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Financial Impacts of the Semiconductor Shortage on Original Equipment Manufacturers (OEM)

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Abstract

Does the semiconductor shortage impact Automotives Valuation? Although there are many literatures and opinions on this topic, this paper claims to present a different approach. Driven by insights from practice, a perspective on the coming 3rd year of semiconductor scarcity is opened using the example of the German car manufacturer BMW. Due to a shift in procurement towards general availability of components, changes in value are to be expected. The extent to which these are also applicable to other OEMs remains open, but this effect could be explained in the form of a new factor model. The recommendation grounded in the papers evidence: Averse and risk-conscious reporting rationalizes expectations.

Keywords: Semiconductor Shortage, Procurement Strategy, Volatility, Risk Assessment, Value Chain, Corporate Valuation, Capital Asset Pricing Model, Discounted Cash Flow

1. Introduction

Many of the companies dependent on the semiconductor industry are facing difficult times. From a macroeconomic perspective, a structural demand overhang resulting from long-term imbalances between supply and demand. Triggered by external shocks such as the Corona pandemic, and exacerbated by the war in Ukraine, we are now entering the third year of chip-shortage. However, neither technical analyses of supply chains nor external shocks form the core of this paper. Rather, from a business valuation perspective, familiar financial models are applied to analyze the impact of semiconductor shortages on the valuation of OEMs (Original Equipment Manufacturers), initially using the example of Bayerische Motorenwerke AG (BMW). This industry has its own chip supply chain dynamics and is directly affected by the shortage. During the internship in the Corporate & Investment Banking department of a globally operating bank, which I carried out in parallel to writing this Master's thesis, I gained many insights into the current concerns and problems of MNCs (Multinational Companies). Specialized in automotives, I have been following the development of BMW since day one. Each year so far has written its own story and I intend to continue the story of BMW in 2022 in a way of 'pointing the finger' and demonstrating what change I would implement in the financial statements to ensure adequate consideration of the situation. The fact is that the production and procurement strategy is no longer the same. It is empirically ascertainable that OEMs severely affected by the semiconductor shortage have come to realize that a rethink must take place, away from just-in-time procurement. According to King and Naughton (2021), the automotive industry's insistence on maintaining the just-in-time strategy is no longer state-of-the-art in view of increased bargaining power on the supplier side and the ongoing demand situation in favor of optimal inventory costs. According to another article by Bloomberg (Trivedi 2021), JiT pioneer Toyota has finally recognized this, and changed its supply strategy at least for the duration of the crisis, secured increased inventories by means of long-term loan agreements and accepted the associated additional costs. As a result, Toyota was able to report significant improvements in the supply situation. For example, the solution approach to be discussed later in this paper favors increased inventory levels which can be empirically seen at the example of U.S. manufacturers inventory when considering the increase of the inventory level annual growth rate from 09/12 – 09/22 with 2.6% compared to 7.8% between 09/20-09/22 (St. Louis Fed 2022). Accordingly, it must be assumed that, due to the uncertain and volatile market environment, increased position maintenance would directly affect the cash flow of a company which in turn would directly influence the company's valuation according to the DCF (Discounted Cash Flow) model (Runner 2022).

But it is not only the market environment that can be declared uncertain and volatile, but also the product itself: the chip. Based on the returns of indies replicating this industry, it should be assumed that they are also characterized by a high relative risk in the form of the market beta compared to BMW. In combination with the missing transitory parameter of the inventory, this triggered another reception, namely that of the shift in asset risk. What sounds strange at first instance has, in my opinion, a cumulatively substantial, albeit individually marginal, impact given the scope of the problem. The individual impact will be discussed again using the example of BMW; if the suspicion is confirmed, a comparison with the sector will follow.

Ultimately, the question arises whether a structural impact of semiconductor scarcity on the stock performance of car manufacturers and downstream whether this impact is also reflected in the company valuation. As a final and thus concluding analysis of this paper, I would like to discuss to what extent a pre-crisis dependence of automakers leads to lower abnormal returns during scarcity and to what extent this, let's call it chip beta, is also responsible for any relative firm valuations. This hypothesis can also be tested using appropriate regressions.

2. Literature Review

2.1 The semiconductor shortage and the automotive sector

The fact that sales of semiconductors have almost doubled in the last decade is not yet an indicator of a general shortage, but it is definitely a sign of high demand, which has also recently experienced a significant boost (European Central Bank 2021). The Semiconductor Industry Association issued a press release on the 1st of August 2022 stating that the global semiconductor sales rose 13.3% in 2Q2022 compared to previous year's quarter (Semiconductor Industry Association (SIA) 2022). Furthermore, in conjunction with the World Semiconductor Trade Statistics database, forecasting that the global semiconductor market will grow by 16.3% in 2022, followed by 5.1% growth in 2023 (World Semiconductor Trade Statistics (WSTS) 2022). In addition to that, the semiconductor sales revenue reached its all-time peak in sales revenues with $51.82bn in May 2022 (SIA and WSTS 2022). This is in irreconcilable contrast to the law established by Intel founder Moore in 1965 who stated that "the number of transistors incorporated in a chip will approximately double every 24 months" (Moore 1965) which would generally imply that more transistors fit into smaller spaces, processing power increased, and energy efficiency improved, all at a lower cost for the end user (Intel 2022). This can be explained solely by the fact that demand has increased all the more.

According to Burkacky *et al.* (2022a) the current digital transformation will lead to a sustained boom in the semiconductor industry, which he estimates will be worth $1 trillion by the end of the decade. He defines the digital transformation in concrete terms as the growth of applications including AI, increasing demand for electric cars and the general trend toward remote working. As a consequence of this "manufacturers and designers should now take stock and ensure they are best placed to reap the rewards" (Burkacky *et al.* 2022a). "Drilling down into individual sub-segments, it is estimated that about 70 percent of growth will be driven by just three industries: automotive, computation and data storage, and wireless" (Burkacky *et al.*

2022a). The breakdown of market demand and growth expectations by industry can be found in Appendix 1.

In another paper, Burkacky *et al.* (2022b) notes that the automotive industry in particular is pursuing a “just-in-time” procurement strategy in the interest of optimal inventory costs. This led to a corresponding decline in (long-term) orders for semiconductors in the face of lower demand for vehicles in early 2020. An approach that took its revenge, as it was not possible to respond accordingly to improved demand due to a lack of inventories. Those companies and industries not following the “just-in-time” method were in a much better position at this time, as additional capacities were secured when automotive players cancelled or reduced their orders.

This assertion was fully reiterated by the management consultancy Roland Berger, which noted that semiconductor shortages have caused OEMs to think strategically about semiconductor supply rather than continue to see it as purely an automotive component. Therefore, they are changing their strategies from just-in-time to just-in-case, and accumulating semiconductor inventories. From an OEM’s point of view, this will only intensify the shortage in the short term (Meissner *et al.* 2021). JiT pioneer, Toyota; stated on a company website, that Covid-19 was trigger and contributor at the same time, since it slowed production and caused major shipping delays across the globe. In symbiosis with increasing innovations and accordingly increased demand for chips as well as a fallacy regarding the automotive sales forecasts back in March 2020 which finally lead to the inability of serving the even increased demand (Bullwhip-Effect) in light of the long lead times for semiconductors (Toyota 2022).

In an earlier post, Burkacky (2021) summarized argumentatively that companies might have to reconsider, at least in part, the current practice of just-in-time delivery and low stock levels along their delivery chains. A trend that was also comprehensively highlighted in a Financial Times article published on the 20th of December 2021. This article highlighted the insistence of car manufacturers to make the delivery obligations of semiconductor producers binding over the more long-term. to guarantee their continued access to devices (Masters and Edgecliffe-Johnson 2021). Based on another article by McKinsey & Co, these long-term supply contracts lead first and foremost to the suggestion that “61 per cent of companies had increased inventory of critical products and 55 per cent had taken action to ensure they had at least two sources of raw materials” (Alicke *et al*. 2021). In light of the semiconductor scarcity this has led to a surplus ordering of the automotive industry in the range of 10% to 20% more than needed to ensure inventory and safeguard production (Burkacky *et al.* 2022b).

Considering the assessment conducted by Dylan Walsh the very first initiative is that “Most immediately, companies are taking whatever microchips they can get and then building more adaptive manufacturing processes to deal with the obstacles that arise from this indiscriminate approach” (Walsh 2022). The chapter began with Intel's founder and his law and should now close with the prognosis of the current CEO Pat Gelsinger who predicted to the news provider CNBC that he expects restrictions due to the semiconductor shortage until 2024 (Stankiewicz 2022). This estimation is used as a reference for the following considerations.

2.2 Corporate Valuation

Very briefly, I will explain the well-known CAPM and go into the special features that are relevant for the further analysis. There are many different reasons for undertaking a business valuation (Bachl 2007). Business valuations are most common in the context of mergers and acquisitions (Schmeisser and Spree 2008). The DCF (Discounted Cash Flow) method has been the standard method for valuing companies for many years. Its basic idea follows the net present value calculation of investment appraisal. In the DCF method, the enterprise value is determined by forecasting and discounting future cash flows. The rationale behind this is that the value of a company is derived from its future cash flows (Wala *et al.* 2010). An overview that divides the DCF into a total of five different operations can be found in Appendix 2. Cash flow represents the surplus of payments, which is the expected future benefit that the company may choose to provide to its investors (Ernst *et al.* 2008). A schematic calculation of the FCF (Free Cash Flow) can be found in Appendix 3. Furthermore, a detailed practice oriented FCF calculation can be found in Appendix 9 using the example of BMW. To spare further basics, I refer you to Appendix 4 which contains what I consider to be a useful overview of WACC dervation. NWC (Net Working Capital) plays a special role here and will be discussed below.

NWC, or the change in it over a given period, consists of four components: cash, inventory, payables, and receivables. The management of the second, inventory, plays an important role in the business activities; purchasing, production, and marketing (Crum *et al.* 1983) while maintaining appropriate inventory levels is associated with the cycle of business activities, and it incurs inventory related costs such as ordering, carrying, and stock out costs (Moyer *et al.* 2009). The approach taken in inventory management directly influences the working capital performance (Yang *et al.* 2005). Holding too much inventory may incur high carrying costs; however, it also reduces risk of ‘stock-out’ shortages which could be even more costly (Krane 1994).

Markowitz (1952). Sharpe (1964) and Lintner (1965) discovered the Capital Asset Pricing Model (CAPM) which assumes investors in capital markets make investment decisions based on their individual risk-return trade-offs and generally prefer mean-variance portfolios. For theoretical interpretation, the CAPM underlies certain assumptions. The fundamental assumptions to highlight are a) the existence of a market portfolio, b) containing all available assets, investors' risk aversion and c) their focus on the mean and variance of a single-period investment. The formula for the traditional CAPM is stated as follow in equation

$$Return_i = r_f + \beta_i * (Return\ (Market\ Portfolio) - r_f)$$

the expected return of security i equals the risk-free rate plus securities’ i market risk factor times the excess return of the market portfolio over the risk-free rate (Appendix 5).

In the CAPM, the beta factor measures the systematic risk of a listed company i compared to the market portfolio. The systematic risk is the risk element that cannot be eliminated by investors through diversification (Damodaran 2006a and Damodaran 2011).

Despite its significant relevance to value, the determination of the beta factor regularly poses great challenges to valuation in practice, not only due to the large number of degrees of freedom and scope for discretion (Hierzenberger 2013). Against this background, the following three approaches to determining the beta factor of a company have emerged:

a) Determination based on fundamental information, b) determination based on implicit information and c) determination based on historical information. It will be limited to the explanation of the latter, as the approach most relevant to this work. The determination of the beta factor based on historical returns of the respective security is the most recognized and popular method in German and international valuation practice (Ziemer 2015 and Damodaran 2006b). For building the theoretical market portfolio it must be determined whether a global, regional or local stock index is used for the respective regression analysis (Castedello 2014).

In addition, the observation period as well as the observation interval for the yield measurement must be defined, in principle daily, weekly or monthly returns can be measured.

In the final step, the determined and tested beta factors must generally be adjusted to the future capital structure of the valuation object (Aschauer and Purtscher 2011). Given the capital structure trade-off theory, firms either decide to target a certain leverage ratio by contrasting debt benefits and costs (Modigliiani and Miller 1958). The unlevered beta is calculated on the basis of the leverage ratio as well as the equity and debt beta, which can be determined using the CAPM. The formula is as follows:

$$Unlevered\ (Asset)\ \beta_i = Levered\ (Equity)\beta_i * \frac{E}{(D+E)} + Debt\ \beta_i * \frac{D}{(D+V)}$$

Without going into detail on cash flow forecasting techniques, it should be added that, in addition to the annualized discounting of the known/estimable cash flows, the calculation/estimation of the terminal value takes place (Copeland *et al.* 2002). However, I refrain from doing so, as it is only intended to provide information on the marginal change in the company's value during the period of the semiconductor shortage. To determine the terminal value, it is usually assumed that the valuation-relevant cash flow of a company grows or remains constant during the second phase. The present value of phase one and the present value of phase two form the basis for the enterprise value (Frühling 2004). The most important steps and interrelationships can be seen in the schematic figure (Appendix 6).

2.3 Exchange Traded Funds (ETF)

One difficulty to be overcome is the tangibility and measurability of the scarcity situation. Therefore, it is important to explain how ETFs work, since synthetic replication can be used to replicate companies in certain sectors, in this case the semiconductor industry. An analysis of the past performance of these indices makes it possible to establish a relationship to other sectors. An exchange traded fund is an index fund that is traded on the stock exchange (Krauss 2015). It is usually passively managed and differs in several respects from traditional active investment funds (Harrer 2016). One key difference is, for example, that ETFs do not explicitly aim for a positive tracking error relative to a given index. Rather, they imply the inherent intention to track it as closely as possible (Gunter 2013). Tracking error (TE) is a relevant management metric for ETFs and is often seen as a risk indicator. It determines the accuracy of index tracking by indicating the deviation between portfolio return and the corresponding benchmark (Bruns and Meyer-Bulldiek 2013). The main components to be identified are, for instance, management fees, custody fees, tax payments or transaction costs, as these are not considered or do not appear in an index (Zimmermann 2017).

The fundamental difference between alternative ETFs lies primarily in their replication styles, i.e. the way an index is replicated in the issued product. In this context, a fundamental distinction must be made between physical and synthetic replication. In the case of physical replication, index replication can be carried out using various methods. Issuers can choose the full replication method, which is probably the most trivial approach from a conceptual point of view. As the name suggests, the index is replicated one-to-one, and the ETF portfolio contains the same securities as the index itself. The weighting of the individual securities is congruent between the fund portfolio and the index (Götte 2010).

In contrast to physical replication, the securities of the target index are not explicitly acquired in the synthetic approach, but an attempt is made to replicate the performance using alternative methods. For example, the issuer launches a specific ETF whose holdings may differ significantly from the underlying index. So-called swap contracts are concluded to replicate the performance of the benchmark (Engst 2017). As a rule, these imply a contractual obligation that the swap counterparty must deliver exactly the performance achieved by the selected index. Since the latter condition is completely determined, a low tracking error usually results (Picard and Braun 2010). A significant difference between the individual replication types lies in the indices they can track. ETFs, which are constructed via swaps, allow participation in almost all markets. For example, “emerging markets, currencies, commodities or short strategies can be mapped at low cost” (Götte 2010) (Appendix 7 and 8).

3. Data Presentation and Analysis

3.1 Case Study BMW

As already mentioned, I was responsible for OEMs as part of my internship and accompanied the development of BMW in particular. Various appointments gave me an insight into the problems the car manufacturer sees, with the context of the semiconductor shortage playing a special role. Topics of discussion included working capital solutions to prevent the volatile price environment and, more fundamentally, obtaining the bank's expertise for effective sourcing. A meeting with senior executives and technical experts from the car manufacturer on the one hand, and equally qualified participants from my bank on the other, dealt in depth with the fact that the automotive sector is not defying the warnings of many analysts of a lack of demand facing the looming pandemic. It was only the collective cancellation of orders for the chips, which take an average lead time of six to nine months (Hansen 2021), before delivery, that led to the actual outbreak of the crisis, as already described in the introduction. In hindsight, it is always easy to say "what if", but the discussions also moved towards the problem that, given the aforementioned production and procurement changeover, a negative scenario is to be expected, which could show up for the first time in the balance sheets of the calendar year that is coming to an end: The short-lived usability and timeliness of the chips could lead to a collective exit from these devices and related components, given the windy pace of innovation, especially at EV- and thus R&D-heavy BMW. I now step into the lender's shoes who, given the external influences, makes his own calculation, based on the circumstances of BMW AG.

Therefore, I will now use the example of the accompanied car manufacturer to show what a corresponding balance sheet consideration might look like. The significance of the topic is determined by analyzing the marginal change in the automobile segment value. Although this has already been taken into account, a dilemma arises against the background of the generally ambitious forecasts currently being made. In order to be able to meet them, the cash-rich car manufacturer is dependent on consistent compensation orders. I would also like to illustrate this by means of an increased cost component and the corresponding effects on the stock and discuss a valuation-relevant effect.

I would like to start with what the three scenarios presented have in common. A) The situation: We are at the end of the year and are considering a fictitious year-end in 2022. B) The period: Two years of crisis are behind us, and according to experts there will be at least two more ahead of us. Therefore, the projection period is 2022-2024. C) The schematic simplification: Due to the divergences in the derivation of the cash flows, the forecast was formed on the basis of the past ratios between EBIT and FCF as reported by BMW. I am aware that this does not correspond to the basic procedure for determining FCF, but this simplification serves the purpose of comparability and is expedient in view of the given constancy of the ratio. Moreover, it is common practice that the company strives to establish a relative constancy in these parameters. Further common principles can be found in the following overview:

Valuation			
WACC-Impact			
Steps	**Values**	**Considerations**	**Factors**
Empricial Market Beta BMW	1.062	Regression-based	
Return on Equity BMW	9.71%	CAPM	
		Risk Free Rate (Germany)	2.19%
		MRP	9.27%
WACC	5.49%	D/E - Ratio BMW	1.412
		Debt Beta BMW	0.20
		Cost of Debt BMW	3.61%
		10 Year avg. Tax Rate	30.80%
Unlevered/Asset ß BMW	0.558		

The derivation of these parameters requires an explanation: I first became aware of the topic, which immediately aroused my interest, after the publication of the quarterly figures on 30.09.2022. This was the decisive factor in my decision to base the determination of the respective CAPM market betas on a 10-year period. Specifically, I took the aforementioned properties of a total of seven semiconductor indices (product information sheets are included in the supplement) and generated their weekly returns using Capital IQ in the period from 5 October 2012 to 5 October 2022. I did the same for the returns of BMW AG and the uniform benchmark in the form of the iShares MSCI World Index ETF. The suitability of using this market benchmark for a DAX-listed car manufacturer is certainly debatable but given the global nature of today's supply chains and the simple need for comparability, this seemed to me to be the most appropriate compromise. The objective of this operation was to generate a comparison of BMW's market risks against the semiconductor indices. For BMW, this results in a coefficient (market beta) of 1.06, while that of the chip indices is 1.27. The respective regression outputs can be found in Appendix 10. The coefficient for BMW is based on an R^2 of 0.35, which can be interpreted as meaning that 35% of BMW's risk (variance) can be explained by the market portfolio, while 65% is attributable to company-specific risks that could potentially be explained by other factors. The last remark on this regression is the reference to the statistical significance at each commonly used confidence level on the basis of the p-value of 0. In addition, the Jensen alpha could be determined by means of the intercept, with the aid of a risk-free rate, but this is not part of the core of this work. In principle, I will refrain from explaining the regression parameters in the following and will only refer to the R^2 and p-value. Accordingly, it should be noted that the R^2 for the semiconductor regression is 0.64 and also statistically significant at each commonly used confidence level. In terms of the CAPM, the following formula could now be constructed for BMW resulting in its equity cost of capital:

$$Return\ (BMW) = 2.19\% + 1.069 * (9.27\% - 2.19\%) = 9.71\%$$

The fact that any credit risk can be traced back to the parent company, which is located in Munich, Germany is simultaneously the justification why the German risk-free rate of 2.19% (St. Louis Fed 2022a) is applied to the CAPM. In addition, the return of the market portfolio is based on the annualized return of the iShares MSCI World Index ETF. The cost of debt is 3.61%. The tax rate is taken from the Annual Report 2021 and amounts to 30.8% (BMW Group 2021, 171). In symbiosis with the debt-to-equity ratio for the automotive segment determined based on the Annual Report 2021 (in € mio.) of 141.2% the WACC of 5.49% is now calculable. In order to anticipate the later need to calculate the unlevered (asset) beta of BMW, this can be represented accordingly by rearranging the formula as follows:

$$\frac{D}{E} = \frac{18{,}518 + 55{,}504}{50{,}296} = 141.2\%$$

$$WACC = \frac{1.412}{2.412} * 3.06\% * (1 - 30.8\%) + \frac{1}{2.412} * 9.72\% = 5.49\%$$

The purpose of the first model is to create a fictional situation at the end of 2022 according to which the corona pandemic and the associated semiconductor shortage would not have occurred:

Marginal Segment Valuation Impact				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (NS)				
CF		4,971	5,175	5,388
WACC		5.49%	5.49%	5.49%
PV	**13,954**			

The second scenario is intended to be as close to reality as possible in view of the publication of the 3Q2022 quarterly figures and the forecast contained therein. BMW's key determinant has always been EBIT or the EBIT margin, which is expected to be in the range of 7% - 9% for 2022. As I have actively followed the business development from the lender's side and also gained insight into stipulated covenants, I know that this is one of BMW's concerns. I would like to use this 2% margin, also with regard to the last scenario presented. At this point, it would also have been possible to discuss the usefulness of products that can be attributed to the working capital solution, but I am rather aiming at a different issue. For this, let's call it just-in-time scenario, we set the EBIT margin for 2022 at 8.00% and let it remain constant over time. Furthermore, we rely on the adequate projection of the assumed variables based on the average of the presented historical calculations as well as the CAGR for some figures such as revenues. In summary, this appears as follows:

Marginal Segment Valuation Impact				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (JiT)				
CF		5,118.38	5,278.55	5,443.74
WACC		5.49%	5.49%	5.49%
PV	**14,234**			

Finally, we come to the third and last case: the Just in Case scenario. This comprises my actual recommendation for action and personal forecast about the current circumstances, i.e. the lack of transitory stocks and their accumulation as a consequence of the shortage situation. Although it will be referred to again at a later point in time, I would like to emphasize again that this is not only explicitly aimed at the chip itself, but also the upstream and downstream production stages (e.g. the lack of semiconductors to ensure the window function also causes a congestion at any switches or even at windows themselves). Seen in this way, the risk created by the semiconductors also replicates the risk of a resulting production congestion caused by them. The keyword here is therefore: value chain-induced risk.

In the next step, it is decisive which share of the inventory is to be declared as semiconductor (& -related components). For this purpose, I draw in equal parts on surveys, assumptions and the annual report. The latter writes on page 102 that "the increase in inventories [was] resulting from production adjustments caused by semiconductor supply bottlenecks." Multiplied by the counted 3-year moving average growth rate of the years 2012-2021, I set the difference between inventories in 2021 and 2020 at $€\,14{,}868m - €\,13\,391m * (1 + 5.5\%) = €\,1{,}558m$. However, I would also like to add another circumstance with which I introduced the JiC scenario: Since OEM semiconductor and affected inventories should not be regarded as transitory items, there should also be no direct allocation as cost of sales. As inventories are no longer directly linked to product sales, IAS 2 is thus partially overridden which states: "When inventories are sold, the carrying amount of those inventories is recognized as an expense in the period in which the related revenue is recognized. The amount of any write-down of inventories to net realizable value and all losses of inventories are recognized as an expense in the period the write-down or loss occurs" (IFRS 2022). Assuming and wisely anticipating that inventory write-downs may become necessary as a result of the procurement transition, I would proactively, and certainly in line with many auditors, propose an approach at the lower end of the projected EBIT margin of 7-9%. The difference to the JiT scenario above will either take the form of an inventory write-down or be classified as pre-emptive. Be that as it may, we save ourselves the double consideration of depreciation in the income statement and the cash flow statement, since the effect of depreciation cancels each other out. A special feature of the approach taken, however, is that the FCF is formed from the ratio with the EBIT. (No outflow of funds although outflow of value). This component is measured at $(8\% - 7\%) * € 96{,}000m = €960m$, whereas the € 96,000m as well as the 7%-9% forecast EBIT margin is based on the 3Q2022 forecast, which predicts slightly lower deliveries in terms of revenue, I assume that (at least) the same revenue will be achieved in 2022 by means of price adjustments. Cumulatively, the semiconductor-related inventories derived in this way amount to $€\ 960m + €\ 1{,}558m = €\ 2{,}518m$. Measured against the total automotive assets of € 121,318m, the share is 2.08%. The identified increased risk in the assets has been identified and is now quantified according to the share in the total assets of BMW. In a first step, it is necessary to unlever the beta of BMW (debt beta was previously calculated using the CAPM):

$$Unlevered\ (Asset)\ ß = \frac{1.412}{2.412} * 0.2 + \frac{1}{2.412} * 1.062 = 0.558$$

Based on the data presented by A. Damodaran, this can be repeated for the chip industry. (Damadoran 2022). According to the thesis that the semiconductor share must now be adequately considered in the risk assessment, the following correlations arise, which can be seen in detail in the supplement:

ß Equity Semiconductors	1.269	Regression-based	
Unlevered/Asset ß semiconductor	1.208	Risk-free Debt / Debt ß Semiconductor	0.287
		SEMI D/E-Ratio:	0.0678
Share semiconductors & components of assets	2.08%	Semiconductor & Components in inventory:	2518

Share other assets	97.92%
New unlevered/asset ß	0.736
New ß Equity BMW	1.086
New Return on Equity BMW	9.88%
New WACC	5.56%

In deriving the semiconductor ratio, I mentioned that I assume that inventories are depreciated at the end of the year. However, since the depreciation effect is offset by the calculation of cash flow from the ratio to EBIT, another effect comes into play in my JiC scenario: Despite tailwinds from price increases and headwinds from the chip shortage, constant sales were predicted. To make this possible, a reaction to the write-off must take place in terms of compensatory purchases of additional inventory. We assume that the effect will mitigate over time or even out by the end of 2024 and that the EBIT margin will develop positively accordingly (7.5% in 2023, 8.0% in 2024). As mentioned earlier, to keep the process as simple as possible, this compensation is assumed to be equal to the EBIT difference from the JiT scenario. In a nutshell, the impacts combined looks as follows:

Marginal Segment Valuation Impact				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (JiT)				
CF		5,118.38	5,278.55	5,443.74
WACC		5.49%	5.49%	5.49%
PV	**14,234**			
C.P. Impact (JiC)				
CF		3,518.58	4,445.37	5,444.68
WACC		5.58%	5.58%	5.58%
PV	**11,946**			
Percentage Change	-16.07%			

A decomposition of the effects as well as a comparison of described scenarios and a sensitivity analysis of the variables can be found in Appendix 11.

Analogous to this case study, I expect a lower cash flow as a result of additional expenses that have become necessary, which is to be declared as a BMW-individual component. However, the fact that asset betas have increased as a consequence of the semiconductor shortage would be an empirically verifiable circumstance that I would now like to investigate.

3.2 Increased Automotive Asset Risk - Pattern or Fallacy?

In order to investigate the extent to which there was a fundamental increase in asset beta during the semiconductor shortage, I again use the tool of regression. This time, however, a comparative value and a comparative period are needed, so that a comparison group must be selected in a first step. The second step is to calculate the unlevered beta of this peer group before the shortage. An individual analysis of each was dispensed with in this step and reliance was placed on diversification across the range of all OEMs. Accordingly, the key figures D/E ratio, interest expense and net debt were generated via Capital IQ, while the statutory tax rate of the countries of the respective companies was based on an OECD publication (OECD 2022).

The equity beta, on the other hand, was again determined by means of a regression against the selected market portfolio for which the iShares MSCI World Index ETF is consistently used. The frequency of the generated data was always weekly, and the data collection period was from 08.01.2010 - 01.01.2020, which is why the risk-free rate in the form of the U.S. government bond was used based on the yield as of 02.01.2020 in the amount of 1.88% (U.S. Treasury 2022). The following figure summarizes the results:

Comparable Data

Prior Shortage

Comparable	Beta Levered (2010-2020)	D/E	Debt/EV	Cost of Debt	Equity/EV	Statutory Tax Rate	Debt Beta	Beta Unlevered	Interest expense	Net Debt
Toyota	0.81	102.0%	50.5%	0.16%	49.5%	29.7%	0.09	0.45	44114.00	18972945.00
Mitsubishi	1.08	116.8%	53.9%	0.85%	46.1%	29.7%	0.46	0.75	70038.00	5787415.00
Volvo	1.39	115.3%	53.6%	1.15%	46.4%	20.6%	0.62	0.98	1562.00	108104.00
Ford	1.24	568.0%	85.0%	0.57%	15.0%	25.8%	0.31	0.45	1034.00	134404.00
Mercedes	1.35	234.3%	70.1%	0.15%	29.9%	29.8%	0.08	0.46	261.00	120030.00
VW	1.41	158.0%	61.2%	1.05%	38.8%	25.8%	0.57	0.89	2291.00	161731.00
BMW	1.28	194.6%	66.1%	0.28%	33.9%	29.8%	0.15	0.54	438.00	108473.00
Renault	0.99	228.9%	69.6%	0.58%	30.4%	25.8%	0.31	0.52	351.50	45256.00
Hyundai	0.61	113.9%	53.3%	0.38%	46.7%	27.5%	0.20	0.39	316186.00	60998210.00
Saab	1.63	54.0%	35.0%	4.46%	65.0%	20.6%	2.41	1.91	277.00	4928.00
Mean				0.96%			0.52	0.73		
Median				0.57%			0.31	0.53		
Beta Unlevered	**0.53**									

According to the hypothesis derived from BMW, an unlevered (asset) beta of more than 0.53 should be expected if the period adjusted is 10/01/20 - 01/12/22, i.e. approximately the declared period of scarcity. The risk-free rate is again the US government bond, this time as of 01.12.2022 in the amount of 3.53%. However, after performing the same steps results:

Comparable Data

During Shortage

Comparable	Beta Levered (2020-2022)	D/E	Debt/EV	Cost of Debt	Equity/EV	Statutory Tax Rate	Debt Beta	Beta Unlevered	Interest expense	Net Debt
Toyota	0.64	102.9%	50.7%	0.11%	49.3%	29.7%	0.059340058	0.34	32458.00	20785352.00
Mitsubishi	0.42	76.7%	43.4%	0.91%	56.6%	29.7%	0.49	0.45	68148.00	5277977.00
Volvo	1.14	125.5%	55.7%	0.67%	44.3%	20.6%	0.36	0.71	1183.00	139565.00
Ford	1.85	308.3%	75.5%	1.05%	24.5%	25.8%	0.57	0.88	1379.00	97788.00
Mercedes	1.44	136.3%	57.7%	0.26%	42.3%	29.8%	0.14	0.69	353.00	97004.00
VW	1.38	107.8%	51.9%	1.03%	48.1%	25.8%	0.56	0.95	2221.00	160226.00
BMW	1.04	114.6%	53.4%	0.12%	46.6%	29.8%	0.06	0.52	140.00	84963.00
Renault	1.48	215.5%	68.3%	0.71%	31.7%	25.8%	0.39	0.73	386.00	40147.00
Hyundai	1.27	568.0%	85.0%	0.36%	15.0%	27.5%	0.20	0.36	442083.00	88465385.00
Saab	0.72	35.1%	26.0%	-11.39%	74.0%	20.6%	-6.15	-1.06	307.00	-2141.00
Mean				-0.62%			-0.33	0.63		
Median				0.52%			0.28	0.60		
Beta Unlevered	**0.60**									

It turns out that based on the generated data there has indeed been a shift in the unlevered asset beta. It is not possible to generalize this statement in view of the relatively small peer group and the lack of transparency of the generated data.

3.3 The Chip Beta

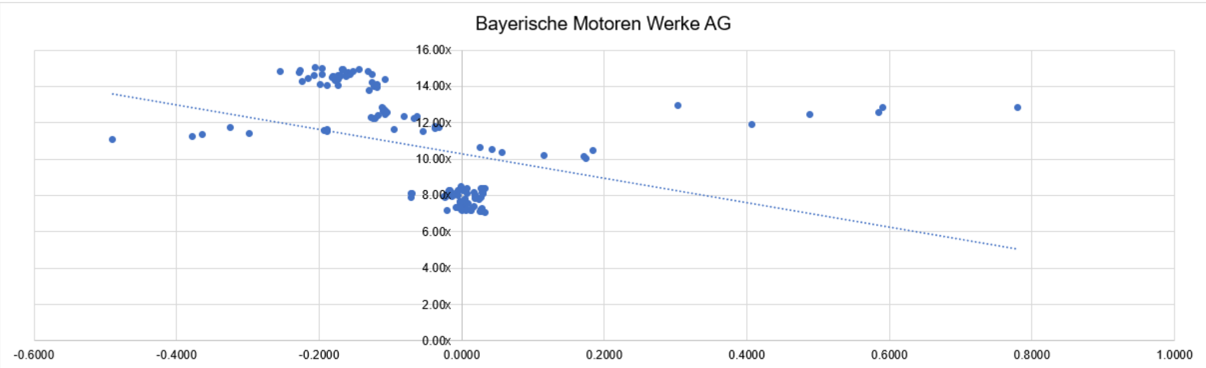
Finally, I raise the question of whether and to what extent there is a structural demonstrable relationship between semiconductor scarcity and the eventual performance of the selected automotive peer group. To answer this question, I choose a congruent approach to the previous chapter. This time, however, the explanatory power of the stock performance is to be obtained by an extension of the CAPM. The determination is done by a multivariate regression so that the dependent variable remains the stock returns of the respective car manufacturers, while a chip beta is introduced as an additional independent variable besides the market beta. The objective function of the regression would look as follows:

$$Expected\ Return_{\mathrm{i}} = \beta_{\mathrm{i,\,m}} * (\mathrm{MRP}) + \beta_{\mathrm{i,\,chip}} * (\mathrm{factor\ premium}) + \alpha_{\mathrm{i}}$$

I now apply this model to the weekly past returns of automobile manufacturers in the period 08/01/2010 to 01/12/2020. While the market beta is calculated based on the MSCI World Index, the chip beta is calculated based on the average return of the semiconductor ETFs. The further steps are based on the hypothesis that with a high value of the chip beta comes a high attachment (and thus dependence) to the semiconductor industry. Hence, I want to check to what extent the OEMs with high factor exposure have achieved low abnormal returns during the actual crisis. The abnormality of the returns is measured by a benchmark, namely the NASDAQ OMX Global Automotive. The following table summarizes the results, sorted in descending order by the level of the chip beta factor.

Company	ann. Return	abnormal return	Chip Beta	Market Beta	CAPM
Volkswagen AG	-0.05%	-11.15%	0.1999	1.0473	6.55%
Mercedes-Benz Group AG	9.43%	-1.66%	0.1763	1.1051	6.72%
BMW AG	4.69%	-6.41%	0.1758	0.9800	6.36%
Renault SA	-5.99%	-17.09%	0.1647	1.4836	7.81%
Ford Motor Company	15.63%	4.53%	0.1529	0.9830	6.37%
Toyota Motor Corporation	9.62%	-1.48%	0.1271	0.5907	5.24%
AB Volvo	7.63%	-3.47%	0.1161	1.1543	6.86%
Saab AB	5.19%	-5.90%	0.1053	0.7229	5.62%
Hyundai Motor Company	15.34%	4.24%	0.0376	0.5451	5.10%
Mitsubishi Corporation	16.83%	5.73%	0.0291	1.0269	6.50%

Based on this result, it is difficult to argue that the hypothesis has been fundamentally refuted. It should be noted that the selected benchmark outperformed the peer group on average. It is worth mentioning that the calculated chip beta for the pre-crisis period for all OEMs except Hyundai is statistically significant at least at the 95% confidence level. However, one can see that the average R^2 value of 0.33 suggests that there could be other factors that explain past stock returns and that the one-factor CAPM with its factors deviates substantially from the actual realized returns. Given the limited variance explained, I doubt that this deviation could be mitigated by determining a factor risk premium, but this could definitely be an approach for deeper analyses. One last possibility I would like to raise is to establish a connection between the OEMs and the introduced chip beta, this time aimed at the company value represented by the EV/EBITDA multiple, whereby here in principle a negative connection would be expected, i.e. that the company value falls with increasing chip beta. As a final argumentation medium, I chose the graphical illustration of the events from February 2020 to December 2022. After the chip betas have been determined over time, the time-congruent data sets are first transferred to a diagram and then tested for their correlations using linear regression. The horizontal line contains all determined chip betas while the vertical line shows all EV/EBITDA multiples generated by Capital IQ. As an example, the example of BMW is illustrated below, which clarifies the project.



This time it has to be pointed out vehemently that all regressions show considerable statistical insignificance in contrast to the market beta determined in the previous step and in the same regression. It is striking that all slope coefficients have a negative sign, which would confirm our hypothesis. However, given the statistical insignificance, the hypothesis can be refuted at any commonly used confidence level, and the result can be regarded as a trend but not as confirmed. It is important to note that although the chip betas were determined by multiple regression as shown in the above formula, the final correlation was only established between the chip beta and the multiple. Appendix 12 also contains the examples of Toyota, Renault and Volkswagen.

4. Discussion of Results

Since the topic of this entire paper was the discussion of financial implications of semiconductors on OEMs and specifically on BMW, a unified discussion of the results, not separated by analysis steps, is provided. Nevertheless, I would like to start with the core, namely the JiC scenario of BMW AG. The motivation to dedicate myself to this case study was driven by the events of the coming year, in addition to my personal attachment to the automobile manufacturer. Undoubtedly, the customer's concerns overwhelmed me and prompted me to take a closer look at the individual situation. What stuck with me in particular was the fact, mentioned in 2.1, that carmakers will not be able to meet the rising demand in the projection period. With the JiC approach presented here, I would like to make the urgent recommendation from the lender's perspective, which is favorable to the company, to take precautions by increasing inventories and even beyond (compensatory acquisition for any inventory shortfall) in order to avoid any production stoppages. Fama's efficient market hypothesis can be cited at this point and applied to the facts of the case. Although we have succeeded in presenting an approach to quantifying risk, we should always assume that the market is at least as intelligent in its pricing, so that the status quo, measured against the current stock price, replicates the most realistic picture of the status quo (Fama 1970). Whatever the circumstances in the coming year and in particular about the annual financial statements for 2022, only an indication can be given in view of the uncertainty and the diversity of macroeconomic influencing factors. This would mean that the company has a responsibility to proactively provide for impairment. Looking at the 2Q2022 results published on the 30th of June 2022, this has been recognized: “International semiconductor and commodity markets remain highly volatile. […] The further course of the coronavirus pandemic is also subject to a high degree of uncertainty, with potential adverse repercussions for sales volumes and global supply chains” (BMW 2022). Furthermore, management felt obliged to change their assessment of the issue: “In the first quarter, the BMW Group had assumed that the supply situation for semiconductor components would ease during the second half of 2022. In the meantime, however, it is no longer expected to improve appreciably over the remainder of the year” (BMW Group 2022, 26). Obviously, management followed up this admission with action, considering that measures were taken such as cooperating with VW to standardize semiconductor requirements (Brooke and Edgecliffe-Johnson 2021) or a long-term supply contract with the semiconductor manufacturer INOVA, which is also headquartered in Munich (regional relations instead of intercontinental dependencies) (Schillmoeller 2021). Measures that are absolutely in line with the action guidelines published by the strategy consulting firm BCG in a management recommendation. It includes building resilient supply chains (considering geopolitical risks when making long-term supply decisions i.e., buy regionally), align semiconductor strategy with product strategy (cooperating with automotive competitors to standardize commodity integrated circuits) and establishing the place in semiconductor value chains to support critical supply needs (incl. building win-win partnerships with chip makers) (Aakash *et al.* 2022). In conclusion, BMW is clearly on a good path, yet I am convinced that presented scenarios can mature into practical relevance.

Detached from the specific, practical approach of BMW AG, chapter 3.2 pursues the goal of confirming the previously expressed assumption of a potentially increased asset risk. Although this attempt does not lead to the desired success, the focus here is on the companies' own responsibility just mentioned. The asymmetry of information distribution leaves the investor perspective with a black box if one considers that only the company-specific insiders have precise insight into the accumulating components, assuming that a corresponding procurement changeover has taken place at all. In addition, during the internship I became aware that the focus of today is strongly on operational diversity. For example, serviced automotive manufacturers without an affiliated financial service segment are looking at a fundamentally different future in the face of rising interest rates. The ability to self-finance and at the same time generate additional profits (among other factors such as inevitable customer retention as a result of long-term credit agreements) is a huge asset today.

The chip beta approach was the most likely to produce an expected, if not statistically significant, result. The extension of factor models has often been done, but only a few have been established and maintained over time. In our scenario, we had to disprove the hypothesis that high chip beta is associated with low abnormal returns and vice versa. However, this would not be enough: It is advisable to look at the OEMs individually and then notice that European companies in particular performed comparatively poorly during the crisis. The international dependency published in the aforementioned BCG paper could be an indicator why this is the case but to what extent this is really true would be subject to further analysis. The international dependency published in the above BCG paper may be an indicator of why this is the case, just adding the fact that the two companies with the lowest chip beta are among the top three ranked by abnormal return, namely Mitsubishi and Hyundai. The individual success of Hyundai can be confirmed by an article and shows that the approaches discussed are empirically significant. There, it is described that Hyundai avoided the chip shortage as far as possible by maintaining its inventory and building up stocks even beyond that when no one else did. Furthermore, Hyundai and its sister company Kia were the only global automakers able to continuously meet the growing demand as a result of the bullwhip effect Lee 2021). Finally, we determined whether the chip beta during the actual period of scarcity was correlated in any way with the enterprise value of our automotive peer group. For this purpose, I calculated the beta over time and formed the data set together with the EV/EBITDA multiple at the respective reporting date. The respective chip betas had to be determined in congruence with the market betas and in contrast to the latter, the chip betas did not show any statistical significance as already mentioned in the other section, but nevertheless in contrast to the pre-crisis period. On the one hand, this could be due to the lower estimates; on the other hand, I consider it more likely that the number of influencing factors in the crisis period was too large and too significant for a valid determination to be possible. Nevertheless, I took the resulting values as an opportunity to plot them on a stand-alone basis together with the respective multiples and at least the expected relationship occurred: A rising chip beta implies, according to a regression to be taken with caution, a lower enterprise value. Especially at this point, further testing would be recommended, as there are several other variables to be considered. For example, operational leverage would come to mind as a determinant that can provide information on whether the company is borrowing to meet regular payment obligations, which in turn would indicate an increased exposure to volatile market conditions instead of the "Toyota way", i.e. the depletion of inventories.

5. Limitations and Final Remarks

The goal of this work was multi-layered: On the one hand, an analysis was to be opened on the basis of the case study of BMW, which is supported by practical relevance, a theoretical, evaluation-relevant consideration of the semiconductor scarcity finds. On the other hand, answers to empirical questions should be found and discussed, which could be formulated from this case study. It now remains to state that I must again refer to the companies' own responsibility as a consequence of the Significant Information Asymmetry. In this respect, I had the good fortune to gain insights into processes and opinions that would otherwise have been unavailable to an outside investor, so I can certainly say that I was happy to have reflected the role of the lender in this work in a crude way.

The BMW example has clearly shown that management is committed to mitigating the consequences of the semiconductor shortage and that the sensitivity of the influencing factors draws attention to the importance of the problem and ultimately also shows that precautionary measures would be in the interest of investors.

Finally, however, it is important to point out shortcomings in the analysis and omitted influencing factors. First, it must be acknowledged that it is difficult to adequately describe the broad nature of the semiconductor shortage in this finance-driven thesis. In this regard, one could have argued, for example, using inventory coefficients, an approach that is outside the scope of this thesis. Furthermore, the versatility of working capital management must be acknowledged, the requirements of which were only met in the most necessary way here. Those representatives would presumably have had a better claim to publish a practice-oriented paper on this topic and would have only wearily smiled at the finance-oriented WACC approach. Furthermore, while care has been taken to stay within the norms of the general accounting framework, this is not considered and justified in detail. This is reflected in the fact that a hypothetical financial forecast was omitted. The simplified forecast was not intended to calculate an exact value for the BMW Automobiles segment using the DCF method, but rather to show the sensitivity of the effects of the identified variable influencing parameters. Finally, it is important to point out that peer group analysis is always subject to a frequent source of error, in particular due to the now fluid transition between different segments, which can lead to distortions of some parameters such as the D/E ratio. Due to the group size, I assume to have compensated for misleading outliers.

References

Alicke, Knut, Bariball, Ed and Trautwein, Vera. 2021. "How COVID-19 is reshaping supply chains." *McKinsey & Company*. Accessed November 24, 2022. https://www.mckinsey.com/capabilities/operations/our-insights/how-covid-19-is-reshaping-supply-chains.

Arora, Aakash, Waas, Albert, Palma, Ramiro, Feng Jimmy, Breidenbach, Karl, Xue, Harrison, Jesse, Eric, Lopez, Thomas and Dhanjy, Minhal. 2022. "Tracking the Next Phase of the Automotive Semiconductor Shortage." *Boston Consulting Group*. Accessed October 17, 2022. https://www.bcg.com/publications/2022/tracking-next-phase-automotive-semiconductor-shortage.

Aschauer, Ewald and Purtscher, Victor. 2011. *Einführung in die Unternehmensbewertung*. Vienna: Linde Publisher.

Bachl, Robert. 2007. „Firm Valuation." In *Einführung in die Unternehmensbewertung*, 4. Vienna: LexisNexis Publisher.

BMW Group. 2022. "BMW Group Half-Year Report 2022." Accessed September 22, 2022. https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2022/q2/BMW_Q2-2022_EN.pdf.

BMW Group. 2021. "BMW Group Report 2021." Accessed October 18, 2022. https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2022/bericht/BMW-Group-Report-2021-en.pdf.

Burkacky, Ondrej, Dragon, Julia and Lehmann, Nikolaus. 2022a. "The semiconductor decade: A trillion-dollar industry." *McKinsey & Company*. Accessed October 3, 2022. https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry.

Burkacky, Ondrej, Johannes Deichmann, Philipp Pfingstag, and Julia Werra. 2022b. "Semiconductor shortage: How the automotive industry can succeed." *McKinsey & Company*. Accessed September 28, 2022. https://www.mckinsey.com/industries/semiconductors/our-insights/semiconductor-shortage-how-the-automotive-industry-can-succeed.

Burkacky, Ondrey, Lingemann, Stephanie and Pototzky, Klaus. 2021. „Coping with the auto-semiconductor shortage: Strategies for success." *McKinsey & Company*. Accessed October 17, 2022. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success.

Bruns, Christop and Meyer-Bullerdick, Frieder. 2013. *Professionelles Portfoliomanagement: Aufbau, Umsetzung und Erfolgskontrolle strukturierter Anlagestrategien.* Stuttgart: Schäffer-Poeschel Publisher.

Castedello, Marc. 2014. „Die Unternehmensbewertung.“ In *Institut der Wirtschaftsprüfer in Deutschland e.V.(Hg.): WP-Handbuch. Wirtschaftsprüfung, Rechnungslegung, Beratung*, edited by Ingo Bertram, Stefan Schöniger, Andreas Tschöpel and Jörg Wiese, 1-203. Düsseldorf: IDW- Publisher.

Copeland, Tom, Koller, Tim, Murrin, Jack, McKinsey & Company and Mader, Friedrich. 2002. *Unternehmenswert: Methoden und Strategien für eine wertorientierte Unternehmensführung.* Frankfurt, New York: Campus Publisher.

Crum, Roy L., Klingman, Darwin D., and Tavis, Lee A. 1983. “An operational approach to integrated working capital planning.” *Journal of Economics and Business*, 35(3,4), 343-378.

Damodaran, Aswath. 2022. “Betas by Sectors (US)”. *New York University*. Accessed October 31, 2022. https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html.

Damodaran, Aswath. 2011. *Applied Corporate Finance.* Third Edition. New York: Wiley.

Damodaran, Aswath. 2006a. *Value and Risk: Beyond Betas, Working Paper*. New York: Wiley.

Damodaran, Aswath. 2006b. *Damodaran on valuation. Security analysis for investment and corporate finance.* New York: Wiley.

Damodaran, Aswath. 1999. *Estimating Risk Parameters*. New York: NY.

Engst, Judith. 2017. *Einfach richtig Geld verdienen mit ETFs.* Weinheim: Wiley Publisher.

Ernst, Dietmar, Schneider, Sonja and Thielen, Bjoern. 2008. „Methoden der Unternehmensbewertung.“ In *Unternehmensbewertungen erstellen und verstehen: Ein Praxisleitfaden*, 9-13. Munich: Franz Vahlen Publisher.

European Central Bank. 2021. “Economic and monetary developments.” *Economic Bulletin Issue 4.* Accessed October 30, 2022. https://www.ecb.europa.eu/mopo/devel/html/index.en.html.

Fama, Eugene F. 1970. “Efficient Capital Markets: A Review of Theory and Empirical Work.” *The Journal of Finance* Vol. 25, No. 2: 383-417. https://www.jstor.org/stable/2325486.

Frühling, Volker. 2004. „Sensitivitätsanalyse zum Bauwertmodell der Unternehmensbewertung.“ In *Finanz Betrieb*, 741-746. Düsseldorf: Handelsblatt Magazine.

Götte, Rüdiger. 2010. *Exchange Traded Funds (ETFs): Grundlagen, Funktionsweise und praktischer Einsatz – Das 1 x 1 der Exchange Traded Funds.* Hannover: ibidem-Publisher.

Gunter, Markus. 2013. *Erfolgreich mit Investmentfonds – simplified: Die clevere Art reich zu werden.* Munich: FinanzBuch Publisher.

Hansen, Paul. 2021. „On Automotive Electronics." Accesssed December 13, 2022. https://www.springerprofessional.de/springerprofessional-de/on-automotive-electronics/19026998

Harrer, Andreas. 2016. „Exchange Traded Funds (ETFs): Eine ökonomische und rechtliche Analyse der Chancen, Risiken und Regulierungsmöglichkeiten im Investmentrecht." In *Schriften des Augsburg Center for Global Economics Law and Regulation, Arbeiten zum Internationalen Wirtschaftsrecht und zur Wirtschaftsregulierung*, edited by Thomas Möllers and Matthias Rossi. Baden-Baden: Nomos Publisher.

Hierzenberger, Michael. 2013. „Der White-Test als Gütekriterium bei der Bestimmung von Betafaktoren. Eine empirische Untersuchung am Fallbeispiel der österreichischen Verbund AG." In *Bewertungspraktiker* (2), 50–58.

IFRS. 2022. "IAS 2 Inventories." *The International Financial Reporting Standards Foundation.* Accessed November 24, 2022. https://www.ifrs.org/issued-standards/list-of-standards/ias2inventories/#:~:text=Inventories%20are%20measured%20at%20the,necessary%20to%20make%20the%20sale.

Intel. 2022. "Fueling Innovation We Love and Depend On." *Intel Corporation.* Accessed October 11, 2022. https://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html#vert-item-1-1.

King, Ian and Naughton, Keith. 2021. "Carmakers Forced by Chip Crisis to Rethink Just-In-Time Ordering." *Bloomberg.* Accessed October 31, 2022. https://www.bloomberg.com/news/articles/2021-05-28/carmakers-forced-by-chip-crisis-to-rethink-just-in-time-ordering?leadSource=uverify%20wall.

Krane, Spencer D. 1994. "The Distinction Between Inventory Holding and Stockout Costs: Implications for Target Inventories, Asymmetric Adjustment, and the Effect of Aggregation on Production Smoothing." *International Economic Review* 35(1), 10. https://doi.org/10.2307/2527093.

Krauss, Robert. 2015. *Kapitalmarkttheoretische Beurteilung von EFT und Aktienfonds unter Differenzierung nach Marktphasen.* Münster: MV-WISSENSCHAF Publisher.

Lee, Joyce. 2021. "Analysis: Hyundai bought chips when rivals didn't; its assembly lines are still rolling". Accessed December 13, 2022. https://www.reuters.com/article/us-autos-semiconductors-hyundai-motor-an-idUSKBN2AQ0EF.

Linter, John. 1965. "Security Prices, Risk, and Maximal Gains from Diversification." *The Journal of Finance*: 587-615.

Markowitz, Harry. 1952. "Portfolio Selection." *The Journal of Finance* (7:1): 77-91.

Masters, Brooke and Edgecliffe-Johnson. 2021. "Supply chains: companies shift from 'just in time' to 'just in case'." *Financial Times.* Accessed November 26, 2022. https://www.ft.com/content/8a7cdc0d-99aa-4ef6-ba9a-fd1a1180dc82.

Meissner, Falk, Michael Alexander, Thomas Kirschstein, Andrew Yi, Alexander Fey and Nikos Orologopoulos. 2021. „Steering through the semiconductor crisis: A sustained structural disruption requires strategic responses by the automotive industry." *Roland Berger GmbH.* Accessed November 11, 2022. https://www.rolandberger.com/en/Insights/Publications/Steering-through-the-semiconductor-crisis.html.

Modigliani, Franc and Miller, Merton. 1958. "The Cost of Capital, Corporation Finance and the Theory of Investment." *The American Economic Review*. Vol. 48, No. 3. 48(3): 261-297.

Moore, Gordon. 1965. "Moore's Law and Intel Innovation." *Intel Corporation.* Accessed November 24, 2022. https://www.intel.de/content/www/de/de/history/museum-gordon-moore-law.html.

Moyer, Charles R., McGuigan, James R. and Kretlow, William J. 2009. *Contemporary financial management.* (11 ed.). Mason, OH: South-Western/Cengage Learning Publisher.

Nasdaq. 2022. "NASDAQ Composite Index (COMP)." Accessed October 25, 2022. https://www.nasdaq.com/market-activity/index/comp.

OECD. 2022. "Statutory Corporate Income Tax Rates." Accessed December 11, 2022. https://stats.oecd.org/Index.aspx?DataSetCode=CTS_CIT

Picard, Alain and Braun, Gregor. 2010. *Exchange Traded Funds (ETF): Grundlagen, Funktionsweise und praktischer Einsatz.* Zurich: Finanz und Wirtschaft Publisher.

Runner, Scott. 2022. "Today's chip shortage: Understanding the perfect storm that led us here – Blog Insights: Semiconductor Shortage." *Capgemini Engineering.* Accessed October 11, 2022. https://www.capgemini.com/insights/expert-perspectives/todays-chip-shortage-understanding-the-perfect-storm-that-led-us-here/.

Schillmoeller, Sandra. 2021. „BMW Group signs direct agreement with chip suppliers to secure supplies." *BMW Group Press.* Accessed October 2, 2022. https://www.press.bmwgroup.com/global/article/detail/T0362334EN/bmw-group-signs-direct-agreement-with-chip-suppliers-to-secure-supplies?language=en.

Schmeisser, Wilhelm and Spree, Julia. 2008. „Unternehmensbewertung in praktischer Anwendung." In *Einführung in die Unternehmensbewertung,* edited by W. Schmeisser, B. Görlitz, J. Spree, L. Clausen and F. Schindler, 93-169. Munich: Mering, Rainer Hampp Publisher.

Schmeisser, Wilhelm and Spree, Julia. 2009. *Einführung in die Unternehmensbewertung*. Cologne: Mering, Rainer Hampp Publisher.

Semiconductor Industry Association. 2022. "Global Semiconductor Sales Increase 13.3% in Q2 2022 Compared to Q2 2021." *The Semiconductor Industry Association (SIA).* Accessed October 19, 2022. https://www.semiconductors.org/global-semiconductor-sales-increase-13-3-in-q2-2022-compared-to-q2-2021/.

Sharpe, William F. 1964. “Capital Asset Prices: A Theory of Market Equilibrium.” *The Journal of Finance,* (19:3): 425-442.

St. Louis Fed. 2022a. “Manufacturers Inventories (MNFCTRIMSA).” *Federal Reserve Bank of St. Louis.* Accessed November 26, 2022. https://fred.stlouisfed.org/series/MNFCTRIMSA.

St. Louis Fed. 2022b. “Interest Rates: Long-Term Government Bond Yields: 10-Year: Main (Including Benchmark) for Germany (IRLTLT01DEM156N).” *Federal Reserve Bank of St. Louis.* Accessed November 29, 2022. https://fred.stlouisfed.org/series/IRLTLT01DEM156N.

Stankiewicz, Kevin. 2022. “Intel CEO now expects chip shortage to last into 2024.” *CNBC.* Accessed November 20, 2022. https://www.cnbc.com/2022/04/29/semiconductor-shortage-intel-ceo-says-chip-crunch-to-last-into-2024.html.

Toyota. 2022. “The car chip shortage: What you should know.” Toyota of Orlando. Accessed December 12, 2022. https://www.toyotaoforlando.com/the-car-chip-shortage-what-you-should-know/.

Trivedi, Anjani. 2021. “Toyota Broke Its Just-In-Time Rule Just in Time for the Chip Shortage.” *Bloomberg.* Accessed November 8, 2022. https://www.bloomberg.com/opinion/articles/2021-02-15/toyota-broke-its-just-in-time-rule-just-in-time-for-the-chip-shortage?leadSource=uverify%20wall.

U.S. Department of the Treasury. 2022. “Daily Treasure Par Yield Curve Rates.” Accessed December 14, 2022. https://home.treasury.gov/resource-center/data-chart-center/interest-rates/TextView?type=daily_treasury_real_yield_curve&field_tdr_date_value_month=202212

Walsh, Dylan. 2022. “How auto companies are adapting to the global chip shortage”. *MIT SLOAN SCHOOL OF MANAGEMENT*. Accessed November 15, 2022. https://mitsloan.mit.edu/ideas-made-to-matter/how-auto-companies-are-adapting-to-global-chip-shortage.

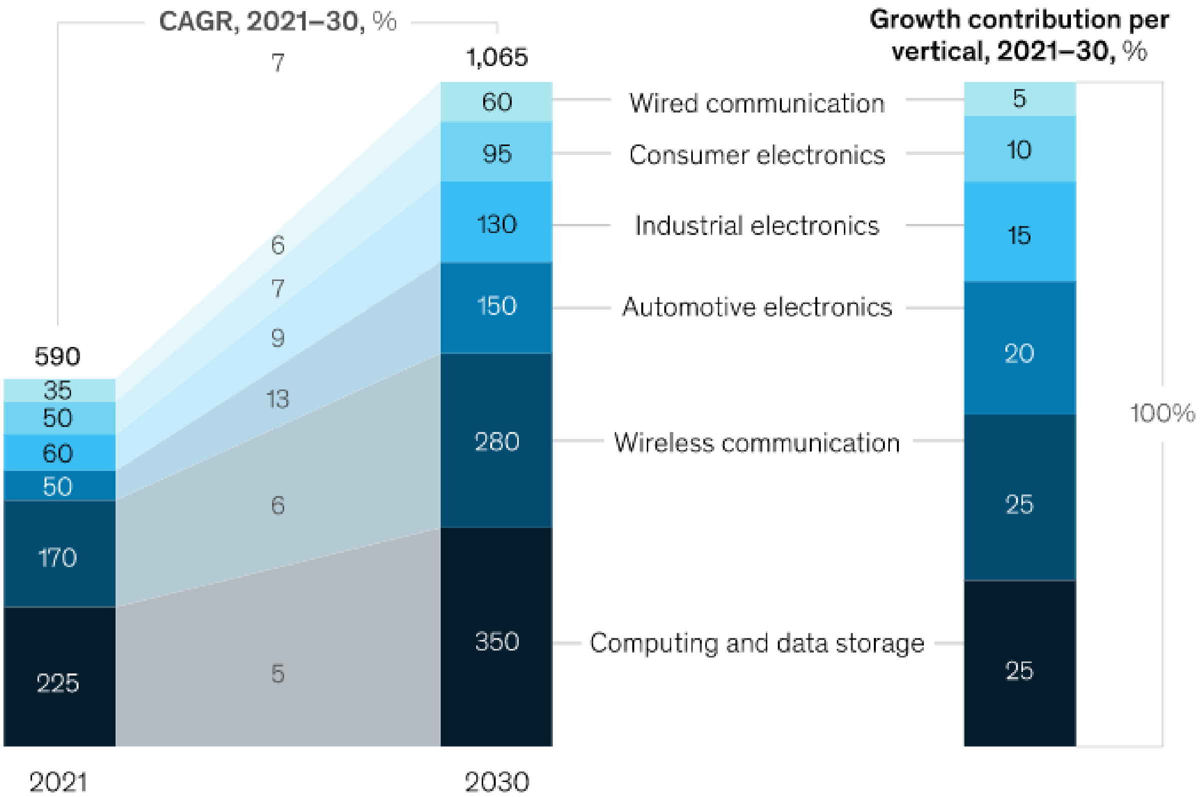
World Semiconductor Trade Statistics (WSTS). 2022. “Semiconductor Market Forecast August 2022.” Accessed October 12, 2022. https://www.wsts.org/76/103/The-World-Semiconductor-Trade-Statistics-WSTS-has-released-its-new-semiconductor-market-forecast-generated-in-August-2022.

Yang, Gino, Ronald, Robert J. and Chu, Peter. 2005. “Inventory models with variable lead time and present time.” *European Journal of Operational Research,* 164(2): 358-366.

Ziemer, Franziska. 2015. *Der Betafaktor – Theoretische und empirische Befunde nach einem halben Jahrhundert CAPM.* Wiesbaden: Springer Gabler Publisher.

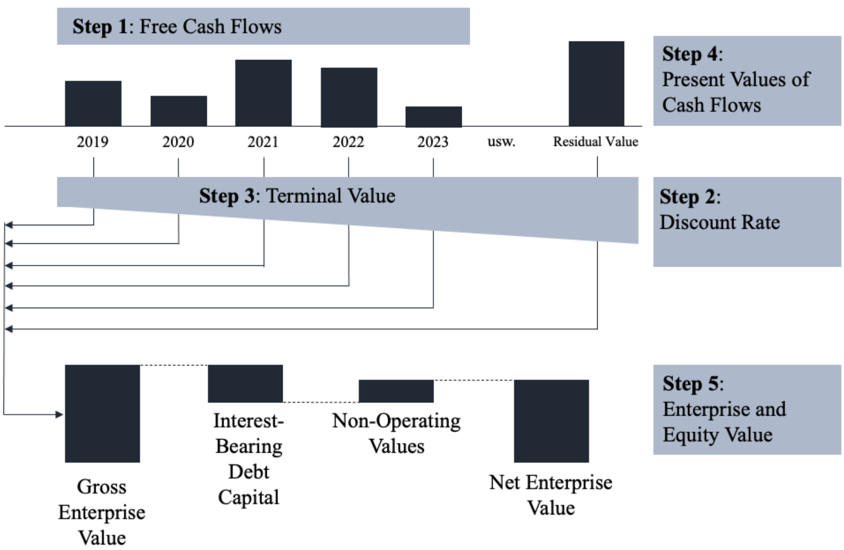
Appendices

Appendix 1 - Global semiconductor market value by vertical, indicative, $ billion



Source: Burkacky et al, 2022a

Appendix 2 - Five steps of DCF valuation



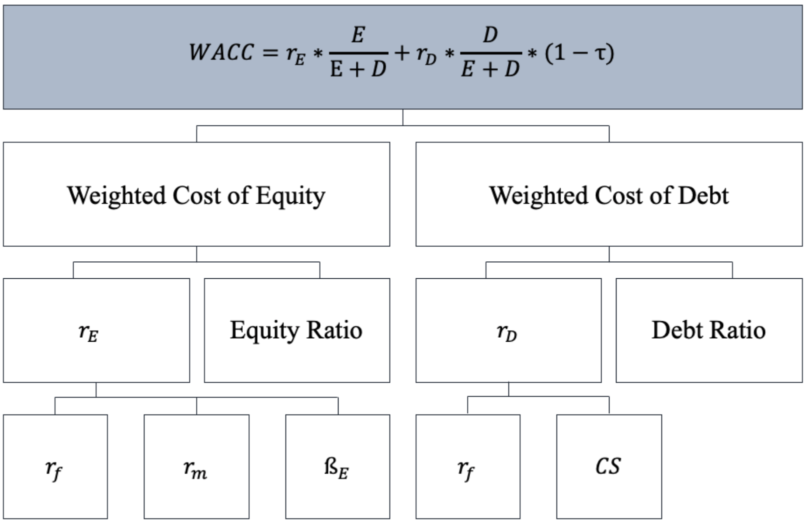
Source: Own illustration

Appendix 3 - FCF Scheme

	Operating Income aka EBIT (Income Statement)
-	**Taxes** (Income Statement)
=	**Tax Effected EBIT**
+	**Depreciation and Amortization** (Cash Flow Statement)
-	**Change in Operating Working Capital** (Balance Sheet)
-	**Capital Expenditures** (Cash Flow Statement)
=	**Free Cash Flow**

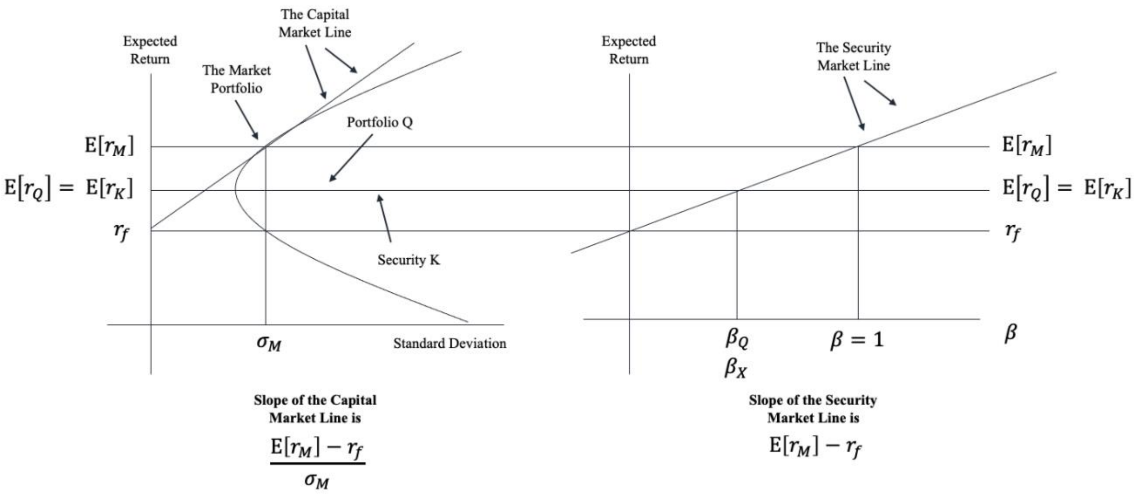
Source: Own illustration

Appendix 4 - WACC Calculation



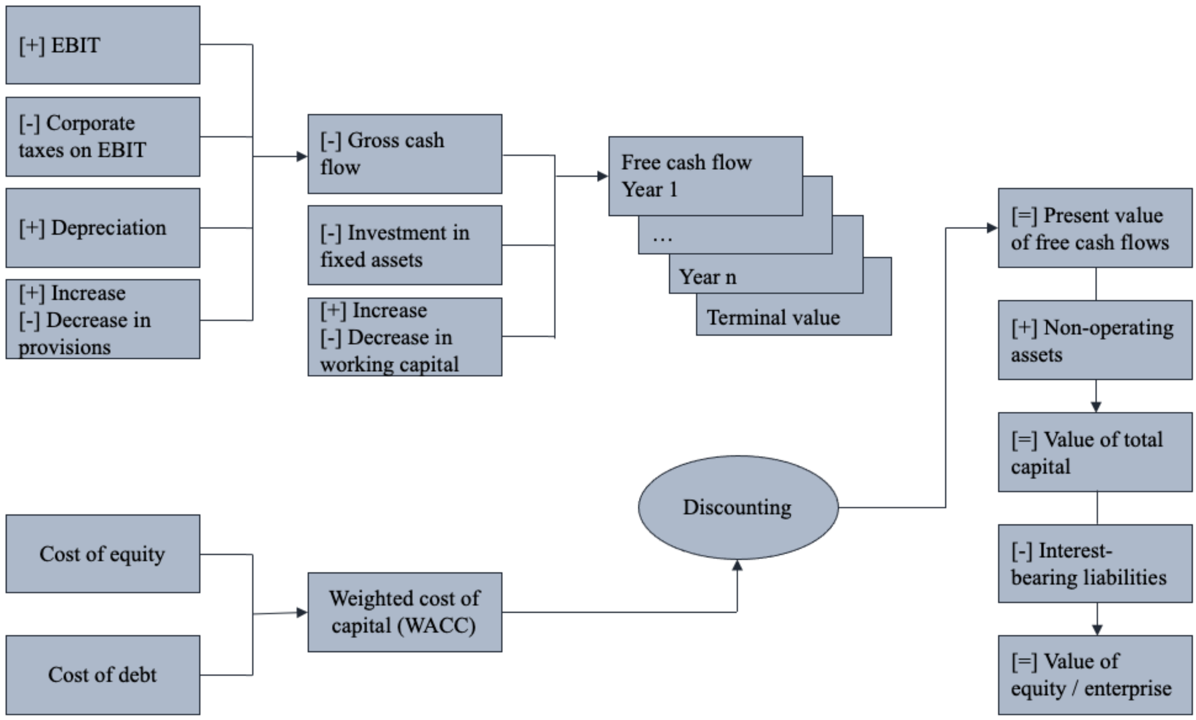
Source: Own illustration

Appendix 5 - Connection Capital Market Line and Security Market Line



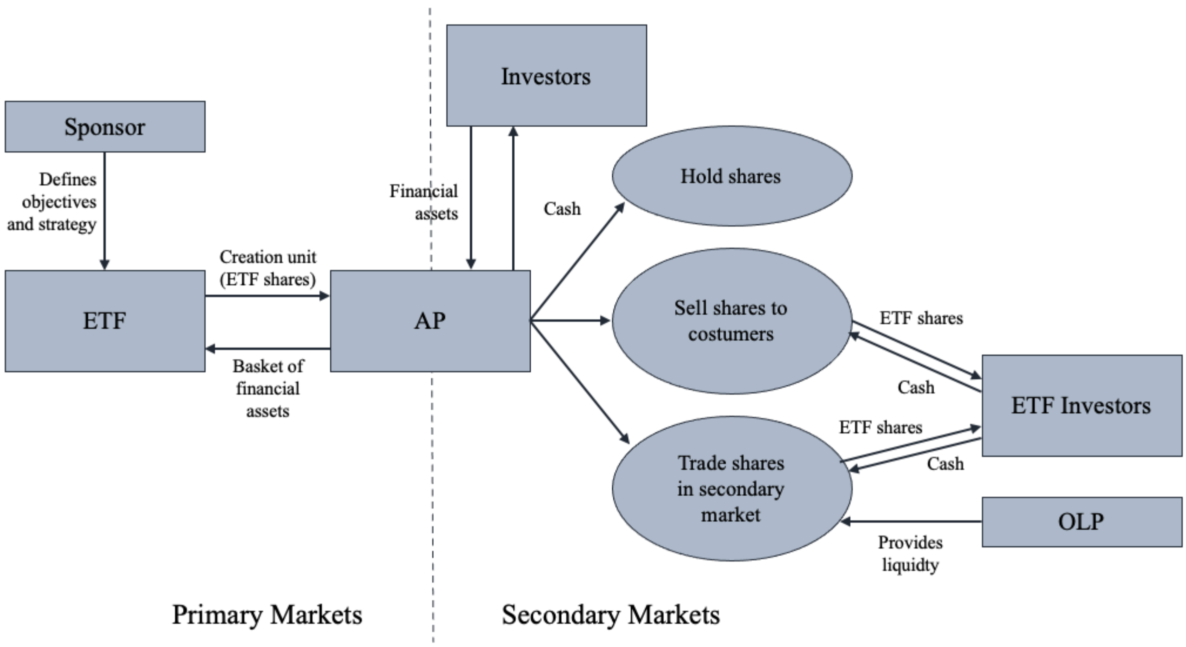
Source: Own illustration

Appendix 6 - Discounted Cash Flow Orbit



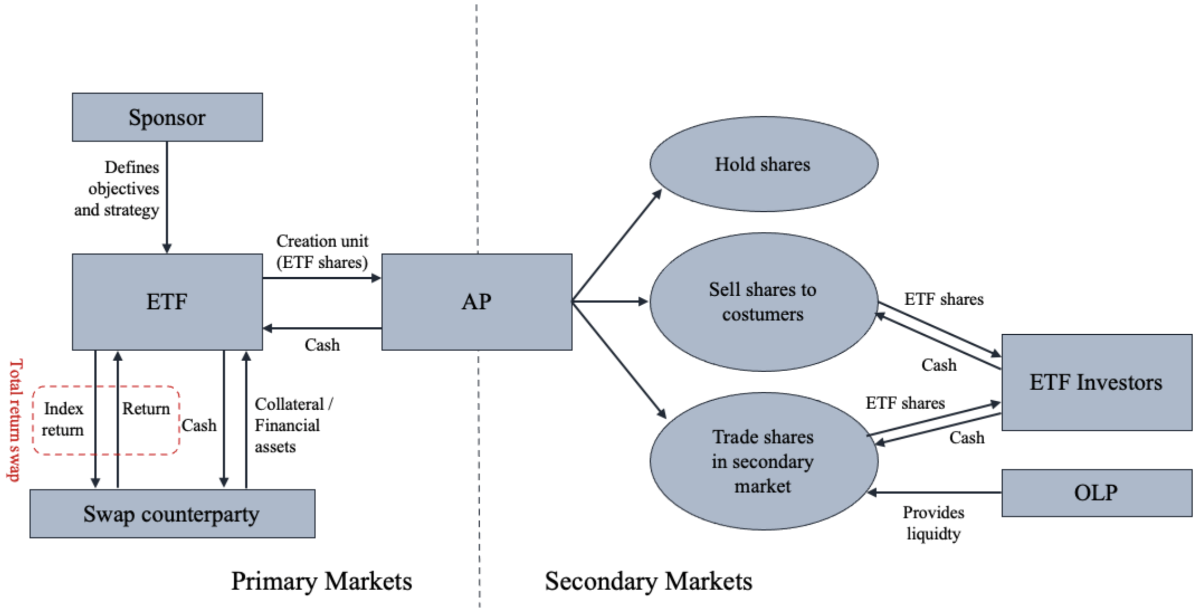
Source: Own illustration following Picard/Braun, 2010

Appendix 7 - ETF with physical Replication



Source: Own illustration following Picard/Braun, 2010

Appendix 8 - ETF with synthetical Replication



Source: Own illustration following Picard/Braun, 2010

Appendix 9 – BMW FCF derivation

Just in Time (As Reported)	31.12.2021
Income Statement	
Revenues	95.476
./. CoGS	-78.637
Gross Profit	**16.839**
./. SGA	-7.580
Oth. Op. Income & Expenses	611
Profit/Loss before tax (EBIT)	**9.870**
Financial Result	1.935
Profit Before Tax (EBT)	**11.805**
Income Tax	-2.645
Net Profit	**9.160**

Cash Flow Statement	
Profit/ loss before tax	11.805
Income taxes paid	-1.805
Interest received	220
Other interest and similar income/ expenses	115
D&A	6.341
Other non-cash income and expense items	-470
Result from equity accounted investments	-1.520
Changes in NWC	762
Change in Provisions	-1.440
Change in other operating assets & liabilities	-1.425
Cash inflow / outflow from operating activities	12.583

Total investment in intangible assets and property, plant and equipment	-6.439
Proceeds from subsidies for intangible assets and property, plant and equipme	43
Proceeds from the disposal of intangible assets and property, plant and equipm	39
Expenditure for investment assets	-132
Proceeds from the disposal of investment assets and other business units	260
Investments in marketable securities and investment funds	-16
Proceeds from the sale of marketable securities and investment funds	37
Cash inflow/ outflow from investing activities	-6.208

Cash Inflow from operating activities	12.583
Cash Outflow from investing activitites	-6.208
Adjustment for net investment in marketable securities and investment funds	-21
Free Cash Flow Automotive Segment	6.354

Appendix 10 – Market Beta Derivations

Summary Output

10 years

Regression Statistics	
Multiple R	0.59215
R Square	0.35064
Adjusted R S	0.34939
Standard Er	0.03174
Observations	522

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.282883919	0.282884	280.7914151	1.03656E-50
Residual	520	0.523875126	0.001007		
Total	521	0.806759045			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.00098076	0.001394687	-0.70321	0.482240867	-0.003720669	0.0017592	-0.003720669	0.001759159
ß BMW	1.062066223	0.063381087	16.75683	1E-50	0.937551764	1.1865807	0.937551764	1.186580682

Summary Output

10 years

Regression Statistics	
Multiple R	0.79793
R Square	0.63670
Adjusted R Squa	0.63600
Standard Error	0.02105
Observations	522

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.40389	0.40389	911.30824	0.00000
Residual	520	0.23046	0.00044		
Total	521	0.63435			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00190	0.00093	2.05297	0.04057	0.00008	0.00372	0.00008	0.00372
ß Semiconducto	1.26905	0.04204	30.18788	0.00000	1.18647	1.35164	1.18647	1.35164

Appendix 11 – Summary of the Case Study

- ## Effects

Decomposition				
WACC Effect				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (JiT)				
CF		5,118.38	5,278.55	5,443.74
WACC		5.49%	5.49%	5.49%
PV	**14,233.72**			
C.P. Impact (JiC)				
CF		5,118.38	5,278.55	5,443.74
WACC		5.58%	5.58%	5.58%
PV	**14,208.15**			
Percentage Change	-0.18%			

Decomposition				
FCF Effect				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (JiT)				
CF		5,118.38	5,278.55	5,443.74
WACC		5.49%	5.49%	5.49%
PV	**14,233.72**			
C.P. Impact (JiC)				
CF		3,518.58	4,445.37	5,444.68
WACC		5.49%	5.49%	5.49%
PV	**11,969.17**			
Percentage Change	-15.91%			

- ## Comparison based on no crisis scenario

Marginal Segment Valuation Impact				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (NS)				
CF		4,971	5,175	5,388
WACC		5.49%	5.49%	5.49%
PV	**13,954.16**			
C.P. Impact (JiC)				
CF		3,519	4,445	5,445
WACC		5.58%	5.58%	5.58%
PV	**11,946.32**			
Percentage Change	16.81%			

Marginal Segment Valuation Impact				
DCF		**2022E**	**2023E**	**2024E**
C.P. Impact (NS)				
CF		4,971	5,175	5,388
WACC		5.49%	5.49%	5.49%
PV	**13,954.16**			
C.P. Impact (JiT)				
CF		5,118	5,279	5,444
WACC		5.49%	5.49%	5.49%
PV	**14,233.72**			
Percentage Change	-1.96%			

- ## Sensitivity Analysis

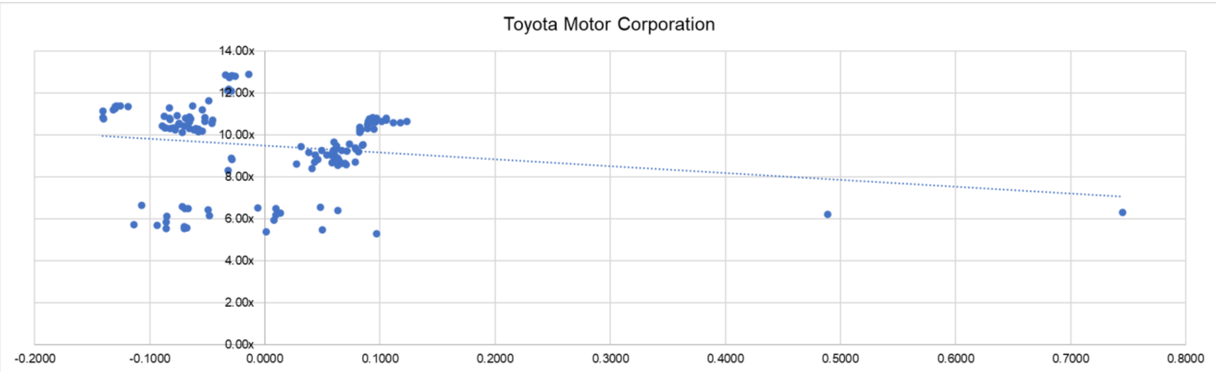
Sensivity Analysis

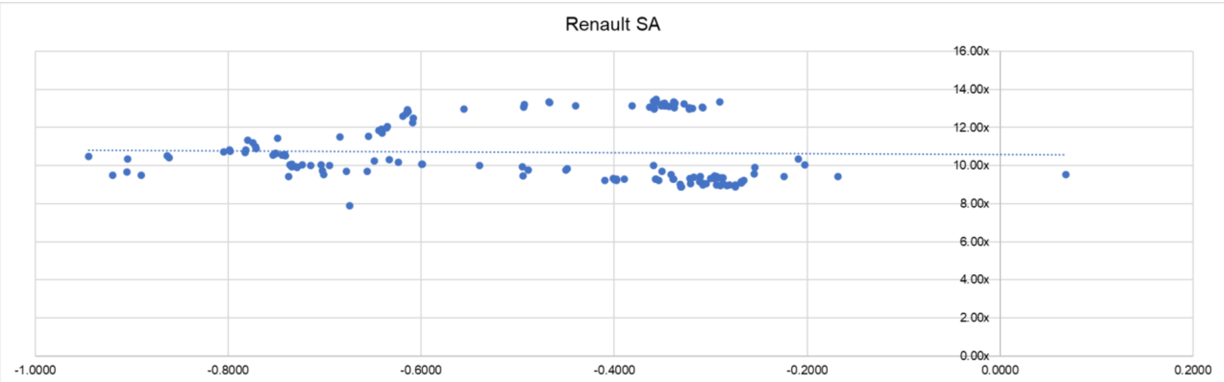
	Inventories				
Inventory Compensation	1	2	3	4	5
-0.5	12,634.82	12,623.43	12,612.05	12,600.70	12,589.36
-0.75	11,968.35	11,957.54	11,946.74	11,935.96	11,925.19
-1	11,301.89	11,291.65	11,281.43	11,271.22	11,261.03
-1.25	10,635.42	10,625.76	10,616.12	10,606.49	10,596.87
-1.5	9,968.96	9,959.87	9,950.81	9,941.75	9,932.71

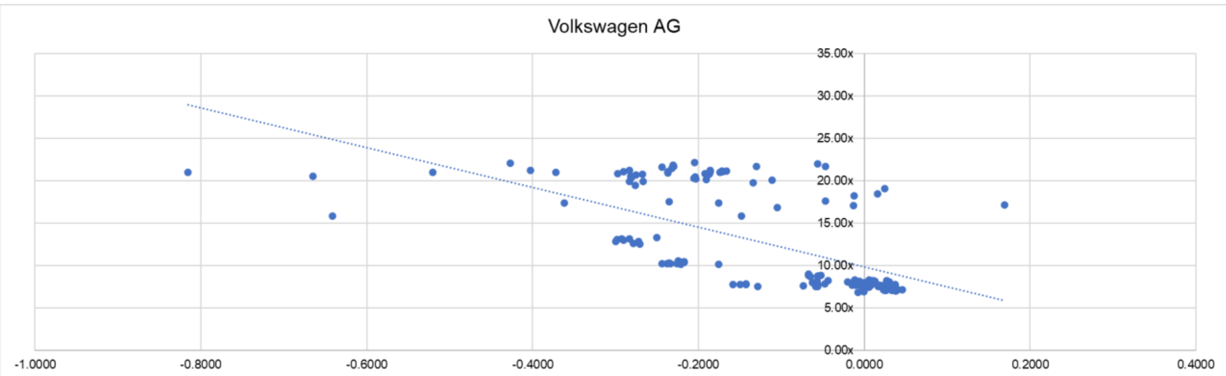
Sensivity Analysis (JiC)

	Inventories				
Inventory Compensation	1	2	3	4	5
-0.5	5.76%	5.67%	5.57%	5.48%	5.38%
-0.75	0.18%	0.09%	0.00%	-0.09%	-0.18%
-1	-5.39%	-5.48%	-5.57%	-5.65%	-5.74%
-1.25	-10.97%	-11.05%	-11.13%	-11.22%	-11.30%
-1.5	-16.55%	-16.63%	-16.70%	-16.78%	-16.86%

Appendix 12 – Plot : EV/EBITDA vs. Chip Beta







Abbreviations

AI	Artificial Intelligence
BMW AG	Bayerische Motorenwerke AG
CAPM	Capital Asset Pricing Model
CEO	Chief Executive Officer
DCF	Discounted Cash Flow
EBITDA	Earning before Interest Taxes Depreciation and Amortization
ETF	Exchange Traded Fund
EV	Enterprise Value
FCF	Free Cash Flow
JiC	Just-in-Case
JiT	Just-in-Time
MNC	Multinational Company
NWC	Net Working Capital
OEM	Original Equipment Manufacturer
TE	Tracking Error
WACC	Weighted Average Cost of Capital