The Impact of Technological Advancements in the Luxury Car Market: A Case Study of Mercedes-Benz Sales in the U.S.A

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Abstract. This study investigates the influence of technological advancements on Mercedes-Benz's market performance in the U.S. luxury car sector, focusing on the period from 2013 to 2023. Employing multiple regression analysis, the research examines the relationship between key variables: technological adoption rates, sales volume, average selling price, and revenue. The study reveals that while the average selling price significantly enhances revenue, technological adoption contributes positively, though with a less pronounced effect. However, taking such measures as using electric cars and car driving automation technologies has helped Mercedes-Benz to sustain its competitive advantage. Even if this is initially expensive and consumer acceptance or penetration varies, it restricts their immediate revenues. Multiple regression and ANOVA analyses also support the importance of these factors, stressing that an effective pricing policy and constant innovations are crucial for increasing revenue. The result of the study shows that Mercedes-Benz can maintain the leading position in the luxury car segment only if it invests in technological developments and follows the changes in consumer trends. That can only underline the need for further development of technologies in the automotive industry, a situation luxury brands must face in the long run, as they must satisfy consumer demand for high-end features to generate constant revenues.

Keywords: Luxury car market; technological advancements; Mercedes-Benz; multiple regression analysis.

1. Introduction

The market of luxury cars has always been associated with technological advancement, reliability, and status; the sector continues to attract a rather selective class of consumers keen on both efficiency and reputation. The global luxury car market has expanded in the last twenty years, showing a market annual growth rate of about 3% in 2021. This has increased to 8.7% in the year 2021 to the year 2024 [1]. This growth has been occasioned by high levels of technological changes that have changed the facets of automotive, including the engineering, designing, and economic structures in the market.

Recent studies have identified key factors such as Perceived Luxury Consumption, Self-Identity, and Brand Love that positively affect consumer attitudes towards luxury car brands [2]. Mercedes-Benz is among the leading luxury car makers globally and is acknowledged in the industry as one of the best. In 2023, Mercedes-Benz was virtually the most prominent luxury car brand globally, with over 2 million vehicles sold, with a market share of 3.07% [3]. The company follows technological advancement, offering various technological innovations, including autonomous driving systems, electric mobility, and infotainment technologies. These innovations have significantly impacted the pleasures of driving and the directions consumers have sought, and the outcomes of market rivalry have been determined.

The Mercedes-Benz has vast technological developments, which can be grouped into categories. Mercedes-Benz's safety innovations are among the best in the automotive industry, with the new models featuring fully automated security systems [4]. For example, a new service innovation process model called "DOING," aimed at meeting customer needs and enhancing the mobility service ecosystem amid digital transformation, can help with that [5]. Technologies such as self-driving firmly establish themselves as features of today’s luxury car, with industry forecasts on the future of autonomous vehicles claiming promising development of EQS and S-class DRIVER PILOT vehicles by 2026 [6]. The other technology is electric vehicles (EVs), which have exhibited a lot of recent growth, especially in the luxury EV market, with a projected market value of $951.9 billion in 2030

in all companies, which Mercedes will hold 50% of the total sales due to consumers' progressive demand for environmentally friendly and high-performance vehicles [7].

However, the advancements in these technologies raise many economic benefits. For instance, automating production components comes with the costs of implementing those technologies, and it is currently estimated that electric cars cost 20 to 30 percent more to produce than conventional internal combustion engine cars [8]. However, for Mercedes, these costs are typically compensated by the premium status of the first couple of products because marketers of Mercedes-Benz car models don't compromise the latest technology. Furthermore, consumers' buying behavior of Mercedes cars is due to the company's high technological appeal and good brand image environment [9].

This study will examine key variables such as technological adoption rates, sales volume, and market share to understand how technological advancements affect market performance. These variables are closely interrelated, as technological innovations directly influence consumer demand, impacting sales volume and the market share of brands like Mercedes-Benz. The method selected for this research, multiple regression, fits this study well, as it enables the analysis of the interaction of these variables on market outcomes. It offers an understanding of the strength and nature of this relationship to the emergence of the technological enhancement of Mercedes-Benz in the U.S. luxury car market. Analyzing the data will give insights into how technology has improved the firm's revenue. In 2023, they collected a revenue of 133 billion dollars.

2. Methods

2.1. Data Sources

The data for this work is extracted from the Mercedes-Benzes-U.S. Figures from 2013 to 2023. It involves several indicators of economic development, sales, and technological relations connected with the Mercedes car market. The data is sorted into 12 observations per year, so changes in consumer demand are considered.

2.2. Variable Selection

The study's control variables include the Technological adoption rates (X1), Average price (X2) and volume of sales (X3) to determine consumption trends toward emergent technologies like electric cars and autopilot systems. These variables have quite complex interconnections since they all pertain to defining the critical dynamics in the global markets [10].

Table 1. U.S. sales volumes, Average Price, Technological adoption rate, and Revenue of Mercedes-Benz (2013-2023)

Year	U.S. Sales (Units)	Average Price ($)	Revenue (Billion USD)	Technology Adoption Rate Increase (%)	Returns (%)
2013	334,504	192,255	64.31	15	
2014	357,509	205,869	73.60	20	14.45
2015	367,236	228,191	83.80	5	13.86
2016	373,651	238,993	89.30	10	6.56
2017	372,240	252,560	94.40	7	5.71
2018	349,084	266,698	93.10	16	-1.38
2019	352,129	303,582	106.9	14	14.82
2020	324,708	303,596	98.58	22	-7.78
2021	329,665	332,610	109.65	20	11.23
2022	342,887	375,692	128.82	19	17.48
2023	342,240	388,616	133	25	3.24

The table 1 shows Mercedes Benz's sales, which allowed them to achieve great revenue. This is shown from their annual return rates, which show a positive return except in 2018, which was due to

reduced sales volume in that year, and also in 2020, which was a big negative return due to the COVID-19 pandemic, which reduced the sales from 352,129 in 2019 to 324,708, hence resulting in a negative return of -7.78%.it also shows the average price, technology adoption rate values and how these variables affect revenue generation each year. For instance, the technology rate in 2013 was 15%, but as years went by, it increased to 25% in 2023, which led to a rise in revenue from $64.31 billion to $ 133 billion in 2023.

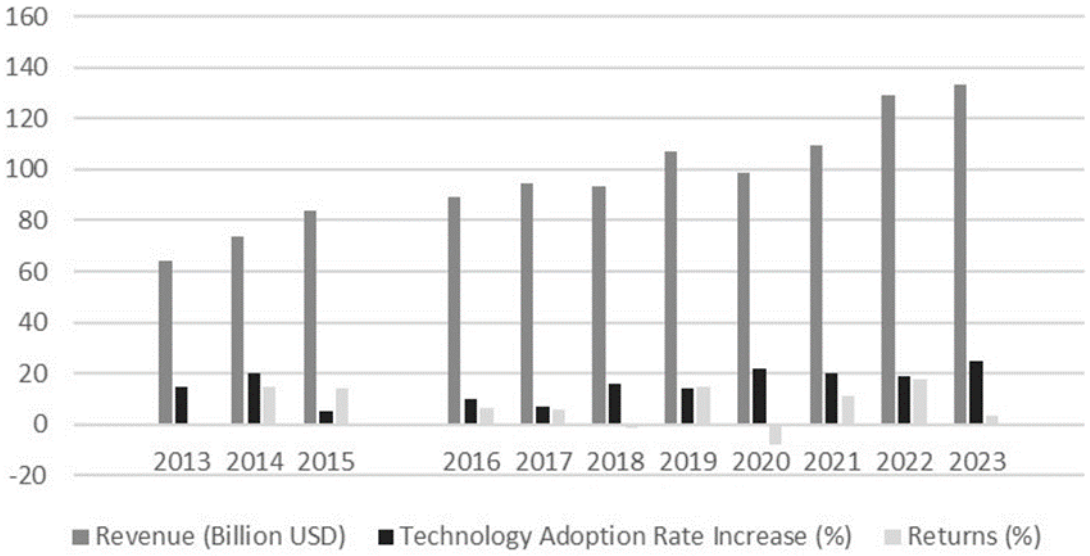

Fig. 1 U.S. Mercedes Benz Revenue and Technology Adoption Rate

The figure 1 shows that from 2013 to 2023, Mercedes Benz has adopted different technologies such as DISTRONIC Plus, Drive Pilot, MBUX System, MULTIBEAM LED, and others, which has led to increased revenue for the company.

2.3. Model Selection

Multiple Regression Analysis is used in this research to establish the correlation between technology and market performance. It finds out the correlation between the volume of sales and the proportions of market share of Mercedes-Benz and other factors such as economic indicators and the application rate of technology. With multiple regression analysis, not only does one get an estimate of the direct effect of these factors on the brand's market performance, but understanding the effect of changes in technology and economic conditions is made easier. One of the significant advantages of this approach is the multivariate interactions and dynamics of the systems under consideration. Given its latest technologies, it can offer an extended and complex analysis of Mercedes-Benz's economic impacts. The multiple regression formula is,

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + e_i \quad (1)$$

Y is the dependent variable (Revenue). β_0 is the intercept term, representing Y's baseline value when all independent variables are zero.

3. Results and Discussion

3.1. Data Processing

This section presents the key tables and figures that visually represent the data analysis conducted in the study. These visual aids help understand the relationships between variables and the results of the statistical tests. Figure 2 shows the t, sig, Beta and Tolerance Chart of the U.S Mercedes Benz sales. Figure 3 shows the residual graphical representation data of U.S Mercedes Benz sales.

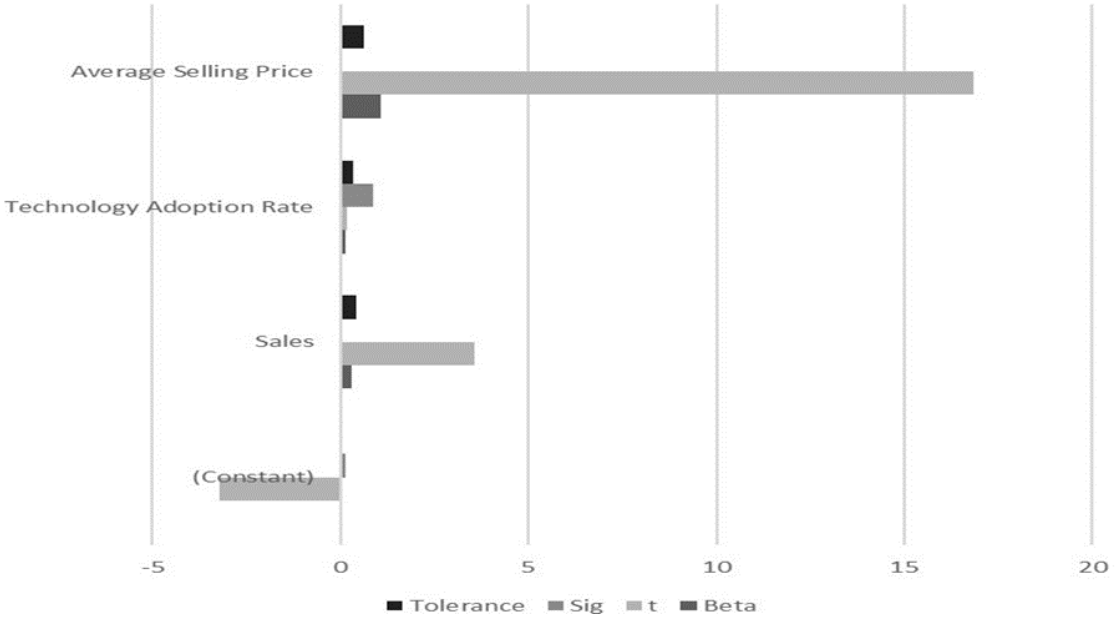

Fig. 2 T, sig, Beta and Tolerance Chart of the U.S Mercedes Benz sales

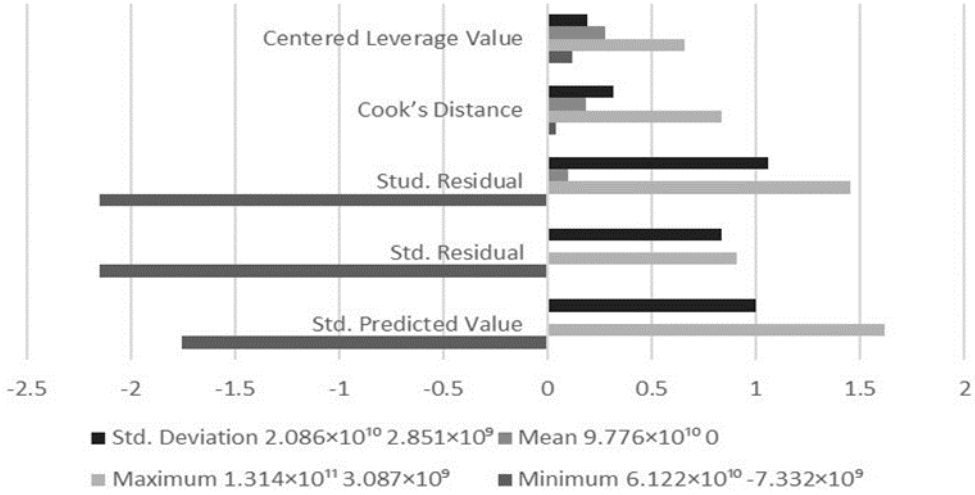

Fig. 3 Residual graphical representation data of U.S Mercedes Benz sales

3.2. Model Results

This section provides detailed interpretations of the data, explaining the significance of the statistical results and their implications for Mercedes-Benz's market outcomes. The study utilized multiple linear regression (MLR) analysis to examine the influence of technological innovation on Mercedes-Benz's market outcome in the United States (Table 2). Revenue was the dependent variable in the model, while the independent variables were Sales Volume, average sales, and Technology Adoption Rate.

The MLR analysis reveals that the Average Selling Price has the most substantial positive effect on Revenue with a highly significant p-value ($p = .000$). This finding suggests that the firm's revenues will rise when new technology is introduced, such as a superior safety system or electric car technology tend to increase ASP.

Table 2. Multiple Linear Regression Results

Variable	Beta	t	Sig	Tolerance
(Constant)		-3.220	0.150	
Sales	0.285	3.563	0.009	0.409
Technology Adoption Rate	0.140	0.155	0.881	0.336
Average Selling Price	1.092	16.863	<.001	0.625

Sales also have a high coefficient and are significantly associated with Revenue (p =0. 009). This implies that although sales volumes improve revenues, the sales price is mainly influenced by technological improvement, which greatly increases the company's revenue.

Notably, the Technology Adoption Rate is related to revenue, which resulted in a p of 0.881. This may mean an increase in technology adoption, but the implications for the revenue line are not high. This is mainly because technology is first expensive to adopt due to all the training sections required and the machinery purchases. Also, some people are slow to adopt one technology or another. All these factors result in slow revenue for Mercedes' newly adopted technological means.

3.3. Correlation Analysis

Pearson Correlation analysis was conducted to gain deeper insight into the association between the study variables. The correlation analysis in Table 3 shows that the selling price factor is the most influential in the company's revenue growth of Mercedes-Benz. The revenue has a correlation of 0.961 with the average price, indicating that high prices arising from incorporating more advanced technologies greatly boost revenues. This is in line with the market of luxury cars, where consumers are ready to spend extra dollars to acquire new technologies and improve the reputation of car brands. On the other hand, the Sales and Revenue model correlates with .258, suggesting that increased sales volumes may sometimes also positively affect revenue per sale.

Table 3. Pearson Correlation

Variable	Revenue	Sales	Average Price	Technology Adoption Rate
Revenue	1.000	0.258	0.961	0.462
Sales	0.258	1.000	0.488	0.769
Average Price	0.961	0.488	1.000	0.612
Technology Adoption Rate	0.462	0.769	0.612	1.000

Moreover, the revenue-boosting results of the Technology adoption rate, as established by the correlation coefficient of .462, underscores the impact of technological advancements on revenue generation. While the effect is not as strong as pricing, it still points out that using advanced technologies, like electric cars and autopilot systems, increases revenues. This implies that even though price strategies have a more definite impact on Mercedes-Benz's competitive performance, incorporating new technologies is also beneficial in drawing consumers willing to be associated with the company's innovation.

3.4. ANOVA Test

An Analysis of Variance (ANOVA) was conducted to assess the regression model's overall significance. The ANOVA results in Table 4 prove that the regression model is statistically significant, as indicated by the high F-statistic (124.945) and a p-value of 0. This affirms that the independent variables Sales, Average Selling Price, and Technology Adoption Rate strategically affect Revenue. For Mercedes-Benz, this supports the fact that these factors are significant determinants of the company's financial performance, especially in the U.S. market for luxury cars. The importance of these variables points directly to the relationship between movements in the variables and movements in revenue, ensuring the competitiveness of this element not only through efficient pricing strategies but also through efficient use of technology to achieve its objective (Table 4).

Table 4. ANOVA Results

Model	Sum of Squares	df	F	Sig
Regression	4.352×10^{21}	3	124.945	0.000
Residual	8.13×10^{19}	7	0.000	0.000
Total	4.432×10^{21}	10		

Moreover, the residual sum gives a value of 8.13×1019 while the total sum of squares is 4.432×1021; therefore, the model explains most of the revenue variance. This re-emphasizes that Mercedes-Benz's revenue is not only a function of the number of cars it sells but also a function of how those cars are priced and how much new technologies are incorporated. The results imply that Mercedes-Benz considers all the factors, each with a particular weight, to maximize its revenue. The results show a high adoption rate of technology, which is crucial in improving company revenue.

3.5. Model Diagnostic

The residuals are the differences between the observed revenue and the predicted revenue based on the multiple regression model. In this case, the residuals range from approximately −$7.33 billion to +$3.09 billion, with a mean of $0, indicating that, on average, the model's predictions are accurate and unbiased (Table 5).

Table 5. Residual Statistics

Statistic	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	6.122×10^{10}	1.314×10^{11}	9.776×10^{10}	2.086×10^{10}
Residual	-7.332×10^{9}	3.087×10^{9}	0.000	2.851×10^{9}
Std. Predicted Value	-1.752	1.614	0.000	1.000
Std. Residual	-2.152	0.906	0.000	0.837
Stud. Residual	-2.152	1.455	0.100	1.061
Cook's Distance	0.040	0.837	0.184	0.314
Centered Leverage Value	0.120	0.655	0.273	0.192

Standardized Residuals: The standardized residuals range from −2.152 to 0.906. Since these values are within the range of ±3, they suggest that the residuals do not contain any significant outliers that could distort the model's results. A value of −2.152 means that one of the observed revenues was lower than the predicted value by about 2.15 standard deviations. In contrast, a value of 0.906 indicates a predicted revenue that is slightly higher than the observed revenue by less than one standard deviation.

Studentized Residuals: These residuals, adjusted for variance, range from −2.606 to 1.455, with a mean of 0.010. The highest studentized residual of 2.606 indicates that one observation has a residual of about 2.61 times the standard error of the residuals, suggesting moderate influence but still within acceptable limits.

Cook's Distance: This metric measures the influence of each observation on the fitted values of the model. The maximum Cook's distance value is 0.837, which is below the critical threshold of 1, meaning that no individual observation has an undue influence on the regression model. The average Cook's distance of 0.184 supports the idea that the model is generally robust against the influence of single data points.

Centered Leverage Value: The leverage values range from 0.012 to 0.655, with a mean of 0.273. The highest leverage value of 0.655 indicates that one observation is somewhat influential, but it is still within acceptable limits. High leverage points could potentially distort the model if they coincide with large residuals, but in this case, there doesn't seem to be any such problem.

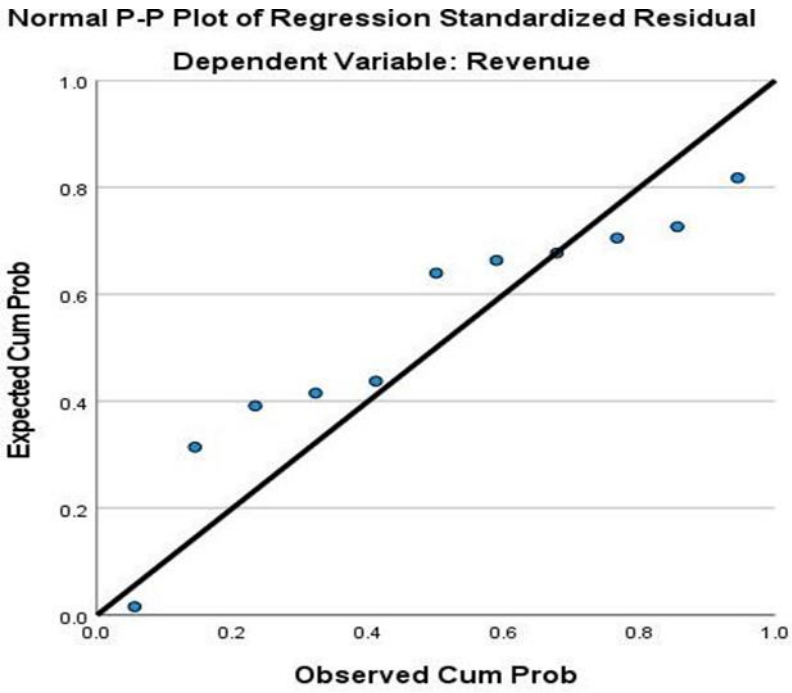

Fig. 4 Normal P-P Plot of Regression Standardized Residual

The P-P plot shows the distribution of the standardized residuals for the regression model predicting revenue (Figure 4). Most residuals are centered around 0, indicating that the model's predictions are generally accurate, with a slight skew due to one outlier around -3. The residuals are close to a normal distribution, supported by the superimposed curve, and the standard deviation of 0.837 suggests that most residuals are within one standard deviation of the mean.

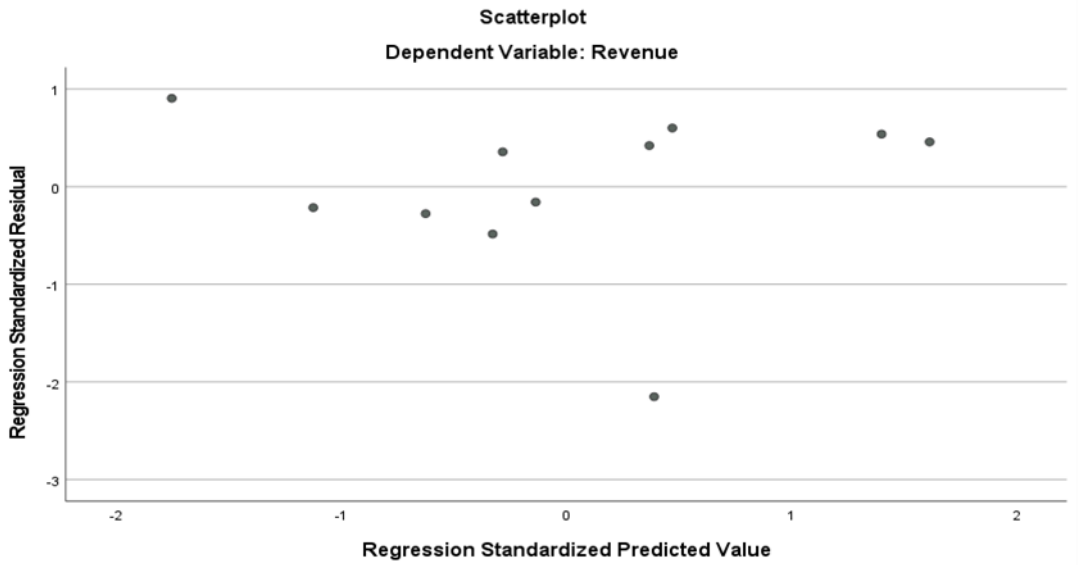

Fig. 5 Regression standardized residual

The scatterplot shows the relationship between the regression standardized predicted values and the standardized residuals for the revenue model (Figure 5). The points are scattered without a clear pattern, suggesting that the residuals are randomly distributed, which is a good sign that the assumptions of linearity and homoscedasticity are met. The lack of a systematic pattern indicates that the model does not suffer from major issues like heteroscedasticity or non-linearity.

4. Conclusion

In conclusion, this study illustrates that technological advancements significantly shape Mercedes-Benz's market performance in the U.S. luxury car sector. Although electric vehicles and autonomous driving systems are the sources that enable Mercedes-Benz companies to maintain the competitiveness of the automobile business, it is crucial to note that the pricing of these new technology products has the most profound impact on revenue generation. The research shows that although technology adoption is essential, it does not instantly lead to substantial revenue increases due to the high implementation costs and varied consumer adoption rates. However, the strong correlation between the average selling price and revenue highlights the effectiveness of leveraging advanced technologies to justify premium pricing. Ultimately, continuous innovation and strategic pricing are critical for Mercedes-Benz to maintain its leadership in the evolving luxury car market.

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