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Analysis of the international competitiveness of the automotive industry in the age of artificial intelligence

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Abstract

The article examines the international competitiveness of the automotive industry in China, Germany, Japan and the United States, considering the impact of artificial intelligence and related technologies. The main goal is to identify the key competitive factors in the era of digitalisation and evaluate their impact on the strategy of automotive corporations. A statistical analysis and a correlation measurement model were used. In this new paradigm, success is not determined by the size of the corporation or its historical heritage, but by its ability to quickly adopt and implement technological solutions that will shape the future of mobility. The introduction of artificial intelligence in production and products is recognised as the most important factor in increasing the competitiveness of goods and services. Other factors include innovation, adaptability to market changes, integration of sustainable practices and digital transformation. Based on a comparative analysis of leading corporations, recommendations are proposed to strengthen positions in the global market segment. The results of the study will be useful for automotive corporations, as well as for government and non-profit organisations that support the industry.
Keywords: international competitiveness, automotive industry, artificial intelligence

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分析智能时代汽车业的国际竞争力

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简介

文章研究了中国、德国、日本和美国汽车行业在人工智能及相关技术影响下的国际竞争力。主要目的是找出数字化时代竞争力的关键因素，并评估其对汽车企业战略的影响。研究采用了统计分析和相关测量模型。在这种新模式下，成功与否并不取决于企业的规模或历史传承，而是取决于企业能否快速适应和应用技术解决方案，从而塑造未来的移动性。在生产和产品中引入人工智能已被公认为提高商品和服务竞争力的最重要因素。其他因素包括创新性、对市场变化的适应性、可持续实践的整合以及数字化转型。在对领先企业进行比较分析的基础上，提出了加强在全球细分市场中的地位的建议。研究结果对汽车企业以及支持该行业的政府和非营利组织都很有用。这项工作的新颖之处在于采用综合方法分析竞争力，并将人工智能技术考虑在内，为全球汽车制造商的战略发展提供了新的视角。
关键词： 国际竞争力、汽车行业、人工智能

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Introduction

In an era of rapid technological development and artificial intelligence, the international competitiveness of the automotive industry is of particular importance. Globalisation and market integration present new challenges that require corporations to adapt and actively implement innovative technologies in order to lead the global race.

As one of the most technologically advanced industries, the automotive sector is reconsidering its strategies in the context of digitalisation. Competition is intensifying in terms of both products and services and automated production processes [Bityutskaya, Klochko, 2020]. Artificial intelligence is applied at every stage, from model design to logistics and servicing. Companies investing in AI technologies such as autonomous driving, intelligent safety systems and adaptive interfaces are setting industry standards and taking leading positions [Volkov, Rotkin, 2024].

At the same time, the industry must become more flexible and adaptable. Accelerating innovation cycles, transitioning to sustainable production processes, and meeting the demand for green transport are all key to success. Data analysis is crucial for strategic planning, enabling more accurate demand forecasting, improved quality and increased customer satisfaction [Akhmedov, 2022].

The integration of advanced technologies and adaptability provide a competitive advantage on a global scale. Innovative activity, strategic partnerships, and the ability to manage change flexibly are the main drivers of the industry's growth and sustainable development [Rybakov et al., 2021].

Studying the global competitiveness of the automotive industry in the artificial intelligence era enables us to identify trends, predict changes, and develop effective strategies to achieve sustainable leadership [Voropaeva et al., 2022].

1. Market description and research methodology

In the 21st century, the automotive industry is on the threshold of a new era where artificial intelligence, advanced technological solutions, and sustainable development are the main driving factors. In this digital age, where technology is deeply embedded in all aspects of life, evaluating the global competitiveness of the automotive industry necessitates a fresh perspective that considers innovation, environmental responsibility, and the evolving landscape of consumer preferences [Ogneva, 2024].

Since its inception, the automobile industry has been one of the foundations of the world economy. Since Henry Ford's assembly line produced the first cars, the industry has consistently developed, introducing new technological solutions and expanding international markets. The exchange of engineering knowledge and production technologies between countries has contributed to the formation of a global competitive environment, in which each manufacturer seeks not only to follow trends, but also to get ahead of them [Teshaboev, 2021; Tishchenko, 2021].

Currently, the world's leading automobile manufacturing countries are employing a variety of strategies to boost their competitiveness. Germany, for example, emphasises engineering innovation and high quality standards; Japan focuses on improving hybrid technologies; and the United States prioritises the mass production of electric vehicles and infrastructure development. Meanwhile, the Chinese automobile industry is actively developing the market through aggressive expansion and government support [Antipova, 2024].

The Age of Intelligence is opening up new horizons for the automotive industry, but it is also forcing us to rethink our approach to competition. Those corporations that can adapt by investing in research and development and establishing sustainable production and environmental processes will strengthen their position in the global market and become leaders of the new technological era [Varshavsky, Dubinina, 2020]. It is important to remember that true competitiveness is determined not only by economic success, but also by a company's contribution to societal, environmental and quality-of-life development [Volkov, Rotkin, 2024].

The automotive industry is recognised as one of the key sectors of the global economy, with significant differences in its development across different countries. Leading participants in global auto production include China, Germany, Japan and the United States. Each of these countries has its own unique automotive industry development history and specifics, which determine their current market position and future growth prospects [Smelkov et al., 2024].

China maintains a leading position in the global automotive industry in terms of production and sales. This success is largely thanks to the country's rapid economic growth, which has been supported by the government [Zhang, 2024]. China's auto industry is characterised by its ability to swiftly adopt new technologies and adapt to current trends. Consistent with the national strategy to reduce environmental impact and dependence on foreign petroleum products, Chinese companies are investing heavily in the development of electric and autonomous vehicles [Liu, 2024].

A notable characteristic of the Chinese market is its size. However, local manufacturers face challenges such as improving the quality of their products and strengthening their competitive position in both the domestic and global markets (Lu, 2024). In recent years, Chinese brands have begun to expand into overseas markets, but they have yet to earn consumers' trust in terms of quality and reliability [Gilfanova, Sakhbieva, 2022].

Germany is famous not only for its premium cars, but also for its advanced engineering and innovative technologies. German car manufacturers such as Volkswagen, BMW and Mercedes-Benz are renowned for producing reliable, high-quality vehicles. Germany is at the forefront of producing cars with internal combustion engines, and this has led to the creation of many sub-brands and a wide range of models [Pozharskaya, Vasilyeva, 2020].

As one of the most innovative participants in the global automotive market, Japan places emphasis on impeccable quality, reliability and technological advances. Leading Japanese car manufacturers such as Toyota, Honda and Nissan are at the forefront of hybrid technology. The Toyota Prius has become a symbol of Japan's commitment to environmentally friendly solutions.

The United States has traditionally been at the forefront of the automobile industry, home to giants such as Ford, General Motors and Chrysler. The American market is renowned for its emphasis on mass production, enabling it to provide consumers with a diverse selection of models at various price points. Car enthusiasts in the United States often prefer larger vehicles, including SUVs and pick-up trucks.

The impact of international competition factors within the framework of comparative economic analysis was assessed by constructing a model of economic efficiency in the automobile industry and measuring correlation.

2. Comparative analysis

All of the countries discussed have made significant contributions to the global automotive industry, each with its own unique features and advantages. China stands out thanks to the speed with which it integrates new technologies and its production volumes, which are making it an increasingly prominent player in the global market. Germany continues to lead the way in innovation and the premium segment. Japan is renowned for the quality and variety of its exports. Meanwhile, the United States stands out for its ability to mass-produce and innovate in the fields of electronics and electric vehicles (Fig. 1).

It is important for each of these countries to strike a balance between environmental responsibility, economic efficiency, and technological innovation. Global trends, such as the shift towards renewable energy sources and the digitalisation of the automotive industry, mean that manufacturers must be flexible and ready to adapt quickly [Goncharova et al., 2023].

In this study, mathematical analysis tools were used to analyse the data and construct graphs displaying the dynamics of production and sales in the automobile industries of China, Japan, Germany and the United States. The STATA programme was used for modelling [Demurcheva, 2022].

The analysis indicates that the economic efficiency of car production and sales will decrease in the future due to rising costs and the impact of renewable energy.

A weight graph was constructed for the *i*-th member of the exponential smoothing series based on the results of the analysis (attenuation factor = 0.8) (Fig. 2) [Kamenev, Zambrzhitskaya, 2024].

As the analysis showed, the cost of producing and selling cars is increasing due to higher demand.

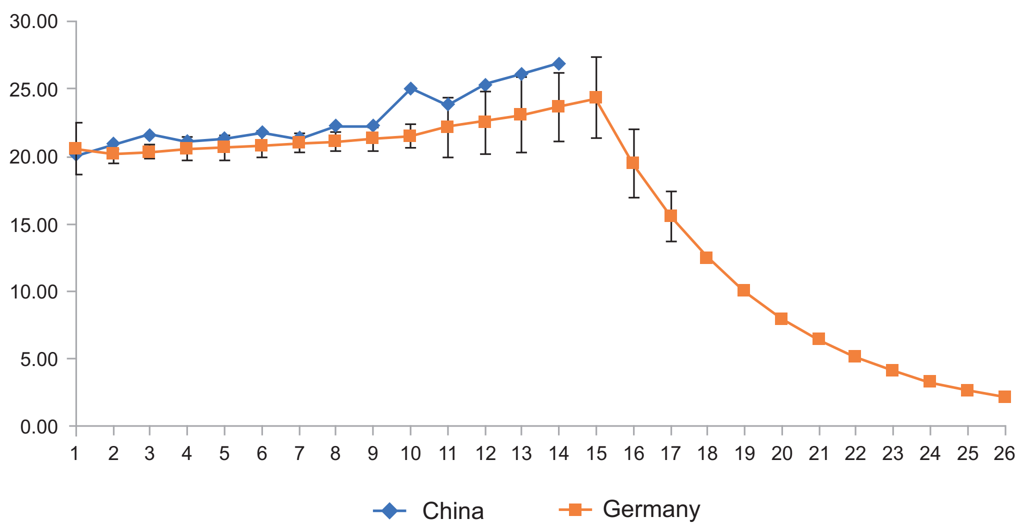
A weight graph was constructed for the *i*-th member of the exponential smoothing series based on the results of the analysis (attenuation factor = 0.6) (Fig. 3). According to the analysis, producing and selling cars is economically efficient due to demand from other countries. Based on these results, a weighted graph was constructed for the *i*-th member of the exponential smoothing series (attenuation factor = 0.7) (Fig. 4).

Financial security is recognised as a key factor in implementing project decisions for transport infrastructure development.

A weight graph was constructed for the *i*-th member of the exponential smoothing series based on the results of the analysis (attenuation factor = 0.8) (Fig. 5).

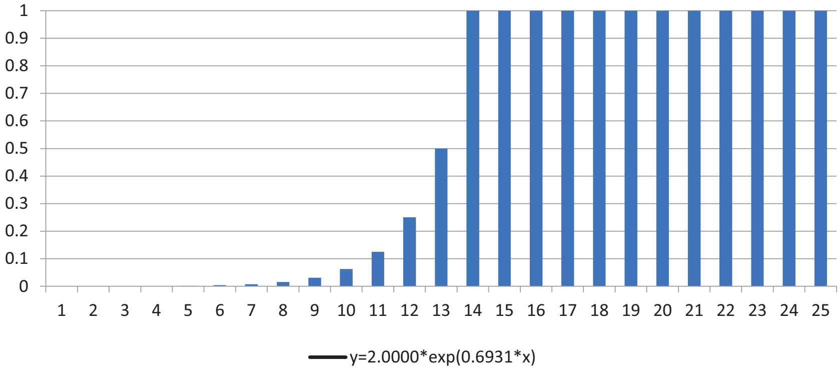
A weight graph was constructed for the *i*-th member of the exponential smoothing series based on the results of the analysis (attenuation factor = 0.8) (Fig. 6).

Fig. 1. Dynamics of car production volume in different countries



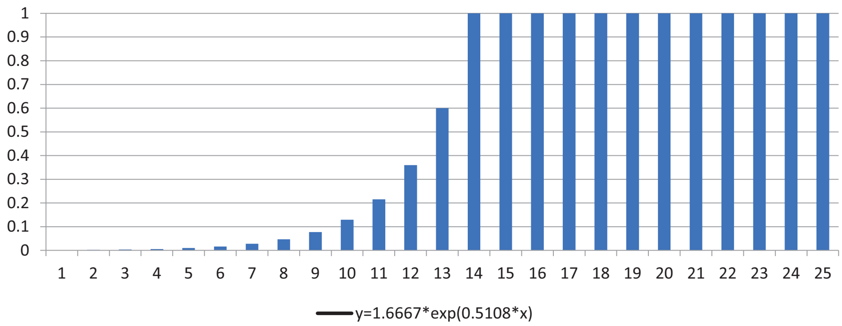
Source: compiled by the authors..

Fig. 2 Graph of weights for the *i*-th term of the exponential smoothing of the economic efficiency in automobile sales, taking into account the planning efficiency factor (attenuation factor = 0.5)



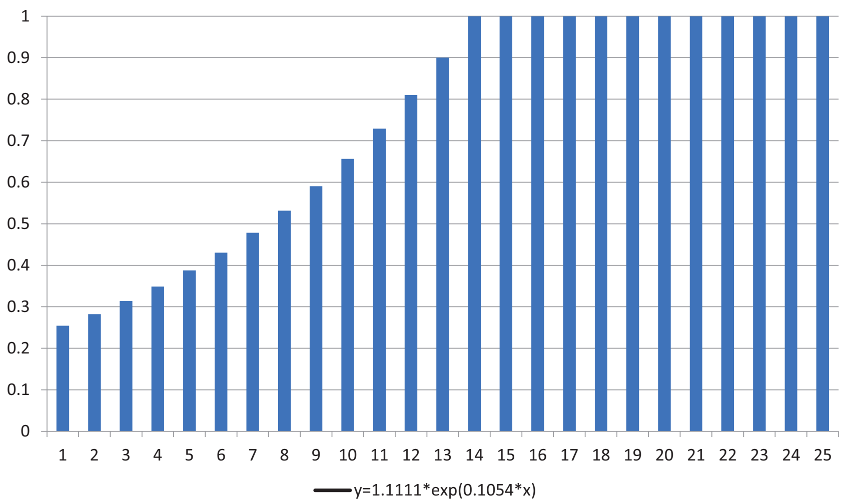
Source: compiled by the authors

Fig. 3. Graph of weights for the *i*-th member of the exponential smoothing series (attenuation factor = 0.6) for the economic efficiency of producing and saling cars, taking into account the efficiency factor of CA planning



Source: compiled by the authors.

Fig. 4. Graph of weights for the *i*-th member of the exponential smoothing series (attenuation factor = 0.7) for the economic efficiency of producing and saling automobiles taking into account the factor of financial security



Source: compiled by the authors.

The car industries in China, Germany, Japan and the United States take different approaches to innovation, production processes and marketing, reflecting the unique economic and cultural characteristics of each country.

They are united by a desire to improve technology, act in an environmentally responsible manner, and meet the needs of their target audience. In today's rapidly changing global economy, the ability to adapt and implement cutting-edge solutions is becoming a key factor for all major market players.

3. Factor economic analysis

This study analyses the formation of automobile production prices from 2004 to 2024.

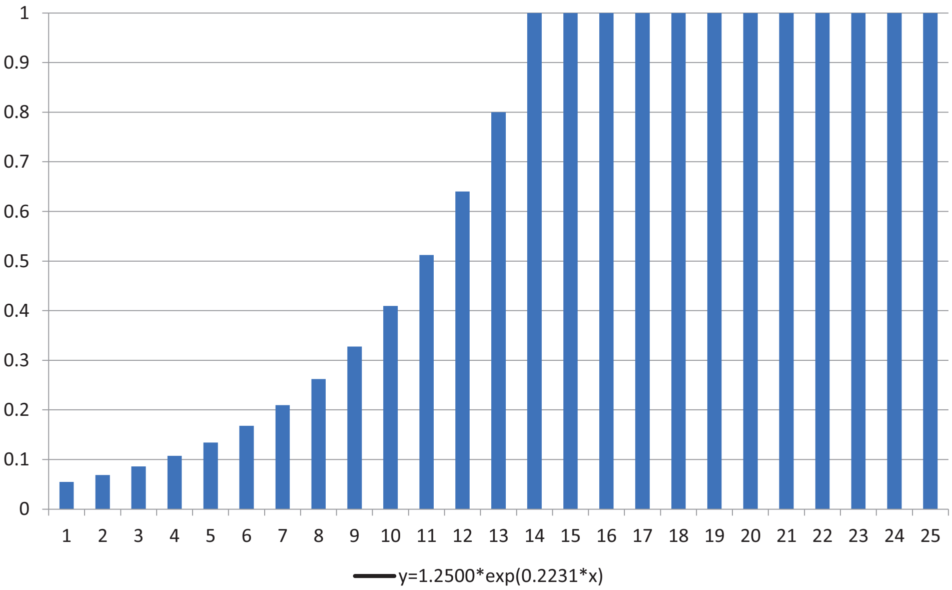
It is interesting to compare the competitiveness of the automobile industries in China, Germany, Japan and the United States, given the unique economic structures, production processes and marketing strategies that characterise each country.

These countries' competitiveness is determined by their ability to adapt to the global market, invest in innovation, and strike a balance between quality and cost. As the global automotive industry becomes more integrated, each country is contributing by promoting unique, sustainable growth strategies and taking leading positions in technology.

China, once seen as a cheap manufacturing hub, is now making strides towards technological leadership. The country is focusing on electric vehicles and autonomous technologies, supporting these areas through research and government initiatives. Companies such as BYD and NIO are strengthening their positions not only in the domestic market, but also competing confidently with Western corporations on the global stage.

Renowned for its quality and engineering innovation, Germany places emphasis on sustainable manufacturing and the development of electric vehicles. Volkswagen, BMW and Mercedes-Benz are investing heavily in clean technology, aiming to reduce their carbon footprint while remaining at the forefront of technological development. The practical and meticulous nature of the German

Fig. 5. Graph of weights for the *i*-th member of the exponential smoothing series (attenuation factor = 0.8) for the economic efficiency in car production and sales, taking into account the factor of project budget management



Source: compiled by the authors.

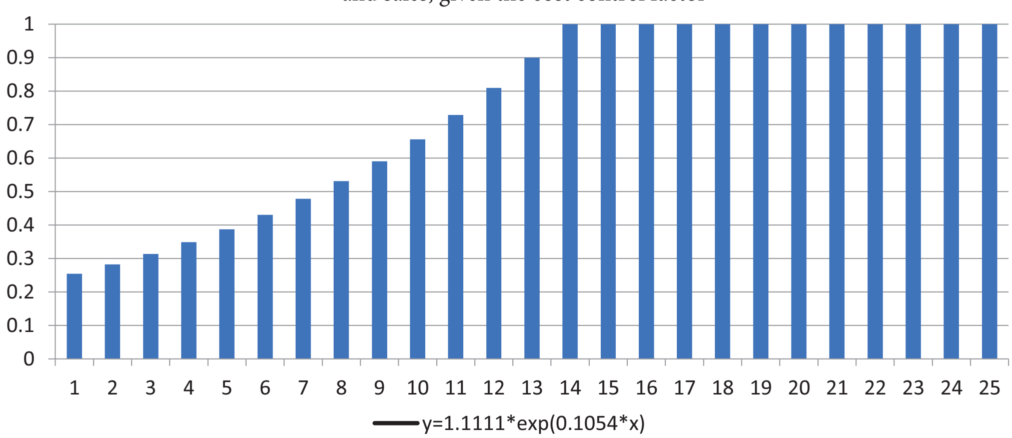
automobile industry helps it to maintain its status as a top-notch manufacturer.

Japan's unique manufacturing approach and Kaizen philosophy of continuous improvement mean it is focusing on hybrid technology and product reliability. Leading the hybrid segment are companies such as Toyota and Honda, which influence global trends and set quality standards. Japan's commitment to developing hydrogen energy further highlights its focus on innovation and environmentally friendly solutions.

The United States remains a key player in the global economy, with its automotive industry historically symbolising economic power and technological innovation. Companies such as Ford and General Motors are modernising their manufacturing processes aggressively to meet modern market demands, with a particular focus on electrification. Additionally, companies such as Tesla are driving disruption and significantly influencing the global automotive agenda and the cost of battery technology.

The development of artificial intelligence, blockchain and Internet of Things (IoT) technologies has fundamentally transformed the way automobiles are manufactured and operated. Automakers that successfully integrate these technological solutions will lead their market segment. Using deep and machine learning algorithms optimises design and engineering processes, significantly reducing the time and cost of bringing a new product to market. Particular attention should be paid to the development of autonomous vehicles, which represent the pinnacle of the industry's intellectual achievements.

Fig. 6. Weight graph for the *i*-th exponential smoothing series (attenuation factor = 0.8) of the economic efficiency of automobile production and sales, given the cost control factor



Source: compiled by the authors.

In the era of the Fourth Industrial Revolution, the automotive industries of China, Germany, Japan and the United States are facing a new era of international competitiveness. These are determined by rapid technological change and geopolitical challenges, as well as rising consumer expectations for sustainable, intelligent vehicles.

The following conclusions can be drawn based on the constructed box plots:

- influence automobile production, such as export volumes, investment in innovation, and the introduction of environmentally friendly technologies. This suggests that there are significant differences in the strategies adopted by different countries to develop their automobile industries.
- abnormal values are present.

ДWe will conduct a correlation analysis on the original data array. For this, we will use the corr() function from the Python Pandas data library (Fig. 7).

We will also check the correlation coefficients for significance. To determine the significance of the correlation coefficient, we will use the Student's *t*-test. In this test, we will test the hypothesis that the correlation coefficient is equal to zero.

We will also conduct a correlation analysis of data on the production process and car sales (Fig. 8).

Today's consumers are increasingly aware of the impact their vehicle choices have on the environment. This has led to an increased demand for environmentally friendly technologies, such as electric and hydrogen-powered engines. By strategically integrating these developments into their production processes, corporations can not only comply with environmental regulations, but also capture new markets, making their products more attractive to environmentally conscious consumers. (Figure 9).

Let's calculate the estimates of $\hat{a}_0$, $\hat{a}_1$, $\hat{a}_2$, $\hat{a}_3$, $\hat{a}_4$, $\hat{a}_5$, $\hat{a}_6$, $\hat{a}_7$ and S_{ELR} or the parameters of the linear regression model. To do this, we can use the Regression tool by selecting the appropriate menu item in the Data Analysis add-on of Microsoft Excel (Fig. 10).

Based on the analysis results, a graph was created using exponential smoothing (attenuatuion factor = 0.5) (Fig. 11).

Улучшение управления цепочками поставок с помощью Improving supply chain management through the use of smart technologies plays a crucial role in reducing risks and optimising logistics processes. With economic stability often at risk in today's global market, flexibility and the ability to adapt quickly are becoming essential factors for creating a competitive advantage. The choice of countries for placing production facilities and resources for automobile corporations significantly impacts their ability to stay competitive in the market. An exponential smoothing graph (damping factor = 0.6) was created based on the analysis (Fig. 12).

As the analysis shows, with the increase in production and transportation volumes, the cost of maintaining the transport infrastructure also increases. Based on the results of the analysis, an exponential smoothing graph was created

Fig. 7. Correlation analysis of economic efficiency factors in car production

	Y	X1	X2	X3	X4	X5	X6	X7
Y	1.000	0.667	-0.016	0.087	0.322	-0.666	-0.489	0.615
X1	0.667	1.000	-0.105	-0.190	0.045	-0.505	-0.274	0.483
X2	-0.016	-0.105	1.000	0.184	0.046	0.046	-0.270	0.111
X3	0.087	-0.190	0.184	1.000	0.242	-0.233	-0.424	0.313
X4	0.322	0.045	0.046	0.242	1.000	-0.258	-0.310	0.313
X5	-0.666	-0.505	0.046	-0.233	-0.258	1.000	0.507	-0.490
X6	-0.489	-0.274	-0.270	-0.424	-0.310	0.507	1.000	-0.573
X7	0.615	0.483	0.111	0.313	0.313	-0.490	-0.573	1.000

High positive correlation
Weak positive correlation
Average positive correlation
Negative correlation

Source: compiled by the authors.

Fig. 8. Correlation map for car sales data

	Y	X1	X2	X3	X4	X5	X6	X7
Y	1.000	0.643	-0.004	0.100	0.306	-0.648	-0.537	0.605
X1	0.643	1.000	-0.448	-0.197	0.040	-0.490	-0.335	0.480
X2	-0.004	-0.448	1.000	0.493	0.107	-0.051	-0.190	0.084
X3	0.100	-0.197	0.493	1.000	0.246	-0.260	-0.457	0.327
X4	0.306	0.040	0.107	0.246	1.000	-0.182	-0.286	0.260
X5	-0.648	-0.490	-0.051	-0.260	-0.182	1.000	0.617	-0.449
X6	-0.537	-0.335	-0.190	-0.457	-0.286	0.617	1,000	-0.613
X7	0.605	0.480	0.084	0.327	0.260	-0.449	-0.613	1.000

High positive correlation
Weak positive correlation
Average positive correlation
Negative correlation

Source: compiled by the authors.

Fig. 9. Correlation map for competitiveness data

	Y	X1	X2	X3	X4	X5	X6	X7
Y	1.000	0.672	-0.014	0.059	0.219	-0.697	-0.540	0.579
X1	0.672	1.000	0.000	-0.182	0.015	-0.538	-0.338	0.498
X2	-0.014	-0.000	1.000	-0.030	-0.114	0.008	0.385	-0.137
X3	0.059	-0.182	-0.030	1.000	0.295	-0.257	-0.425	0.356
X4	0.219	0.015	-0.114	0.295	1.000	-0.183	-0.291	0.274
X5	-0.697	-0.538	0.008	-0.257	-0.183	1.000	0.674	-0.492
X6	-0.540	-0.338	0.385	-0.425	-0.291	0.674	1.000	-0.588
X7	0.579	0.498	-0.137	0.356	0.274	-0.492	-0.588	1.000

High positive correlation
Weak positive correlation
Average positive correlation
Negative correlation

Source: compiled by the authors.

Fig. 10. Regression analysis result

ВЫВОД ИТОГОВ								
рессионная статистика								
Множеств	0,815719							
R-квадрат	0,665398							
Нормиров	0,634168							
Стандартн	25724,62							
Наблюден	83							
Дисперсионный анализ								
	df	SS	MS	F	ачимость F			
Регрессия	7	9,87E+10	1,41E+10	21,30666	1,6E-15			
Остаток	75	4,96E+10	6,62E+08					
Итого	82	1,48E+11						
	Коэффициен	дартная ош	статисти	Р-Значение	ижние 95%	ерхние 95%	ижние 95,0	рхние 95,0
Y-пересеч	141151,1	384639,6	0,36697	0,714675	-625090	907392,5	-625090	907392,5
Среднеду	1,549299	0,390438	3,968101	0,000164	0,771506	2,327092	0,771506	2,327092
Индекс пс	-424,442	3604,181	-0,11776	0,90657	-7604,34	6755,455	-7604,34	6755,455
Доля обо	-224,582	369,1571	-0,60836	0,544784	-959,981	510,8168	-959,981	510,8168
Обеспече	66,95394	33,19689	2,016874	0,047288	0,822339	133,0855	0,822339	133,0855
Доля насе	-2759,85	818,7329	-3,37088	0,001187	-4390,85	-1128,85	-4390,85	-1128,85
Уровень б	-768,483	753,1918	-1,0203	0,310865	-2268,92	731,9517	-2268,92	731,9517
Доля горс	644,6361	304,6531	2,115967	0,037667	37,73588	1251,536	37,73588	1251,536

Source: compiled by the authors.

(damping factor = 0.7) (Fig. 13). Based on the analysis results, an exponential smoothing graph was constructed (damping factor = 0.8) (Fig. 14).

As the analysis shows, controlling costs allows optimising expenses for the production process and sale of cars. Based on the results of the analysis, an exponential smoothing graph was created (damping factor = 0.9) (Fig. 15).

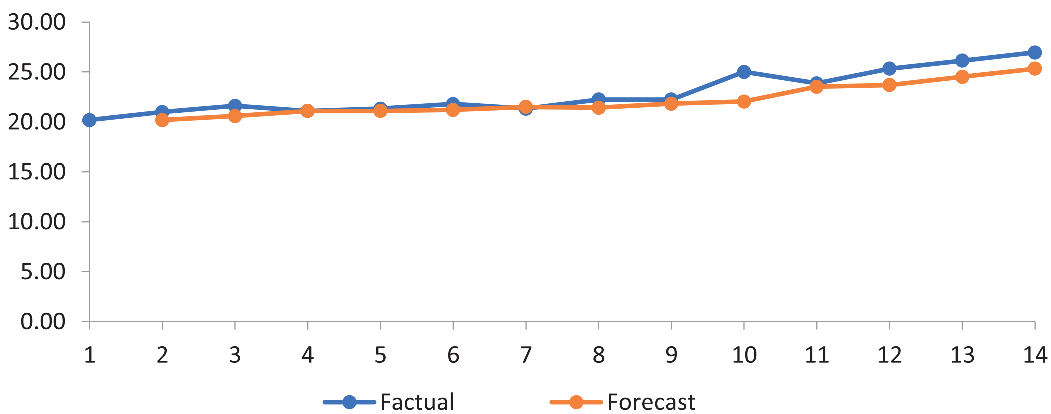
Changing lifestyles and consumer preferences are influencing the automotive industry. Safety, comfort, and integration of connected technology are making cars more attractive to the next generation of users. Understanding what influences individual choice can help corporations anticipate and set trends.

At the forefront of this intelligent disruption is China, which has firmly established itself on the global automotive stage thanks to its large-scale manufacturing processes and innovations in automation and artificial intelligence. Chinese corporations are heavily investing in research and development, supported by government programs such as 'Made in China 2025'. The electric vehicle market in China is expanding rapidly, helping to position the country as a leader in this sector.

The United States continues to lead the way thanks to its strong innovation ecosystem, which is primarily located in Silicon Valley. American companies such as Tesla and Ford are actively developing electric and connected vehicle technology solutions, providing unique solutions for integrating transportation and the Internet of Things. These solutions include intelligent infotainment features and advanced automatic driving assistance functions.

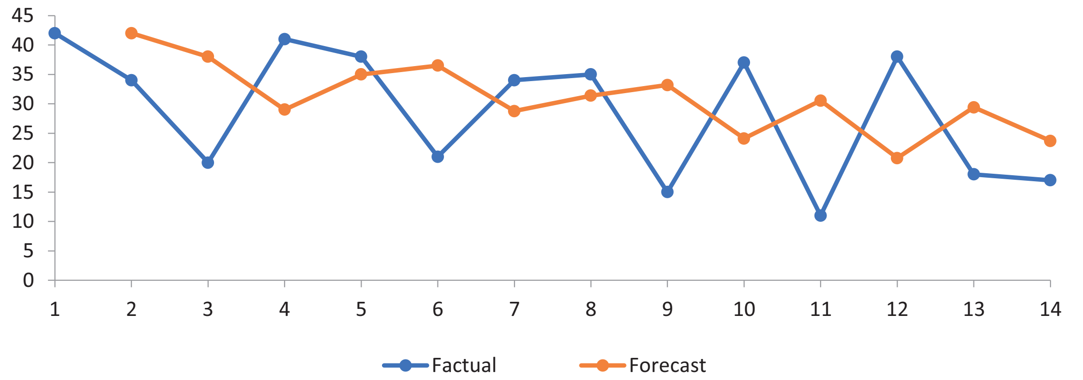
Thus, the international competitiveness of the automotive industry today depends not only on traditional production factors, but also on the ability to adapt and implement intelligent technological solutions. These unique national and regional strategies form the basis for the future

Fig. 11. Exponential smoothing plot (attenuation factor = 0.5)
of China's automobile production and sales



Source: compiled by the authors.

Fig. 12. Exponential smoothing plot (фttenuation factor = 0.6)
of Japanese automobile production and sales



Source: compiled by the authors.

of the global automotive sector. Innovation and intelligence are key drivers of growth and development in this complex field.

Conclusion

A factor economic analysis of competitiveness in the automotive industry during the age of intelligent technology highlights the importance of adaptability and innovative technologies. Growth and success will depend on corporations' ability to effectively integrate intelligent technological solutions, taking into account environmental and social trends and the ability to quickly adapt to changing conditions on the global market. Only those who are able to adapt with the times will be able to maintain their leadership position in this new reality.

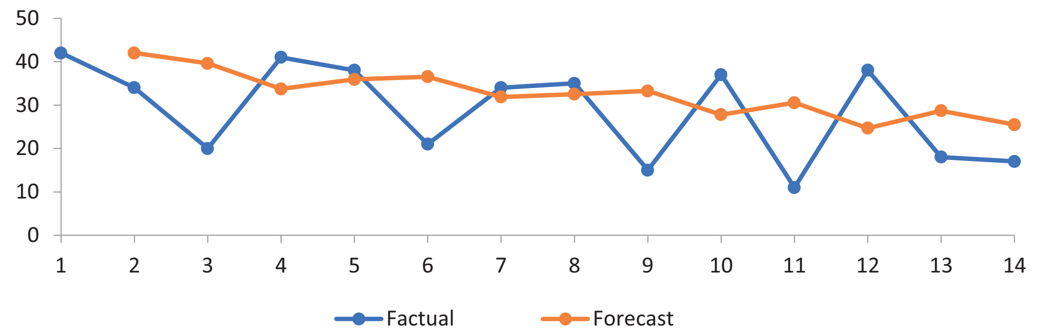
In an age of rapid technological innovation and globalisation, the automotive industry is undergoing a fundamental change. Traditionally, competitiveness has been based on factors such as production capacity, labor costs, and geographical advantages. However, this is giving way to new criteria driven by smart technologies. Success in this new paradigm is not determined by the size or historical legacy of a company, but rather by its ability to adapt quickly and apply innovative solutions that shape the future of transportation [Asmolov et al., 2024] .

Artificial intelligence and automation are key to competitiveness in the industry. The future of automobiles, especially with the development of autonomous driving, requires manufacturers to have deep expertise in machine learning, computer vision, and real-time data analysis. Automakers who can integrate these technological solutions into their manufacturing processes will gain a significant advantage by reducing costs and improving product quality [Shukurov et al., 2020].

Research and development are becoming the main driver of competitiveness. Corporations in China, Germany, Japan and the US need to invest heavily in innovation to create cars that are not only technically advanced but also meet changing consumer expectations. Manufacturers that focus on sustainable energy, electric vehicle development and safety improvements have a better chance of success given the growing emphasis on sustainability and safety among their audiences.

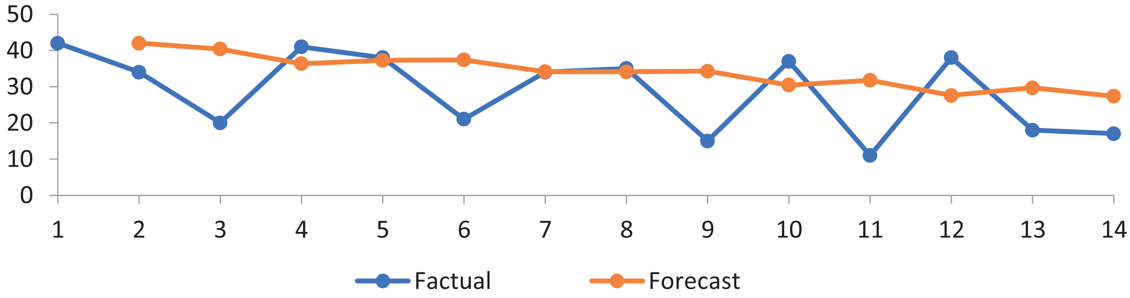
Digital transformation of all stages of the vehicle lifecycle, from concept development to after-sales service, has been recognised as an essential factor in maintaining competitiveness. By using intelligent data analysis, corporations can predict consumer behaviour, optimise supply chains, and manage production processes more effectively, leading to higher quality standards and increased customer satisfaction.

Fig. 13. Exponential smoothing plot (attenuation factor = 0.7)
of German car production and sales



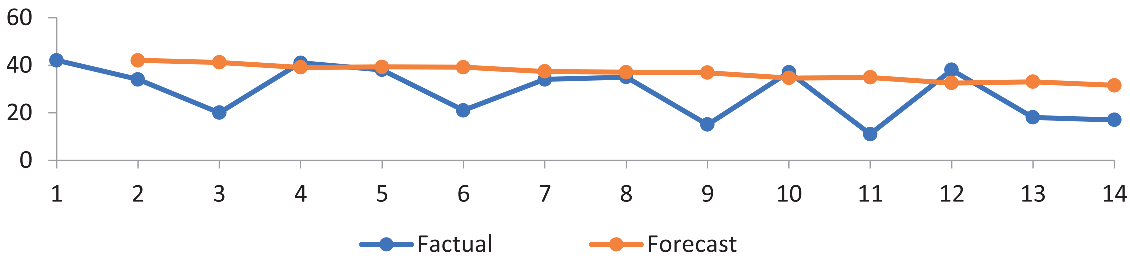
Source: compiled by the authors.

Fig. 14. Exponential smoothing plot (attenuation factor = 0.8) of US auto production and sales



Source: compiled by the authors.

Fig. 15. Exponential smoothing plot (attenuation factor = 0.9) showing the profitability of auto production and sales in China, Germany, Japan and the United States



Source: compiled by the authors.

Moreover, competitiveness in the age of intelligence is determined by the ability to produce not just vehicles, but complex digital ecosystems. Consumers expect not only physical products, but also their integration with digital services, such as navigation, multimedia systems, or the ability to connect to the internet of things. Corporations that are able to create smart cars connected to a ecosystem of technologies and services will be at the forefront of the industry.

Thus, the competitiveness of the automobile industry in China, Germany, Japan, and the United States during the era of intelligent transportation requires flexible adaptation to change, implementation of advanced technologies, and a deep understanding of rapidly evolving market landscapes. Only those companies that master these trends and turn challenges into new opportunities will be able to withstand fierce competition and shape the future of the industry.

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