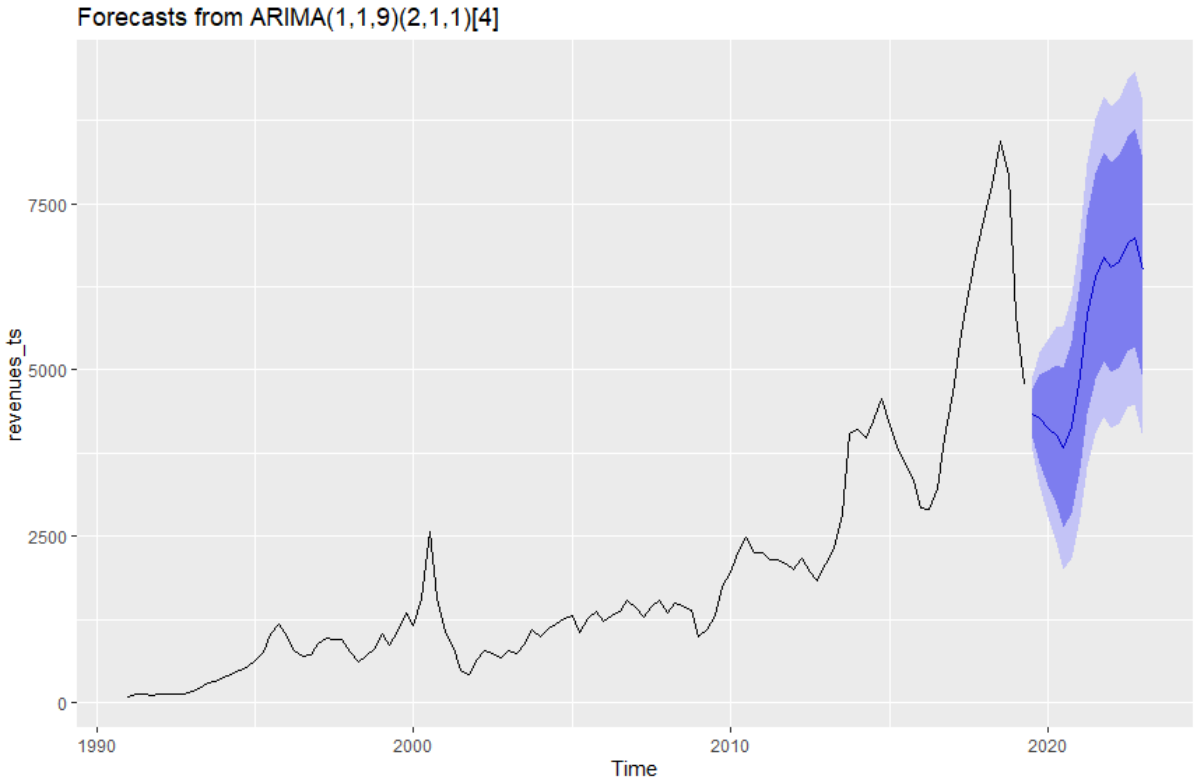
From the market research we know that the memory revenues tend to move in cycles. The cycles are characterized by a two years growth followed by two years decline in the growth. The cycles have a positive trend, which means that the growth is in general higher than the following decline. The market research also predicts a decline in the CAGR of familiar markets until 2020. New technology that is expecting to take a big part in future earnings are not expected to do so in the immediate future. From the market research we also know that producers now are starting to ramp down their productions to push prices upwards, which is an indicator of increasing prices in the following years.

The market research suggests a downward growth until 2020 followed by an increase in revenues. We can see graphically that the Auto AIMA model (0,1,1)(2,1,1) predicts an immediate increase in revenues which is unlikely. The two other models predict a continuation of the declining revenues which is more consistent with the market research. The ARIMA model (7,15)(1,0,0) predicts an immediate decrease in revenues after 2022 Q1 while the ARIMA model(1,1,9)(2,1,1) is more consistent with the ARIMA model(0,1,1)(2,1,1) which scored the best on long term forecasts.

6. Sales forecast

The model selected is **ARIMA model (1,1,9)(2,1,1**). The model has no lags outside the 95% confidence interval indicating it captures all information in the time series. The residuals are normally distributed and follows a white noise process. The model is consistent with the market research and predicts closely to the ARIMA model(0,1,1)(2,1,1) in the long term, which scored the best on long term forecasts.

Figure 20: Forecast of ARIMA(1,1,9)(2,1,1)



```
Call:
arima(x = revenues_ts, order = c(1, 1, 9), seasonal = c(2, 1, 1))

                                                Coefficients:
     ar1     ma1      ma2     ma3      ma4      ma5     ma6      ma7     ma8      ma9     sar1     sar2     sma1
   0.3574  0.1360  -0.1174  0.0390  -0.1107  -0.2046  0.2187  -0.1281  0.0866  -0.3681  -0.0797  -0.4074  -0.8757
s.e.  0.3102  0.3016   0.1852  0.1127   0.1785   0.1425  0.1599   0.1027  0.1609   0.1491   0.1893   0.1631   0.0821

sigma^2 estimated as 80720:  log likelihood = -778.27,  aic = 1584.55

                                        Training set error measures:
                     ME     RMSE      MAE         MPE     MAPE      MASE        ACF1
Training set 20.05249 277.8123 185.4824 -0.1901627 11.59545 0.7734317 0.01149799
                     ME     RMSE      MAE         MPE     MAPE      MASE        ACF1
Training set 20.05249 277.8123 185.4824 -0.1901627 11.59545 0.7734317 0.01149799
```

Figure 21: Model summary of ARIMA(9,1,1)(2,1,1)

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2019 Q3	4345.503	3978.540	4712.465	3784.282	4906.724
2019 Q4	4265.359	3610.134	4920.584	3263.279	5267.439
2020 Q1	4127.001	3261.180	4992.821	2802.842	5451.159
2020 Q2	4031.035	2984.725	5077.345	2430.842	5631.228
2020 Q3	3833.362	2641.795	5024.930	2011.017	5655.707
2020 Q4	4137.083	2847.197	5426.968	2164.373	6109.792
2021 Q1	4919.897	3520.723	6319.070	2780.045	7059.748
2021 Q2	5828.095	4336.963	7319.227	3547.605	8108.585
2021 Q3	6404.432	4852.974	7955.889	4031.681	8777.182
2021 Q4	6700.881	5129.702	8272.059	4297.971	9103.791
2022 Q1	6543.455	4959.780	8127.129	4121.433	8965.476
2022 Q2	6624.850	5031.542	8218.157	4188.096	9061.604
2022 Q3	6897.243	5287.817	8506.669	4435.838	9358.648
2022 Q4	6986.932	5355.608	8618.255	4492.038	9481.826

Figure 22: Forecasted values from ARIMA(9,1,1)(2,1,1)

Time Series COGS Forecast: Support document

1. Forecasting: Micron Technology COGS

The objective of this forecast is to forecast the COGS-to-Sales of Micron Technology from 2019F until 2022F. The forecast will be used to conduct an investment recommendation on Micron Technology.

1.2 Data used for forecasting

The data set used for the forecast contains the COGS-to-Sales ratios for Micron from 2008 to 2018. The data is downloaded from the Bloomberg terminal the 28.06.2019.

2. Data transformations

2.1 First difference:

$$DY = Yt - Yt - 1$$

Using the formula for first difference we can create a differentiated time series. The time series is created in R using the following code: DY <- diff(Y). We can run a diagnostic on the time series using the autoplot() function. By visually examining the time series it seems more stationary then the original time series, implying a first difference should be used when modeling the time series.

3. Creating models

By examining the ACF and the PACF we can determine the number of p and q used in the ARIMA model.

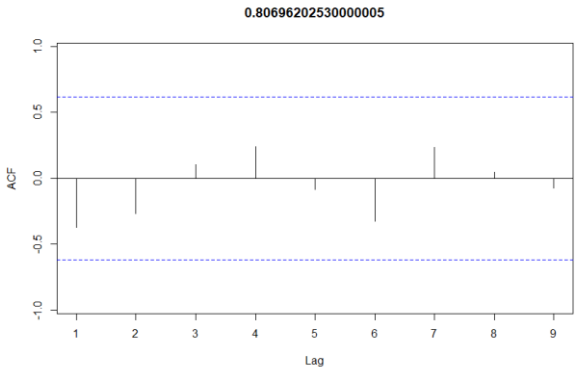


Figure 1: ACF for DY

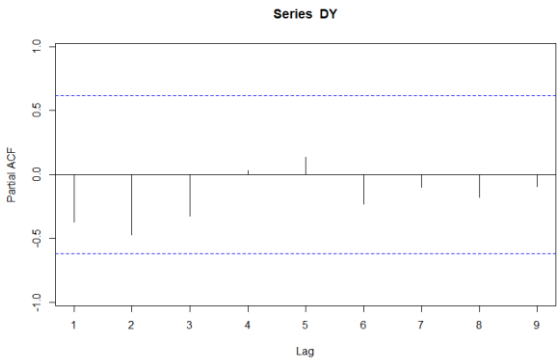


figure 2: PACF for DY

From visually examining the ACF and the PACF we can see that no lag is outside the confidence interval. To choose a model a list of potential models will be created then later inspected. Potential models chosen is:

- fit_arima_011 <- arima(Y, order = c(0, 1, 1))
- fit_arima_012 <- arima(Y, order = c(0, 1, 2))
- fit_arima_013 <- arima(Y, order = c(0, 1, 3))
- fit_arima_110 <- arima(Y, order = c(1, 1, 0))
- fit_arima_210 <- arima(Y, order = c(2, 1, 0))
- fit_arima_310 <- arima(Y, order = c(3, 1, 0))
- fit_arima_111 <- arima(Y, order = c(1, 1, 1))

3.1 Choosing model

The selection process will use AIC as a selection criterion. The model which minimizes the AIC score will be chosen. Results:

- fit_arima_011 <- arima(Y, order = c(0, 1, 1)) – AIC = -3,22
- fit_arima_012 <- arima(Y, order = c(0, 1, 2)) – AIC = -1,33
- fit_arima_013 <- arima(Y, order = c(0, 1, 3)) – AIC = -2,76
- fit_arima_110 <- arima(Y, order = c(1, 1, 0)) – AIC = -2,63
- fit_arima_210 <- arima(Y, order = c(2, 1, 0)) – AIC = -3,99
- fit_arima_310 <- arima(Y, order = c(3, 1, 0)) – AIC = -2
- fit_arima_111 <- arima(Y, order = c(1, 1, 1)) – AIC = -1,23

The chosen model is fit_arima_210

4. Forecasting

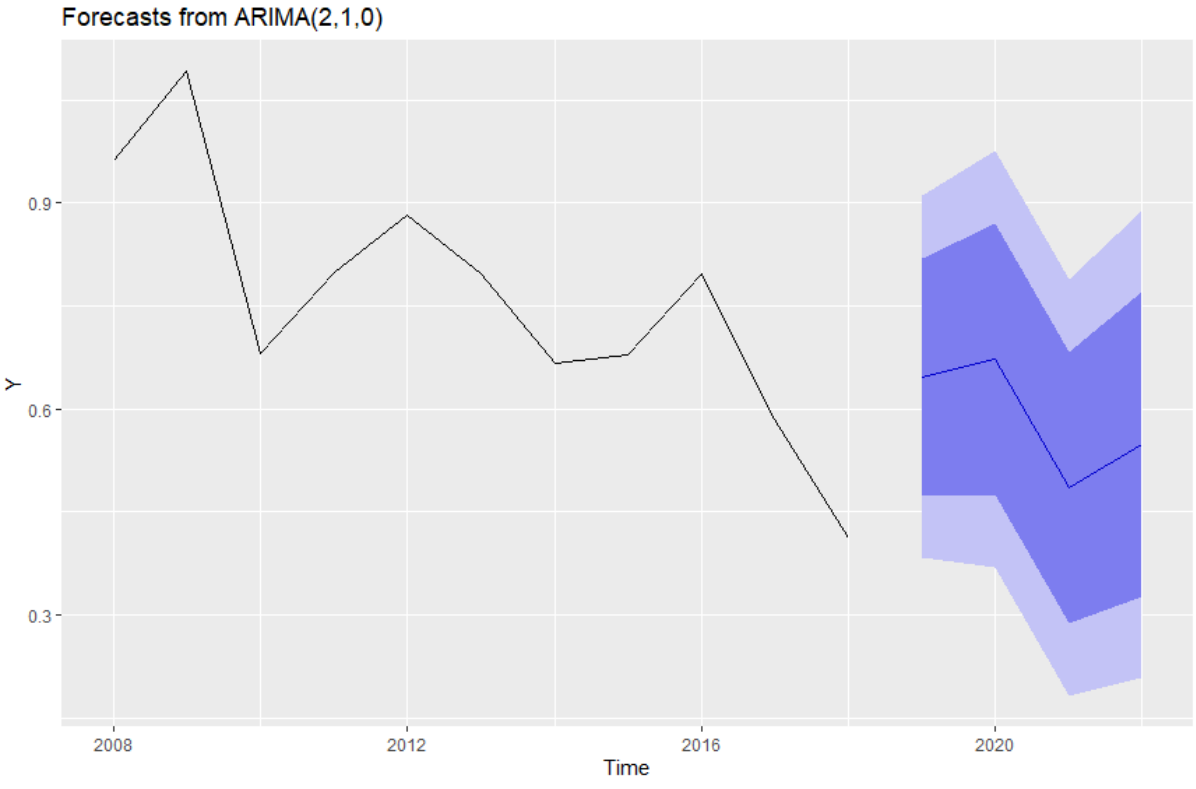


Figure 3: ARIMA forecast(2,1,0)

Forecasted values:

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2019	0.6497307	0.4769867	0.8224746	0.3855416	0.9139197
2020	0.6801322	0.4840004	0.8762640	0.3801745	0.9800899
2021	0.4905754	0.2944321	0.6867186	0.1906002	0.7905505
2022	0.5459607	0.3274759	0.7644454	0.2118171	0.8801042

Analysis of results:

The model reflects the COGS analysis from the industry analysis. As a steep drop tends to be followed by an increase in the COGS the following year. Micron has announced they will reduce capacity which should increase the COGS / Revenue. In 2019F Micron will also introduce 3D Xpoint which will take time to reach yield to maturity. As the bust cycle is estimated to move over to a boom cycle in 2020F the COGS will decrease as capacity is added, and the products reaches a better yield to maturity.

Abbreviation

DRAM – Dynamic random-access memory
NAND – Nonvolatile computer memory
SSD – Solid state drive
SNBU – Compute and networking business unit
MBU – Mobile business unit
SBU – Storage business unit
EBU – Embedded business unit
IoT – Internet of things
ASAD – Advanced driver assistive systems
VR – Virtual reality
AR – Augmented reality
GCCM – Global cloud computing market
GCSTM – Global cloud storage market
ROCE – Return on capital employed
CE – Capital employed
WC – Working capital
NWC – Net working capital
DCF – Discounted cash flows
FCFF – Free cash flow to the firm
CAGR – Compound annual growth rate
CAPM – Capital asset pricing model
EV – Enterprise value
EQV – Equity value
EPS – Earning per share
USD – U.S Dollar
GDP – Gross domestic product
MRP – Market risk premium
E[r] – Expected return
ROA – Return on assets
ROE – Return on equity
F – Forecasted
YoY – Year over year
QoQ – Quarter over quarter
WACC – Weighted average cost of capital
CAPEX – Capital expenditures
D&A – Depreciation and amortization
SG&A – Selling, general and administration expenses
PP&E – Property plant and equipment
SOX – Philadelphia semiconductor index
S&P 500 – Stock market index
MU – Micron Technology, Inc. Stock ticker
AAPL – Apple, Inc. Stock ticker
GOOG – Alphabet, Inc. Stock ticker.

References:

Author Unknown. (2018). "DRAM and NAND Flash Prices Will Dive in Q1 2019." EPS News.
Both DRAM and NAND flash prices are expected to decline in the 10-percent range in the first quarter (Q1) of 2019, according to DRAMeXchange

Author Unknown. (2019). "Guide to Balance Sheet Projections."
Common approaches to forecasting balance sheet line items when building a 3statement model.

Author Unknown. (2019). "NAND memory market share by application worldwide 2019 | Statista." Statista.
The statistic shows a forecast for the distribution of demand for NAND memory bits worldwide in 2019, broken down by device segment.

Author Unknown. (2019). "Time series analysis with R."
A guide for time series analysis with R.

Bokeria, G. F, Matthias. Rahman Sascha (2019). "Future of the Semiconductor Industry: Profitable Growth With New Dynamic Market Trends."
The semiconductor industry faces new challenges in the future . Our experts Grigori Bokeria and Matthias Frahm point out new opportunities for growth.

Duberstein, B. (2018). "Why It's NOT Time for Micron to Start Paying a Dividend | The Motley Fool."
Some shareholders may want the memory giant to start paying a dividend, but not this one.

Electronics, S. (2018). Samsung Electronics FY2018 Annual Report. Samsung investor relations.

Handel H, J. D. (2019). "Memory Technology and Overall Trends in the Semiconductor Industry."
Semiconductor industry overview from SEMICON TAIWAN

Heck, S. K., sri. Pinner, Dickon (2011). "Creating value in the semiconductor industry."
Article from McKinsey on creating value in the semiconductor industry

Intel (2018). Intel 2018 Annual Report. Intel investor section.
The intel 10-K report has been used to analyse Microns competitors and industry analysis

Investment, Z. (2018). "Micron: No Longer A Commodity Manufacturer."
Micron is no longer a commodity memory manufacturer. In the second half of 2019 Micron will start shipment of 3D XPoint. 3D XPoint is promising to be a fundamen

McClure, B. (2019). "The Ups And Downs Of Investing In Cyclical Stocks."
This strategy can be profitable but only if you know when to dump these stocks.

Mellor, C. (2019). "3D XPoint needs to be bigger and cheaper. But how will it get there? – Blocks and Files." Block and Files.
Compared to NAND flash, Intel's Optane DIMM product is low on capacity and high on price. Increasing its capacity should lower the cost/GB and so help address both issues. How might this be done? Optane DC Persistent Memory is Intel and Micron's 3D XPoint (3DXP) in a DIMM form factor with 128GB, 256GB and 512GB ...

Rees, M. (2008). Financial Modelling in Practice, Wiley.

Segal, T. (2019). "Semiconductors: Understanding the Objects That Power Our Digital Lives."
Found in thousands of electronic products, a semiconductor is a product which conducts electricity more than an insulator but less than a pure conductor.

Technology, M. (2018). 10-K report 2018. investors.micron.com.
The 10-report is the main source for all company data. The report is the source for the past IC, BS and CF statements.

Walter, T. (2019). "Time Series Analysis in R Part 2: Time Series Transformations."

In Part 1 of this series, we got started by looking at the ts object in R and how it represents time series data. In Part 2, I'll discuss some of the many time series transformation functions that are available in R. This is by no means an exhaustive catalog. If you feel I left [...]