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Preface

The 8th International Conference on Economic Management and Green Development (ICEMGD 2024) is an annual conference focusing on research areas including finance, economics and business management. It aims to establish a broad and interdisciplinary platform for experts, researchers, and students worldwide to present, exchange, and discuss the latest advance and development in finance, economics and business management.

This volume contains a selection of high-quality papers submitted to the workshop "Policies to Enhance Sustainable Development through the Green Economy" held in collaboration with the ICEMGD 2024. The workshop, chaired by Dr. Javier Cifuentes-Faura from University of Murcia, is part of a broader initiative to examine interdisciplinary approaches in sustainability, green economics, pollution, renewable energy and policies. Each of these papers has gained a comprehensive review by the editorial team and professional reviewers. Each paper has been examined and evaluated for its theme, structure, method, content, language, and format.

Cooperating with prestigious universities, ICEMGD 2024 organized four more workshops in Bratislava, Edinburgh and Beijing. Dr. Lukáš Vartiak chaired the workshop “Practicing How the EFQM Model Helps Manage the Organization”, which was held at Comenius University in Bratislava. Prof. Gbenga Adamolekun chaired the workshop “Decoupling Corporate Finance Implications of Firm Climate Action”, which was held at Edinburgh Napier University. Prof. Xinzhong Bao chaired the workshop “Innovative Strategies in Microeconomic Business Management”, which was held at Beijing Union University. Dr. Li Chai chaired the workshop “Environmental Economics and Sustainable Business”, which was held at China Agricultural University.

Besides these workshops, ICMRED 2024 also held an online session. Eminent professors from top universities worldwide were invited to deliver keynote speeches in this online session, such as Dr. Lukáš Vartiak from Comenius University in Bratislava and Dr. Javier Cifuentes-Faura from University of Murcia. They have given keynote speeches on related topics of finance, economics and business management.

On behalf of the committee, we would like to give sincere gratitude to all authors and speakers who have made their contributions to ICEMGD 2024, editors and reviewers who have guaranteed the quality of papers with their expertise, and the committee members who have devoted themselves to the success of ICEMGD 2024.

Dr. Lukáš Vartiak

General Chair of Conference Committee

Workshops

Workshop – Bratislava: Practicing How the EFQM Model Helps Manage the Organization

September 26th, 2024 (GMT+2)

Faculty of Social and Economic Sciences, Comenius University in Bratislava

Workshop Chair: Dr. Lukáš Vartiak, Associate Professor in Comenius University in Bratislava

Workshop – Murcia: Policies to Enhance Sustainable Development through the Green Economy

October 30th, 2024 (UTC+1)

Research Group on Economics, University of Murcia

Workshop Chair: Dr. Javier Cifuentes-Faura, Researcher in University of Murcia

Workshop – Edinburgh: Decoupling Corporate Finance Implications of Firm Climate Action

August 28th, 2024 (UTC+1)

The Business School, Edinburgh Napier University

Workshop Chair: Prof. Gbenga Adamolekun, Assistant Professor in Edinburgh Napier University

Workshop – Beijing: Innovative Strategies in Microeconomic Business Management

September 27th, 2024 (GMT+8)

Management College, Beijing Union University

Workshop Chair: Prof. Xinzhong Bao, Professor in Beijing Union University

Workshop – Beijing: Environmental Economics and Sustainable Business

September 21st, 2024 (GMT+8)

International College Beijing, China Agricultural University

Workshop Chair: Dr. Li Chai, Associate Professor in China Agricultural University

ICEMGD 2024 Workshop: Policies to Enhance Sustainable Development through the Green Economy

ICEMGD 2024

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Proceedings of ICEMGD 2024 Workshop: Policies to Enhance Sustainable Development through the Green Economy
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The Research of the Correlation Between USD Index and S&P500

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Abstract: This paper investigates existence of equilibrium relationships among the USD index and S&P500 in the long term in the United States. By applying correlation matrix analysis to daily data for the 2016:07:30–2023:08:01 period, this paper finds that there was a slight negative correlation between the USD index and the S&P 500. Basing on the Augmented Dickey-Fuller test (ADF test), this paper shows that that the correlation between the USD index and the S&P 500 is stable while vector autoregressive model (VAR model) proving that changes in the USD index can cause changes in the S&P 500 index. Firstly, using ADF test and VAR model to investigate the relationships between the USD index and A&P500, this paper reveals not only judge the negative relationship between this two, but also studying the stability of this relationship, proving the validity to explain the changes of S&P500 by the changes of the USD index. This conclusion can act as a good judging basic for US leaders to make economic decisions such as raising or lowering interest rates.

Keywords: USD index, S&P500, correlation matrix, ADF test, vector autoregressive model.

1. Introduction

The United States became one of the largest economic entities in the world in 1894, and has kept its front-runner status since then. Also, it is currently the only superpower in the world. As a result, the changing trend of the US economy is critical to the global economy as a whole. As a result, it's really important to study the dollar economy. To do deeper research, based on the belief that the earning of a company is significantly affected by the currency value where it is located, this paper selected two indexes, which are the S&P500 and the USD index. The S&P500, which is a benchmark index of 500 large-cap U.S. stocks, can reflect the U.S. economic performance well. The USD index, which shows the exchange rate of U.S., can reflect the changes in the status of the U.S. in international exports indirectly. As a result, the S&P 500 and the USD index can be used to study the overall relationship between the U.S. economy and other economies. Besides, the quick growth in the global trade and capital flows has leaded to the results that monetary value became one of the most important determinants of corporation's ability to make revenue and stock prices, contributing to considerable interests in the association of exchange rates with stocks prices[1].

Based on the assumption that the corporate earnings will be significantly affected by the fluctuation of currency value, many scholars have conducted analysis in different ways and obtained various conclusions about the negative or positive relationship between the S&P500 and the USD

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index. Furthermore, a lot of papers got the theories of goods market approaches and portfolio balance approaches. However, due to the lack of specific consideration of the special policy or economic environment of the studied country, the defects of these conclusions and theories have been expanded to be more and more obvious with the further expansion of globalization [2]. For that, this paper will focus on the United States' economy situation and explain the correlation between the S&P 500 and the USD index with realistic situation like financial crisis in 2008 and the urgently cut interest rate controlled by the Federal Reserve System in the face of the economic crisis caused by the epidemic in 2020.

The following paragraphs of this paper are organized as follows: In Section 2, the literature review is presented. In Section 3, our empirical test is described, including sample selection, data source and analyze. In Section 4, the conclusion of this paper is drawn.

2. Literature Review

Nowadays, there are lots of different research that focus on the correlation between different change of exchange rates and stocks prices. However, the conclusions of these studies are different. For example, Aggarwal suggests that there is a positive relationship between the U.S. exchange rate and the U.S. stock value [3]. In contrast, Soenen and Hennigar concluded an opposite conclusion [4]. Most of the literature focus on finding links between exchange rates and stocks prices directly. BSH (Balassa-Samuelson) analyzes the impact of economic growth rate on exchange rate, which presents the conclusion that there is a positive relationship between these two [5]. Wu L. and Fu G. used nonlinear model to do research and find that the revaluation of the exchange rate can encourage the rising interest of some short-term cross-border investment that aim to get immediate profit, which furthermore cause the rise of the stock price [6]. Overall, most of the literature agrees that the economic growth rates and stock price has a significant mutual impact.

There are also some literatures do research from other perspective. For instance, Mao and Kao study the different shares of imports and exports in the domestic economic market separately [7]. Nieh and Lee studied separately from long-term and short-term and concluded that there, between the stock price and the exchange rate, is only a short-term relationship, but lacks long-term relationship [8]. Among the research on the degree of mutual impact, Yang and Doong concluded the asymmetric mutual influence between these two through the EGARCH model by finding that the volatility spillover of the stocks market to the currency is more obvious [9]. Except the growth relationship between these two, there are also studies on exchange rate fluctuation. Wilhborg concluded that risk-averse investors will reduce their investment when the exchange rate fluctuation is large, which may further lead to the decreasing of the stock price [10].

3. Empirical test of the correlation between the USD index and the S&P500

USD index is an index that used to reflect the overall performance of the U.S. dollar's exchange rate in the international exchange market, which is used to present the degree changed of the exchange rate of the U.S. dollar against a basket of currencies. The S&P500, which represents the performance of the 500 largest companies in U.S. as a whole, is widely used to present the performance of the U.S. stock price as a whole and be regarded as one of the most representative stock indicators in the United States. According to the historical data, the change of the S&P500 index is closely related to a lot of indices like the value of the dollar, the oil price and the international gold prices [11]. Therefore, the study of the correlation between these two is high valued to the investors, policy makers and economists.

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3.1. Sample selection and data source

This paper selects the daily closing prices of the USD index and the S&P500 from 30 July 2016 to 1 August, 2023 as the sample selection. All studied data obtained from the wind database, all data are taken as log value to eliminate other interference factors.

3.2. Correlation analysis of the USD index and the S&P500

As shown in Figure 1, through a comparative analysis, using the data of the daily closing prices of the USD index and S&P500 in the recent years, it can be found that there is a strong correlation between the trend of the U.S. dollar and the performance of the S&P500 index, and the relationship between the two is affected by international trade friction, the risk of economic recession and the global epidemic.

Overall, the index is a slight negative correlation between the USD index and the S&P500.

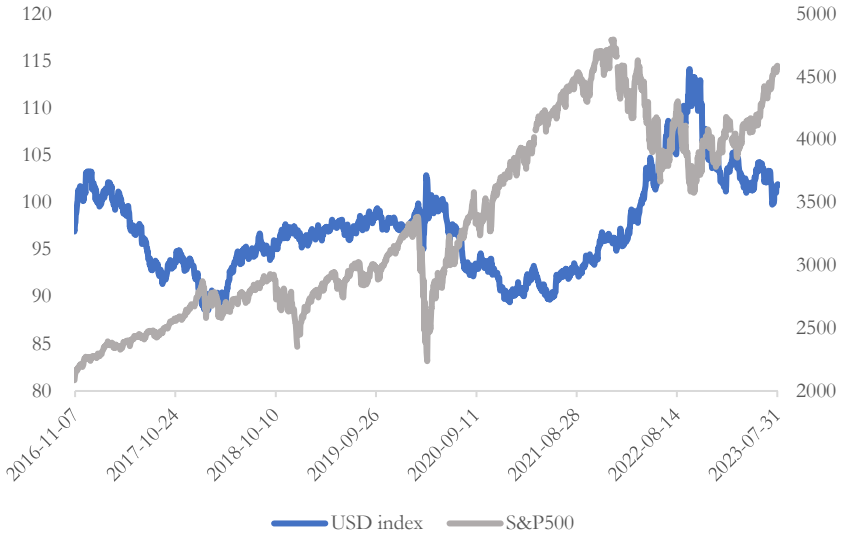

Figure 1: The comparison of the USD index and the S&P500
Photo credit: Original

Through the correlation analysis of the USD index and the S&P500, this paper got the correlation matrix as follows. As shown in table 1, the correlation of the USD index and the S&P500 is negative -0.510, satisfy the conclusion got from the figure 1. To exclude the possibility of a pseudo correlation, the data was further examined and analyzed.

Table 1: Correlation matrix

	USD index	S&P500
USD index	1.000	-0.510
S&P500	-0.510	1.000

3.3. ADF test of the USD index and the S&P500

As shown in the table 2, all the value of the ADF test of the USD index and the S&P500 is larger than the critical value of 1% significant level. So the assumption of the existence of the unit root cannot be rejected and these two sequences are non-stationary.

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Table 2: Unit root test of the USD index and the S&P500

Parameter	Value of ADF test	critical value of 1%	critical value of 5%	Stability
USD index	-2.144	-3.430	-2.860	No
S&P500	-0.944	-3.430	-2.860	No
D(USD index)	-32.190	-3.430	-2.860	Yes
D(S&P500)	-36.687	-3.430	-2.860	Yes

Through conducting OLS regression of the related variables, the Table 3 shows the related results. From Table 3 and Table 4, there is a stable negative correlation between the USD index and the S&P500.

Table 3: OLS regression of the related variables

	Coefficient	Std. Error	t-Statistic	P>|t|
USD index	-0.509	0.070	-7.27	0.000
_cons	0.0004	0.0003	1.62	0.106

This paper used first order difference to analyze this two sequences and then conducted the unit root test. The value of the ADF test is less than the critical value of 1% significant level, so this two sets of the sequences were stable.

Table 4: Cointegration test results of the USD index and the S&P500

Variable	Whether contain constants	Whether contain trend term	Lag order	ADF test value	5% critical value	Conclusion
Z(t)	No	No	0	-2.374	-1.950	Stable

3.4. VAR model of the USD index and the S&P500

In order to capture the dynamic correlation of the USD index and the S&P500, this paper uses AIC、SC、FRE、L and HQ criteria to determine the order of lag length is 2 and built a VAR model based on it. Figure 2 shows that the feature roots are within the unit circle, indicating that the variable model is stable.

Table 5: VAR model test

Eigenvalues	Coefficient
0.9984553	0.998455
0.9875699	0.98757
-0.4684635	0.468463
-0.4120352	0.412035

Through Granger causality test of VAR model, the test results as shown in table 6, the outcome of the Granger test shows that the change of the USD index can lead to the change of the S&P500 index, which means the USD index is the reason why the S&P500 index change. As a result, it is appropriate to take the USD index as an explanatory variable and the S&P500 index as the explained variable.

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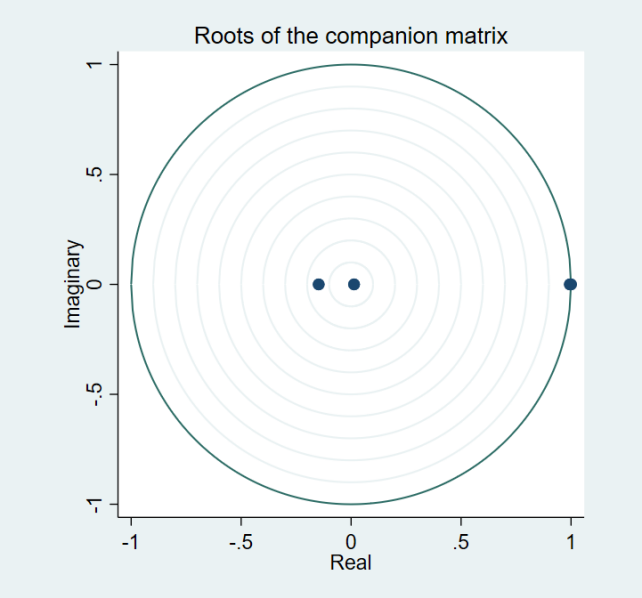

Figure 2: Unit circle test
Photo credit: Original

Table 6: The Granger causality test

Null Hypothesis	Observation	chi2	P>chi2
S&P500 does not Granger Cause USD	685	4.720	0.094
USD does not Granger Cause S&P500		14.466	0.000

4. Conclusion

The main purpose of this paper was studying the correlation between the USD index and the S&P500. Based on the empirical analysis above, this paper concluded that there, between the USD index and the S&P500, is a negative correlation, which means the weakness of the U.S. dollar may be accompanied by the strength of the U.S. stocks to some extent. There are lots of reasons why there is a negative correlation between the USD index and the S&P500: (1) There are lots of factors affecting the stock market, such as the economic cycle, national macro policies, national economic performance, market news and so on. The US dollar index is only one of the influencing factors, which may have different effect to the U.S. stock market by combining with other factors. (2) Among the companies included in the S&P500, 43% of the companies' revenue comes from overseas, and account nearly 60% among the technology industry which ranking top one. If the weakness of the dollar is due to the poor performance of the US economy relative to the rest of the world, it tends to be advantageous for these stocks. (3) The trends of the USD index and the U.S. stock are affected by the environment of the U.S. economy. If the U.S. economy faces challenges or the risks of increasing recession, it may lead to the negative impact on the U.S. dollar and the U.S. stock market. This paper select data from 30 July 2016 to 1 August, 2023, including the trade tensions between the China and the U.S., U.S. presidential election in 2016, brexit, covid-19 and many other tumultuous factors. In this period, the global economy entered a downward channel, forming multiple impacts on the U.S. stock market. (4) The strength of the U.S. dollar may be disadvantage to the export-oriented

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enterprises, reducing the revenue and competitiveness of these multinational companies and then having a certain negative impact on the U.S. stock market.

Compared with the influence of other variables on exchange rate, the impact of U.S. stock market on the exchange rate is relatively small. According to the historical data, the correlation between the changes in the USD index and the S&P500 is uncertain in different time period. It's always essential to consider the actual situation when analyzing the correlation between this two[2]. For example, before the financial crisis in 2008, the USD index and the S&P500 always went up and down simultaneously. However, after the urgently cut interest rate controlled by the Federal Reserve System in the face of the economic crisis caused by the epidemic in 2020, the value of the U.S. stock increased dramatically while the USD index reached a new low; Since the 2022 rate hike cycle, the USD index and the S&P500, the USD index has been rising while the value of U.S. stock has been falling, which agrees with the conclusion this paper got that the strength of the dollar has certain negative affect on the U.S. domestic economy, which influence the rising of asset process such as the U.S. stocks as well. In the conclusion, the relationship between the USD index and the S&P500 is complex, the economic cycle, the national macro policy, the national economic operation status, market news and many other aspects would all affect the U.S. stock market. The devaluation of the U.S. dollar does not necessarily lead to the increasing of the U.S. stock market. Furthermore, it's not appropriate to judge the change of the US. Stock Market simply by the changes of the exchange rate of the U.S. dollar. Therefore, to judge the impact of the dollar index on the US stock market, it's not discreet enough to only pay attention at a single factor, instead, considering more economic, political and market changes is essential. In different time period, these factors will have different effects in different time periods.

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The Contribution of the New Energy Industry(NEI) to Economic Growth: Direct, Indirect, Environmental and Social Effect

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Abstract: This study investigates how the new energy industry (NEI) contributes to the economy's growth. As time went on, more and more countries gradually accepted the concept of new energy development. Evidence shows that NEI helps economic growth and indicates significant benefits including job creation, technological advancements, and enhanced productivity. Besides make direct contributions to the economic growth, the application of NEI also have some positive indirect effect on the economy. NEI increases long-term profits by reducing health care costs and environmental maintenance caused by pollution. However, current research reveals gaps, particularly in the long-term economic impacts of cleaner energy, regional disparities, and the integration of social well-being metrics. Future studies are proposed to address these gaps, including detailed analyses of the impacts on small and medium enterprises, comparative policy effectiveness, and the effects on rural and remote areas. By advancing research in these areas, policymakers and stakeholders can better understand and leverage the economic benefits of the NEI to support sustainable development and global financial stability.

Keywords: NEI, Environmental sustainability, Social sustainability, Employment, Social welfare.

1. Introduction

Nowadays, the lack of fossil fuels and their unrenewable characteristics bring a worldwide problem to countries. To solve this problem, many countries developed programs to put new energy into use. Unlike traditional fossil fuels, new energy resources can be restored quickly and not contaminate the ecosystem. Moreover, some kinds of new energy are more efficient than fossil fuels. Renewable electricity can be generated from various sources. As economic and social energy demands continue to rise, along with the push for a low-carbon society focused on environmental preservation, a significant transition from traditional fossil fuels to non-fossil new energy sources will become inevitable.

Today, people still use fossil fuels in large quantities. A large amount of greenhouse gas enters the air because of the burning of fossil energy, leading to a hole in the ozone layer and global warming. Due to the immaturity of science and technology and the problem of fuel, fossil energy is relatively inefficient and very wasteful of resources. Burning fossil fuels to produce electricity usually leads to

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heat losses of over 50% and in cars even 75% [1]. This inefficiency results in a significant waste of resources and higher greenhouse gas emissions. As a result, The negative effects brought about by global warming are becoming more and more serious. Rather than relying on fossil fuels, we can utilize new energy sources to effectively reduce carbon emissions. New energy technologies like solar panels and wind turbines convert energy more efficiently, resulting in minimal losses. Research shows that a 1% increase in renewable energy consumption per capita decreases the CO2 emissions per capita by 0.259% in the long run [2]. This demonstrates the substantial impact that renewable energy can have on mitigating climate change. The construction of NEI is conducive to reducing and decelerating the negative effects of carbon emissions on global warming.

As the demand for creating an environmentally friendly industry grows, the deployment of NEI in the overall energy structure is expected to rise further. This study aims to explore how NEI contributes to the development and economic growth. Furthermore, this paper will explain the relevance of understanding the economic contributions of the NEI for policymakers, investors, and environmental stakeholders. Direct economic effect, indirect economic effect, environmental and social effect are discussed in the paper to get the conclusion.

2. Literature Review

The NEI includes a wide range of technologies and practices aimed at generating, storing, and distributing energy from renewable and sustainable sources. NEI aims to create environmentally friendly industries while addressing the dilemma of increasingly scarce fossil fuels. With the globalization of the world and the development of science and technology, people gradually realize that excessive carbon emission negatively affect the environment and economy.As a result, new energy technology is gradually being paid attention to and developed. Both governments and corporations are committing to ambitious sustainability goals. This shift is crucial for mitigating climate change. Also, it presents opportunities for economic revitalization and technological innovation.

As people are gradually realizing the importance of protecting the environment, NEI's development has already become an inevitable global trend. Instead of using coals, electricity collected from wind energy and hydro energy is becoming a dominant source of energy. For the NEI to be put into use, some advanced technologies need to be developed. As technology advances and costs continue to decline, the adoption of wind and hydro energy is expected to accelerate, leading the global transition to a more sustainable energy future.

To illustrate the contributions made by the NEI, various theories are required to provide a comprehensive explanation.: endogenous growth theory and the Solow growth model. Endogenous growth theory refers that economic growth is the result of internal forces. On the contrary, the Solow growth model, or exogenous growth model, focuses on the impact of internal forces like capital accumulation, labor, and technological progress on economic growth [3]. These two models explain the contribution of the energy industry internally and externally.

The adoption of new energy sources offers numerous advantages. Investing in the utilization of the new energy sector is crucial for achieving sustainable social progress. To achieve development of sustainable, the NEI makes contribution in three topics: sustainable environment, sustainable economy and sustainable society. The use of wind energy, hydro energy is conducive to reducing emissions of greenhouse gas such as carbon dioxide. Cutting the utilization of traditional fuels can also minimize environmental degradation. On the contribution to economic sustainability, the construction of wind turbines and water projects help offer job opportunities, thus reducing unemployment and increasing productivity. The reduction of carbon emission can effectively reduce the mortality of diseases caused by environmental contamination, thus achieving social sustainability.

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In 2019, International Renewable Energy Agency (IRENA) found that the renewable energy sector employed 11 million people worldwide in 2018[4]. It highlighted the significant job creation potential of renewable energy, particularly in the solar and wind industries. The report also noted that states with robust renewable energy policies experienced higher economic growth rates. These studies show the great importance the NEI has on job creation and long-term economic growth. Comparing between NEI and traditional fossil fuel industry, the economic contributions of renewable energy are seen in increased investment flows, enhanced energy security, and reduced energy costs. Fossil fuel industries have long been major contributors to national GDPs, especially in resource-rich countries. However, these industries are vulnerable to market volatility and environmental regulations, which can impact their economic stability.

3. Direct Economic Contributions

GDP is a crucial factor in assessing the NEI's direct economic impact. The production of NEI directly contributes to GDP. According to the data, clean energy accounted for 9.0% of China's GDP in 2023, up from 7.2% in 2022[4,5]. With the development of NEI, China's GDP has grown constantly. Compared with the traditional manufacturing sector, the growth of the new energy sector has been robust, driven by increasing demand for clean energy technologies. Governments and corporations around the world are working to cut carbon emissions and boost the proportion of renewable energy in their energy portfolios. Policies such as renewable portfolio standards, subsidies, and tax incentives are carried out by governments to drive demand for renewable energy equipment.

NEI not only directly promote the development of the economy, but also generate employment. The construction and maintenance of energy facilities such as wind turbines and water projects offer new career opportunities for citizens. In China, the new energy sector has been a major job creator. The results show that the development of renewable energies has created about 11.5 million jobs in the world by 2019[6]. Type of job varies depends on personal capabilities. Construction jobs, operation and maintenance jobs, and manufacturing jobs are offered in NEI. Solar photovoltaic (PV) installers and wind turbine technicians often earn higher-than-average wages due to the highly advanced technical skills required for these positions. For solar PV installers, the median annual wage was $48,800 as of May 2023[5]. This competitive salary highlights the increasing need for skilled workers in the renewable energy sector. Investing in training and education for these positions can create significant economic opportunities and support the sustainable development of the industry. Furthermore, wind turbine technicians earn a median annual wage of $61,770 as of May 2023. The job outlook for wind turbine technicians is particularly promising, with an anticipated growth rate of 45% from 2022 to 2032[5].

The level of investments in NEI project is very substantial. Both private and public sectors make contribution to such great investments. Also, these investments are very important and necessary to the expansion and development of NEI. According to data provided by IRENA, International investment in the NEI reached $330 billion in 2020[4]. This significant investment highlights the growing commitment of governments and private sectors to transition towards a sustainable energy future. The increase in funding has accelerated the development of renewable technologies, making clean energy more accessible and affordable. Moreover, this investment is crucial for meeting international climate goals and reducing the reliance on fossil fuels.

While governments are vigorously promoting the construction of the NEI, private vectors are also making a lot of contributions. Data indicates that Amazon's solar and wind farms have contributed to over $12 billion in estimated global investment in economy from 2014 to 2022[7]. These endeavors not only aid in cutting down carbon emissions but also significantly impact local economic growth, fostering development and prosperity within communities. By investing in the new energy sector, Amazon serves as a compelling model for other companies, highlighting the critical role of corporate

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responsibility in promoting economic growth and combating climate change. Technologies like grid modernization, energy storage system, Electric vehicle (EV) infrastructure, and renewable energy facilities are developed related to the NEI. For EV infrastructure, Vehicle-to-Grid (V2G) Technology id developed to improve the efficiency of the transportation. Facilities such as charge station are built along highways to form a network of EV. In 2019, the electric vehicle (EV) market was worth about $162.34 billion. By 2027, it is expected to grow to $802.81 billion, with a compound annual growth rate (CAGR) of 22.6%[8]. The electric vehicle industry is very important in the near future to help mitigate and reduce excess carbon emissions caused by vehicle emissions. Because of its superior performance and environmental friendliness, electric vehicles are gradually being respected and popular all over the world.

4. Indirect Economic Contributions

The production of facilities used in NEI requires a great amount of raw materials such as steel, aluminum, silicon and some rare earth elements. For instance, the International Energy Agency (IEA) reports that the demand for minerals, promoted by the new energy transition, is expected to grow substantially. Specifically, nickel demand alone is expected to grow over 140 times from 2020 to 2040[9]. Moreover, rare earth elements are important in the renewable energy industry. The need for these materials boosts the mining sector, leading to increased activities in mining elements like neodymium, praseodymium, dysprosium, and terbium, which are essential for manufacturing efficient EV motors and other renewable energy components. As a result, the production of facilities in NEI contribute to the growth of other sectors, thus making contributions to the economic growth. As there are more jobs, there will be an influx of workers, causing local populations to increase. The increasing population causes local spending to increase, leading to further job creation in local good and service sectors. Moreover, higher employment and business profit created by NEI result in higher tax revenue, thus the governments have more financial budgets to reinvest in developing the NEI.

In the renewable energy sector, research and development(R&D) is required to create newly advanced technologies. As the NEI is still a new model, some technologies are not yet mature enough to be put into the market in a short time.As a result, R&D is crucial and necessary to develop new technologies and the imperfect technology that exists. For instance, existing technologies produce solar panels that are not as efficient as expected and are fragile and require frequent replacement and maintenance. Research are required to find a more efficient way to improve the efficiency of energy transition in solar panels. R&D has led to the development of high-efficiency photovoltaic cells that significantly increase the amount of solar energy captured. Advancements in technology will significantly reduce the costs associated with facility maintenance and energy conversion, which means corporations can earn more profit per unit of their product. In addition to reducing costs and increasing profits, technological innovation can help enterprises become more competitive in the international market. The better performance and quality of the products means that the company can gain a greater advantage over the competition. By leading in energy technology innovation, businesses and nations can capture new markets and promote economic growth. For example, wind turbine technology developed through R&D can help a company to be positioned as a global leader in the renewable energy sector. New energy products, including solar panels, batteries, and wind turbines, are crucial in diversifying a nation's export portfolio. Exporting these advanced technologies allows countries to lessen their reliance on traditional sectors and improve their economic stability. Processing companies from different countries can cooperate with each other to form a new energy industrial chain. Such practice would lead to increased imports and exports between countries. The exportation of new energy products can enhance a country’s reputation as a technological leader in the new energy sector. This leadership is conducive to attracting further investment, research collaboration, and cooperations with other countries.

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5. Environmental and Social Contributions

The deployment of wind and water has led to a significant reduction in the world's carbon emissions. Decreasing emission of greenhouse gas protect the ecosystem and biodiversity by minimizing the negative impact of climate change cause by global warming and pollution. In addition, cleaner energy practices contribute to the health of forests, wetlands, and oceans, which in turn support industries dependent on these environments such as agriculture and tourism. Reduction in carbon emissions cause by NEI can slows soil erosion and allows the soil to retain nutrients for agriculture. Nutrient-rich land and less polluted air encourage crops to grow more vigorously, thus promoting the development of agriculture and the growth of the economy.

According to the data, a 1% rise in carbon emission adds 0.298% more outpatients and 0.162% more inpatients [10]. In some highly developed cities and countries, increasing carbon emissions will cause more serious health problems. Because of the air pollution produced by traditional fossil fuel industry, human deaths from lung infections have increased dramatically. Furthermore, An estimated 125 million additional vulnerable adults were exposed to heatwaves between 2000 and 2016[11, 12]. This combination of air pollution and extreme heat events exacerbates public health crises. Effective policies and investments in renewable energy are essential to reduce these health risks and improve overall quality of life. Nowadays, the development of NEI can reduce the chance of people getting sick by reducing pollution to the environment. Thus, expense on medical care will be lower, which means government can have more financial budgets to develop economy and the society. Reduced pollution levels decrease the frequency of doctor visits, hospitalizations, and medication use. This reduction in medical expenses translates into significant long-term savings for both individuals and public health systems. For instance, improved air quality from cleaner energy sources can lead to fewer emergency room visits and long-term treatments for chronic conditions.

6. Conclusion

In conclusion, the NEI significantly contributes to economic growth through job creation, innovation, technological advancements, export revenues, and enhanced productivity. By generating employment opportunities across various sectors, the NEI supports local economies and helps reduce unemployment rates. Investing in research and development (R&D) within the new energy sector drives technological progress, resulting in more efficient and cost-effective energy solutions. This technology innovation fosters economic competitiveness and help countries to save costs from building more efficient new energy technologies. In addition, new energy products play a significant role in national export strategies to help countries and private firms to earn revenues. Countries that excel in clean energy technology can leverage this advantage to improve their trade balance and attract foreign investment to develop better economy. Because of the technology innovation, highly advanced new energy technology help people to finish their work more efficiently, thus enhancing their productivity. This productivity boost can contribute to growth of economy and competitiveness.

NEI brings benefits to both economic growth and ecosystem in several ways. For economic growth, NEI can reduce health cost, make economy stable, and provide social well-being. New energy can significantly improve air quality, which reduces the incidence of pollution-related health issues. This significant reduction helps communities and individuals to have long-term economic savings by lowering healthcare costs and increasing workforce productivity. The enhancement of living conditions and property values caused by better environmental quality results in economic stability that supports long-term growth and provides a more attractive environment for investment and development.

Because people have only a short time to explore the NEI, the available data is still limited for further research. So far, there are still many countries that have not discovered the importance of a

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NEI for economic development and environmental protection. Furthermore, to track the long-run growth of economy under contribution of NEI, more time is needed to do the research to get a more general conclusion. In the future, the study can focus on long-term economic savings from NEI on healthcare system and technology innovations. By exploring long-term impacts, regional disparities, and specific technological innovations, researchers can provide valuable insights that push further advancements into the new energy sector.

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The Impact of Double Reduction Policy on College Entrance Examination Performance: Empirical Evidence

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Abstract: In China, the College Entrance Examination weights great in both students' and parents' hearts, which is even recognized as the rare chance to change a people's fate. At this circumstances, heavy homework, countless tests, little break time, burning night oils and even extracurricular tutoring on the weekends have become the daily routine for Chinese high school students, which have hurt their health conditions and added great burden on their mental health. To curb this long-standing issue caused by this phenomenon, a new educational policy called Double Reduction was released by the Chinese government on 2021 and nine Chinese cities are selected as the national policy pilot areas to test the effect in advance. This paper aims to verify the impact of the Double Reduction Policy in some provinces in which lie the selected policy pilot areas. Through continuous difference-indifference method, this study found no significant correlation between the Double Reduction and the College Entrance Examination performance in these areas. Policy makers should make proper actions to implement this new policy, in order to lighten the physical and mental burden of students and the financial burden of parents while take students learning effectiveness into consideration meanwhile.

Keywords: Double reduction policy, Difference-in-Differences (DID) model, Examination.

1. Introduction

The Double Reduction Policy refer to the reduction in students' homework burden and the reduction in the off campus training burden. In China, this policy is implemented first in nine selected cities, which has relevance work experience and good financial conditions [1]. Chinese parents tend to send their children to private supplementary tutoring in the purpose of letting their students enter top schools. With the gradually implementation of this policy, an increasing number of education enterprises are forced into transitions, layoffs, bankruptcies or even shut down their off-campus tutoring service, which results in the daily rising concern of pulling down students examination performance in some parents' hearts.This study aims to research the real-world effect of changes in College Entrance Examinations performance of high school students in selected policy pilot areas in China.

The "double reduction" policy was released by Chinese government in the purpose of improving the quality of school teaching, regulate the training behavior of out-of-school training institutions, and reduce the excessive burden of homework and out-of-school training for students in compulsory education stage, Chinese government has released the "double reduction" policy [2]. And according

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to national laws, off-school training institutions should be taken same regulation methods as compulsory education during the high school phase, including schools and education enterprises are forbidden to offer courses to high school students during vacations [3]. And after the implementation of this policy, as a social group, parents are greatly concerned about whether their children can climb up into upper classes through education, as education is mainly composed of three factors: family, school and society, and out-of-school training contributes a lot to the last one [4], while social training institutions, by hyping and taking full advantage of such anxiety, make profits [5]. A number of scholars have conducted studies and discussions on the impact of the policy on different actors around this, such as the problem in government actions with regulating after-school training like lacking true understanding of the policy spirit and omitting the variance of actual situation in the region [6], the impact on the prospects of teacher professional development [7], and effective measures to alleviate the dilemmas encountered in practice , the "managerial" executive thinking and "conservative" implementation of the education administrative department, the "path dependence" and "captive regulation" of the implementation of primary and secondary schools, insufficient competency for teachers to implement "double reduction", the lack of students' adaptation, insufficient parental participation, and poor social atmosphere, have been discussed [8, 9]. The impact of the policy on high school students' Chinese Gaokao performance is also a perspective worth studying and discussing, but few studies have emphasized the impact of the policy on it. This blow to the shadow education of high school stage would definitely affect the Chinese Gaokao performance of high school examinees in selected pilot areas.

This essay will use the method of continuous difference in difference [10] to analyze the impact of the “double reduction” policy on this aspect, addressing parental worries in response to this policy.

2. Literature Review

From the existing literatures, the overall trend of Double Alleviation Policy in high school stage is putting out-of-school education into regulation. This will undoubtedly affect students’ score performance in selected areas. Due to the difficulty in directly obtaining data of National College Entrance score in the city level, this study cannot directly evaluate the effect of difference between national pilot city and other cities brought by this policy change. This article will mainly evaluate how does high school students ultimate test performance, Chinese Gaokao, affected by the remarkable change in the educational field, Double Reduction, in China on a provincial level.

This study adopts continuous difference-in-difference method [10] to evaluate this effect.

2.1. Experimental Data

Relevant data on first line rate, second line rate and score of college entrance examination in five provinces of China (in which each locates one national Double Reduction pilot area) are collected from Beijing Education Examinations Authority, Shanghai Education Examinations Authority, Shandong Province Academy of Educational Recruitment and Examination, Shanxi Province Educational Recruitment and Examination Web and Higher Education Examinations Authority of Henan Province. Due to the variance of time and areas of the College Entrance Examination Admission Policy, high score priority placement line and special type control line are both recognized as College Entrance Examination First tier line (College Entrance Examination First tier line and the total of the first and second tier line of college entrance examination are abbreviated as first line and second line in the later content respectively), and as the several top score in some provinces haven't announced, the Median interpolation method is adopted to calculate the average score. To better reveal the impact of the Double Reduction Policy on high school students college entrance examination performance, Ordinary high school student's average education expenses for general

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public utilities and proportion of full-time teachers with graduate degrees in regular high schools are selected as covariates representing the quality of education based on the Statistical Indicator System for Education Monitoring and Evaluation in China, and data are collected from National Bureau of Statistics, Ministry of Education and Ministry of Education of the People's Republic of China respectively. What's more, as the statistics of those two education indicators are only announced officially until 2022, this can only investigate a short time, approximately one year interval, after the publication of the Double Reduction Policy in educational field, so the relevant data are selected from 2019 to 2022.

Relevant formulas are as follows:

Index.1: First line rate=the number of students who's score is over the College Entrance Examination first line/ total number of students who attend the College Entrance Examination

Index.2: Second line rate=the number of students who's score is over the College Entrance Examination second line/ total number of students who attend the College Entrance Examination

Index.3: Score (Average score) = ∑ (each score*corresponding number of students)/total number of students who attend the College Entrance Examination

Last but not the least, it's worth mentioning here that though Liaoning Province, Guangdong Province and Jiangsu Province are selected as the Double Reduction Policy pilot areas too, but they are not adopted as research objects as they have been experiencing the New college Entrance Examination Reform during this period.

2.2. Continuous Difference-in-differences Model

This study adopts continuous difference-in-difference method to verify the impact of the implementation of the Double Reduction Policy on ordinary high school students' college entrance examination performance in five selected national pilot areas.

Continuous difference-in-differences method is mainly used for evaluating policy effectiveness of variance strength in different areas in sociology. This principle is evaluating changes in factor y observed in regions with different levels of policy implementation intensity based on the continuity policy intensity in different areas.

For an exogenous policy shocks, the samples are divided into a treatment group with high policy intervention and medium policy intervention and a control group with low policy intervention. As province fixed effect and time fixed effect have been considered in ***y*** between the treatment group and the control group, this part can consider the changes in ***y*** before and after the occurrence of policy in the control group as a counterfactual result when the treatment group is slightly affected by policy shocks. By comparing the changes in Treatment group ***y*** (***D1***) and Control group ***y*** (***D2***), then can obtain the actual effect of policy shocks (***DD=D1-D2***).

Beijing city, Shanghai city, Weihai city in Zhejiang Province, Chengzhi City in Shanxi Province and Zhengzhou city in Henan Province are selected among the nine Double Reduction national pilot areas, however, provincial level rather than the city level analysis is adopted as the statistics of city level college entrance examination has not been published. The ratio of national Double Reduction pilot areas and the total number of prefecture level cities are calculated as the policy intensity indicators, with the higher the ratio the stronger the policy impact is, vice versa. Based on this method, these five provinces are divided in three groups: Beijing and Shanghai as high policy intensity group, Shandong province as medium policy intensity group and Shanxi province and Henan province as low policy intensity group. Therefore, the traditional difference-in-difference model is not applicable in this study. Based on this, this study adopts a continuous difference-in-difference model suitable for continuous policy intensity samples. The formula of the model is expressed as follows:

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$$Index_{pt} = \alpha_o + \alpha_1 Post_t + \alpha_2 Treat_p + \alpha_3 Post_t \times Treat_p + \alpha_4 fee + \alpha_5 teacher + \varepsilon \quad (1)$$

Index= first line rate, second line rate and the average score (2)

$Post_t \times Treat_p$ is an interaction term representing whether the exogenous impact have had effect on a sample. It equals 1 for chosen treatment group, high policy intensity areas or medium policy intensity area respectively, once the policy has been implemented and 0 for treatment group before being treated and control group. In this case, $Post_t \times Treat_p$= 1 since July 2021 for all three groups, $Post_t \times Treat_p$ = 0 for other cases. $Treat_p$is an indicator variable representing whether the sample is in treatment group or control group. In this case, it equals 1 for samples in high policy intensity areas referring to Beijing and Shanghai medium and medium policy intensity area referring to Shandong and 0 for all low policy intensity areas referring to Shanxi and Henan. $Post_t$is a dummy variable whose value that represents the time effect.

3. Data Analysis and Results

3.1. First line rate, second line rate and score Regression

The first line rate, second line rate and score of college entrance examination regression results are shown in Table 1.

Table 1: First line rate, second line rate and score regression

	first line rate		second line rate		Score	
	(1)	(2)	(3)	(4)	(5)	(6)
fee	-0.00000 (0.00000)	-0.00001* (0.00000)	-0.00001* (0.00000)	0.00001 (0.00002)	-0.001 (0.001)	-0.013 (0.011)
teacher	-0.193 (0.133)	0.351** (0.095)	-0.117 (0.143)	0.115 (0.640)	-59.083 (42.825)	9.503 (355.748)
post2022:treatment_h	-0.039 (0.040)		-0.063 (0.043)		1.910 (12.987)	
post2022:treatment_m		0.052** (0.016)		0.019 (0.105)		26.237 (58.595)
Constant	0.650** (0.220)	0.114 (0.062)	1.278*** (0.236)	0.227 (0.420)	*570.790* (70.949)	*659.572* (233.471)
Observations	16	12	16	12	16	12
Controls	Yes	Yes	Yes	Yes	Yes	Yes

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Table 1: (continued).

R2	0.994	0.995	0.997	0.940	0.992	0.973
Adjusted R2	0.986	0.980	0.991	0.782	0.980	0.903
Residual Std. Error	0.018 (df = 6)	0.003 (df = 3)	0.019 (df =6)	0.024 (df = 3)	5.711 (df = 6)	13.068 (df = 3)
F Statistic	119.359*** (df = 9; 6)	69.432*** df = 8; 3)	194.411*** (df = 9; 6)	5.926* (df = 8; 3)	80.791 (df = 9; 6)	13.737 (df = 8; 3)

Note: *p<0.1; **p<0.05; ***p<0.01

(1) and (2) are regression results of the first line rate in high policy intensity areas and medium policy intensity area respectively; (3) and (4) are regression results of the second line rate in high policy intensity areas and medium policy intensity area respectively; (4) and (5) are regression results of the average score in high policy intensity areas and medium policy intensity area respectively.

From the table, it's immediately clear that the R2 and Adjusted R2 are approximately 1 and SE are really indistinctive in the regression results of first line rate and the second line rate, which indicate the significant linear relationship between the index and the covariates and the high precision in these two models. The R2 and Adjusted R2 are approximately 1 in the regression results of average score either, which implies the significant linear relationship between the index and the covariates, however, SE of it is obvious, so the model may not be precise. When considering the p-value of F Statistic, it's significant in the first line rate regression in both high and medium policy intensity areas and second line rate high policy intensity areas, revealing the model significance. As post*treatment is considered, it's only obvious in the regression result of first line rate in medium policy intensity area . Thus it can be concluded that the Double Reduction Policy has positive impact on second line rate of high school students' college entrance examination in medium policy intensity area, Shandong province, but exerts slight negative impact on first line rate and second line rate in high policy intensity areas.

3.2. Parallel trend Test

A parallel trend test was conducted to test the robustness of the empirical results. The test was done simply by resetting the ***post*** dummy variable. Its value equals 1 only if current year is the last year before the policy shock, year 2021.

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Table 2: Parallel trend Test

	first line rate		second line rate		Score	
	(1)	(2)	(1)	(2)	(1)	(2)
fee	-0.00000 (0.00000)	-0.00001 (0.00002)	-0.00000 (0.00000)	-0.00001 (0.00002)	-0.001 (0.001)	-0.011 (0.011)
teacher	0.099 (0.171)	-0.009 (0.324)	0.099 (0.171)	-0.009 (0.324)	-89.512* (42.931)	-110.029 (183.461)
post2021:treatment_h	0.012 (0.045)		0.012 (0.045)		-7.608 (11.217)	
post2021:treatment_m		-0.006 (0.048)		-0.006 (0.048)		6.778 (27.265)
Constant	1.000** (0.276)	0.246 (0.397)	1.000** (0.276)	0.246 (0.397)	609.285 (69.263)	*708.279* (225.069)
Observations	16	12	16	12	16	12
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.995	0.940	0.995	0.940	0.992	0.972
Adjusted R2	0.989	0.781	0.989	0.781	0.981	0.898
Residual Std. Error	0.022 (df = 6)	0.024 (df = 3)	0.022 (df = 6)	0.024 (df = 3)	5.514 (df = 6)	13.361 (df = 3)
F Statistic	145.782*** (df = 9; 6)	5.892* (df = 8; 3)	145.782*** (df = 9; 6)	5.892* (df = 8; 3)	86.722 (df = 9; 6)	13.126 (df = 8; 3)

Note: *p<0.1; **p<0.05; ***p<0.01

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It can be seen from table 2 that the ***post*treatment*** dummy variable is both close to zero and insignificant in the regression results of first line rate and second line rate, so the parallel results prove that the first line rate and second line rate regression results are robust.

4. Conclusion

Based on the empirical results, it can be concluded that the Double Reduction Policy has positive impact on second line rate of high school students' college entrance examination in medium policy intensity area, Shandong province, but exerts slight negative impact on first line rate and second line rate in high policy intensity areas.

Due to various reasons such as data availability, this study cannot directly evaluate the impact of the implementation of the Double Reduction Policy on city level, and can only conduct the evaluation only one year after the publication of this act. It may take time and effort for schools, parents and more important, the high school students to adapt to this transformation. In addition, the insufficient research objects, only five provinces, and the variance educational and financial circumstances in different areas in China, this study outcome in these five provinces just a year after the transformation doesn't mean it will have the same policy results in other areas of the country in the following year.

However, these do not mean that the study is meaningless. This study can at least prove that the Double Reduction Policy do has impact on high school students' college entrance examination performance. For high policy intensity areas, it slightly pulled down both the first line rate and the second line rate, however, for medium policy intensity area, it improves the first line rate notably. This study indicates that the implementation of the Double Reduction Policy ha sthe possibility to reduce high school students stress and maintain or even improve their learning performance at the same time, as this policy are implemented well for schools, faculty and students.

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Urban Planning Strategies for Coastal Cities in China in Response to Climate Change

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Abstract: Global climate change has increasingly posed a serious threat to coastal cities, rendering them particularly vulnerable to the adverse effects of rising sea levels, more frequent and intense extreme weather events, and the shifting patterns of climate. Traditional urban planning methods, which had been the cornerstone of city development, were found to be inadequate in addressing these escalating challenges. The previous studies often failed to account for the critical importance of integrating climate factors into the planning process, leading to vulnerabilities in urban infrastructure and design. This study meticulously examined the limitations of these conventional urban planning approaches and explored the potential for adapting urban planning strategies in China's coastal cities to better respond to the looming threat of climate change. By conducting a thorough analysis of the impacts of high temperatures, floods, and other climate-related events, the study proposed a comprehensive series of response measures tailored to the specific conditions of the time. These measures included the integration of green policies into urban planning to enhance environmental sustainability, the strategic selection of building materials aimed at mitigating urban heat, and the enhancement of water resource management systems to alleviate the urban heat island effect. Moreover, the study closely investigated existing climate response measures through detailed case studies in Xiamen and Dalian, two prominent coastal cities in China. The primary objective was to significantly enhance the resilience of these cities, effectively reduce the risks associated with climate change, and promote a path towards sustainable development. Ultimately, the goal was to create more livable, safer, and sustainable urban environments that would be better equipped to face the challenges posed by an unpredictable climate future.

Keywords: Climate change, Coastal cities, Urban planning, Sustainable development, China.

1. Introduction

In recent years, the global climate has undergone significant changes. Record-breaking high temperatures, frequent floods, storms, and rising sea levels, have underscored the undeniable impact of climate change. Due to their special geographical location, coastal cities are climate particularly vulnerable to climate change. The sustainable development of China's coastal cities is increasingly threatened by climate change. Traditional urban planning, which guides urban development, had shown limitations in addressing this global issue. Therefore, traditional urban planning methods need to evolve to effectively respond to climate change [1].

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Traditional urban planning methods often neglected climate change factors. Existing cities are unable to predict and respond to future challenges brought by climate change. Additionally, these methods had the disadvantages of a single spatial layout, lack of diversity and flexibility. At the same time, aging infrastructure also weakens the ability of cities to cope with extreme weather events and rising sea levels [2-3]. These limitations made it difficult for traditional urban planning to cope with the impacts of climate warming, such as the intensification of urban heat island effects, water shortages, damaged infrastructure, and ecosystem degradation [4].

In a study by Zhang et al., the impact of post-earthquake tsunamis on integrated harbor cities was analyzed. It was found that the accessibility of tsunami shelters is a key factor in measuring the city's response to climate change. The study therefore proposes strategies to enhance urban disaster risk resilience based on the impact of tsunamis [5]. In Yang and Chen's study, the potential flooding impacts due to sea level rise were modeled using Macau as an example. The results showed that sea level rise will significantly shorten the return period of flooding events. This implies that coastal cities were not prepared for climate change and were not currently developing appropriate engineering responses. Laina and Iglesias assessed the potential climate change hazards for 10 European cities through a variety of precise indicators. The study helped to prioritize interventions in these cities [6].

This study aimed to explore the progress of coastal urban planning in China in response to climate change by critically analyzing traditional methods and examining the challenges faced by current coastal urban planning. Case studies [7-8] from Xiamen, Shanghai, and Dalian are used to summarize potential planning methods and propose measures to enhance urban resilience and sustainability.

2. Traditional Urban Planning and Coastal Urban Planning in Response to Climate Change

2.1. Analysis of the Characteristics, Advantages, and Disadvantages of Traditional Urban Planning

Traditional urban planning was born with the Industrial Revolution and aimed at industrialization and modernization. Traditional urban planning has played a key role in developing and expanding cities in history. First of all, traditional urban planning takes economic growth as its core and effectively promotes cities' economic development and prosperity by building infrastructure and developing industries. This design concept based on functional zoning, such as separating industrial, commercial, and residential areas, helps to improve the operating efficiency of cities, reduce interference between different functions, and thus promote the rational use of urban space. Secondly, traditional urban planning also focuses on the beautification and image enhancement of cities. Building public spaces such as parks, green spaces, and squares, improves the urban environment, enhances the cultural atmosphere of the city, and improves the quality of life of residents. For example, the famous Chicago urban planning and the transformation of Paris both reflected the powerful role of traditional urban planning in optimizing urban space. In addition, these two plans and transformations had enhanced the attractiveness of cities, and many individuals from surrounding rural areas poured into cities. These labor forces not only fit the development of the Industrial Revolution but also injected momentum into the economic development of cities. Finally, traditional urban planning had accumulated rich experience in the long-term development process and formed a mature theoretical system and methodology, which provided valuable reference and reference for subsequent urban planning [9].

However, as cities develop, this method had also demonstrated many limitations, especially in responding to climate change. Traditional urban planning lacked consideration of climate change, especially the lack of assessment and prediction of flood disasters given rise to sea level rise and

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storm surges, as well as urban high temperatures led to extreme weather events, making it difficult for urban planning and construction to adapt to the challenges brought about by future climate change.

2.2. Coastal Urban Planning to Address Climate Change

In the future, China's coastal cities will be more widely affected by climate change. At present, the impacts of climate change mainly include urban water logging giving rise to high temperatures and floods. Urban high temperatures lead to the combination of high-temperature heat waves and urban heat island effects are global weather disasters; extreme rainstorms and floods caused by climate change can easily lead to urban waterlogging, which has a profound impact on urban planning. Urban planning must consider the impact of these factors to ensure the sustainability of cities and the safety of residents [10].

China, as a country with a long coastline, was significantly affected by climate change. Unfortunately, few countries or cities had developed measures to address the challenges of coastal climate change. Existing measures also focus only on a certain type of disaster, such as tsunamis or floods. There was an inadequate assessment of the full range of hazards that may be caused by climate change. Extreme weather and disasters in recent years have reminded coastal cities of the urban problems caused by climate change [11-12]. Therefore, from now on, it is necessary to take measures to address the climate change challenges faced by coastal cities. The government plays an important role in China's urban planning. Therefore, it is necessary to strengthen the detection and early warning of climate change impacts in urban planning.

3. Case Studies in Coastal City Planning to Cope with Climate Change

3.1. Planning for Flood Disaster Response on Islands: The Case of Xiamen

Xiamen is located on the southeast coast of China and is a typical island city. In recent years, with the intensification of global climate change, Xiamen has faced climate risks such as rising sea levels and frequent storm surges. To effectively respond to these challenges, Xiamen implemented a mangrove ecological disaster reduction plan in the Xiatanwei area to improve the city's ability to resist climate change by protecting and restoring the mangrove ecosystem [13].

In this Xiatanwei’s plan, to protect and restore the area of mangroves, artificial planting, and natural restoration have been adopted. In addition, the structure of the mangrove ecosystem was optimized through scientific planning and reasonable layout. This measure improved its ecological service functions such as tide and wave prevention, embankment reinforcement, and bank protection. At the same time, the monitoring and evaluation of the mangrove ecosystem were strengthened to timely discover and solve ecological problems. To enhance the risk of disaster prevention, the plan combines the characteristics of the mangrove ecosystem and formulates targeted disaster risk prevention measures. Flood control embankments, tide gates, and other engineering facilities were set up around the mangrove reserve to improve the city's ability to resist natural disasters such as storm surges [14] .

3.2. Coastal City Planning: The Cases of Shanghai and Dalian

As China's most prosperous coastal city, Shanghai is particularly affected by climate change. In terms of coping with high temperatures, Lujiazui Greenland Center is Shanghai's core CBD. The ultra-high-density office buildings not only consume a lot of resources and energy but also generate a lot of carbon dioxide emissions. The heat island effect in this area was more obvious than in other areas of Shanghai, especially in the context of global warming. To cope with the challenges brought by climate change, Shanghai Lujiazui Greenland Center had adopted a variety of energy-saving technologies

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and green design methods, such as solar power generation systems, ground-source heat pump systems, and rainwater collection and utilization systems. These measures had effectively reduced the impact on the environment and improved the climate adaptability of the building. In addition, to cope with the flood threat posed by the Huangpu River to Lujiazui, Lujiazui Greenland Center introduced the concept of sunken green space design and rainwater garden design. On the one hand, it reduced the pressure on the drainage system in the area, and on the other hand, it improved the area's flood resistance, which has a significant effect in dealing with several short-term extreme rainstorms. To cope with more extreme flood disasters, Shanghai's urban management department has improved the flood control capacity of the embankment in the Lujiazui area.

Dalian, Liaoning Province, is a typical coastal city. To cope with the impact of climate change, Dalian had set an urban development goal by 2035 or even beyond, namely, to build a coastal city with high climate resilience. To cope with the combined impact of extremely high-temperature climate and urban heat island effect, Dalian had implemented a park city strategy. By connecting green spaces of different sizes such as national forest parks, citizen parks, and pocket parks, Dalian's local climate had been effectively improved, alleviating the adverse effects of urban high temperatures on the health of citizens.

In terms of reducing the city's vulnerability to flood disasters, Dalian's key planning areas included improving meteorological monitoring and early warning capabilities and building a disaster prevention and mitigation system.

(1) Dalian plans to add and upgrade multiple automatic weather observation stations in the next few years to ensure the accuracy and real-time nature of weather data. Early warning of extreme weather is an important prerequisite for effective prevention. Dalian has successfully avoided many urban risks that led to extreme weather through a complete meteorological monitoring network and early warning system.

(2) To cope with possible tsunamis and floods in the Bohai Sea, Dalian City has taken measures to strengthen the construction of coastal protection projects such as flood control dams and seawalls and has formulated emergency plans for various extreme weather events to ensure rapid response when disasters occur.

4. Possible Measures for Urban Planning to Cope with Climate Change

At present, the main climate change threats facing China's coastal cities include extreme heat and urban waterlogging, so urban planning to cope with climate change needs to be given priority consideration. Coping with climate change is not only a beneficial exploration for the future transformation and development of cities but also a major step forward in the health and well-being of all mankind.

4.1. Measures to Deal with Extreme High Temperatures in Cities

To cope with the impact of high-temperature weather on urban planning, urban planning can take measures in terms of urban design, green space, and water resource management.

Increase green space and urban greening. Adding parks and green spaces to urban planning can provide more shade and cooling effects for residents. Parks and green spaces can not only provide leisure and entertainment space but also reduce the temperature of the surrounding environment through the transpiration of plants. Promoting roof gardens and green roofs can reduce the surface temperature of buildings and reduce the urban heat island effect. Green roofs can absorb part of the solar radiation, reducing heat absorption and heat accumulation inside the building.

Choose reasonable building materials. Coastal urban planning can cope with urban heat through urban design and the selection of building materials. Use permeable paving and low-reflectivity

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materials in urban planning to reduce surface temperature and improve the urban thermal environment. Permeable paving can increase surface water evaporation and reduce surface temperature. Low-reflectivity materials can reduce the reflection of solar radiation and reduce surface temperature. Use insulation materials and reflective building materials in building design to reduce heat absorption and heat accumulation inside buildings. Insulation materials can reduce heat transfer, and reflective materials can reduce the reflection of solar radiation and reduce surface temperature.

Strengthen water resources management to mitigate the heat island effect. Urban planning can address urban heat through water resource management and urban planning. For example, a rainwater collection and reuse system can be established to increase urban water resources and reduce the urban heat island effect. Rainwater collection and reuse systems can be used to irrigate green spaces, wash roads, and cool the interior of buildings. Open waters and wetlands can be retained in urban planning to provide evaporative cooling effects and reduce urban temperatures. Open waters and wetlands can increase urban water evaporation and reduce urban temperatures.

4.2. Measures to Deal with Flood Disasters

Construct an urban flood control and drainage engineering system. The urban drainage and flood control engineering system includes the management and restoration of river and lake systems and ecological spaces, the protection of urban mountains, the restoration of rivers, lakes, wetlands, etc., and the preservation of natural rainwater and flood channels and flood storage spaces. At the same time, it is also necessary to implement the construction and renovation of pipelines and pumping stations, increase the construction of drainage pipelines, gradually eliminate the blank areas of pipelines, renovate the rainwater and sewage pipelines that are prone to waterlogging and mixed and misconnected, and repair damaged and dysfunctional drainage and flood control facilities.

Distinguish the difference between flood control and flood control. Although urban waterlogging and floods are both disasters caused by precipitation, their causes, impact ranges and control measures are different. Urban waterlogging mainly gives rise to the accumulation of surface runoff generated by local heavy rainfall or long-duration rainfall in certain low-lying areas, while floods usually lead to heavy rainfall or long-duration rainfall in the basin, especially in the upper reaches, which leads to large flow or high-water levels in rivers or lakes. Therefore, comprehensive consideration of flood control measures is required to control urban waterlogging.

Develop a planning strategy that is tailored to local conditions. Urban waterlogging control should follow the principle of " one city, one policy" and scientifically determine the control strategy and construction tasks based on factors such as natural geographical conditions, hydrological and meteorological characteristics, and urban scale. For example, old urban areas should be renovated and renovated to restore the natural ecosystem, while new urban areas need to be planned from a high starting point and have drainage and waterlogging control facilities built to high standards.

5. Conclusion

At present, traditional urban planning mainly faces problems such as neglecting climate change factors, single spatial layout, and aging infrastructure. This paper discussed possible strategies for cities to cope with climate change through island planning and coastal city planning cases to address climate change issues such as extremely high temperatures and urban waterlogging. To cope with extremely high-temperature weather in cities, it was recommended to increase green space and urban greening, such as parks, green spaces, roof gardens, etc. And reasonably select building materials, such as permeable pavement, low reflectivity materials, and thermal insulation materials. To cope with flood problems such as urban waterlogging, it was recommended to establish an urban drainage and flood control engineering system, such as repairing river and lake water systems and building

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drainage networks. In the planning stage, it was recommended to formulate scientific planning and strategies adapted to local conditions, such as the " one city, one policy" principle. The method of this study focused on qualitative research. It is hoped that future research can explore urban data and quantitative research to achieve a balance between climate change and urban planning and promote sustainable urban development. In order to improve the adaptability of cities to climate change as soon as possible, the combination of green buildings and resilient urban design may be a potential research direction in future research. Although a lot of theoretical research has been completed in the field of resilient cities, there are few successful cases of fully implementing these concepts in actual planning strategies. When coastal cities make strategic plans, it is necessary to combine long-term planning with short-term action plans to make resilient urban designs that adapt to climate change. Therefore, it may be necessary to formulate special urban planning to deal with climate change.

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Research on UK Unemployment Rate Forecast Based on ARIMA Model

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Abstract: The objective of this study is to predict the unemployment rate in the UK and the Eurozone for the years 2014 to 2024 using the time series analysis model known as ARIMA. It is essential to be informed of changes to employment rates in order to address them and changes in the economic environment including historical occurrences such as Brexit, COVID-19, and shifts in the labor market. The ARIMA model was used because it fits non-stationary time series, which is a feature present in the employment rates of both time series. The monthly unemployment rates for each state were seasonally adjusted and the ARIMA parameters were estimated by the automatic method. The study observed that while the interior portion of the trading cycle was effectively predicted by the ARIMA model, it failed to do so for the short-term UK unemployment in the post-2023 period because of exogenous shocks. However, the model was equally successful in predicting a marginal contraction in unemployment rates in the Euro zone after 2023. By performing the Ljung-Box test, it was established that the residuals of the models were random and therefore, the models were fit. Accordingly, the results suggest that the estimates derived from the ARIMA model are beneficial in economic predictions, which helps governments to design better social security programs and other economic plans to address the changing employment landscape.

Keywords: UK Unemployment Rate, Eurozone Unemployment Rate, ARIMA, Economic Forecasting, Labor Market Trends.

1. Introduction

1.1. Research Background and Motivation

Unemployment rate is a measure of a country's economy because it comprises phases of economic cycles, recession and economic volatility. The decade of 2014 to 2024 was characterized marked by significant events in the international environment comprising of COVID-19, Brexit, and shifts in the labor markets through automation, digitalization, and globalization. All these have greatly transformed the employment and unemployment situation in the UK and the Eurozone. These changes and their effects must be well-understood by the governments and other policymakers who face these issues in their countries.

In light of this, the following paper explores the Unemployment trends in the UK and the Eurozone for the major events between 2014 and 2024 and future forecasts. Furthermore, this study proposes

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to look at how forecasting approaches particularly the ARIMA time series model can help in future employment trends and contribute towards the formulation of good social security measures. That is why this survey will be useful for improving government transparency, for the better identification of needs and therefore for the allocation of resources, and for the better understanding of economic policy in everyday life.

1.2. Literature Review

TIKHOMIROVA, Tatiana, in a study of the unemployment rate in the labor market in various regions of Russia, found that most of the techniques for making short-term forecasts of unemployment are based on the use of the ARIMA model, which relates the current value of the indicator to the level of the past period. The authors develop an ARIMA (2,2,0) autoregressive model, which uses the monthly unemployment rate values of the country between October 1994 and October 2017 as source data to develop an expected increase in unemployment rate model for Russia. With good results, according to its estimates for the next 3 months, the country's unemployment rate will be 5.4-5.6% [1]. Md Junayed Hossain studied the relationship between GDP and unemployment rate, he chose ARIMA model to predict the future GDP of Britain, and included unemployment rate as an exogenous variable in the model, trying to analyze the impact of unemployment rate on GDP. The authors used the ARIMA (1,0,0) model for predictive analysis. The configuration of the model includes autoregressive and moving average processing of lagging terms of GDP and unemployment data. When predicting GDP, ARIMA model shows a negative correlation between GDP and unemployment rate, which can capture a certain trend. However, its limited effect in predicting GDP shows the limitations of the model, especially in the processing of complex multi-variable relationships. Thus, using ARIMA for a more single unemployment rate forecast can better capture time series trends [2]. Mayhew and Paul Anand investigated COVID-19 and the UK Labour market, they explored the fact that rise in unemployment in UK resulted from the pandemic. And due to actions of the UK Chancellor of the Exchequer and Bank of England starting to set fiscal and monetary policy as well as the Application for furloughing Scheme or Job Retention Scheme (JRS) by UK government, unemployment in the UK initially rose less than in some other countries, but still reached its peak after a period of moderation until unemployment rebounded from its slump in the later stages of the pandemic [3]. When examining the relationship between the monthly unemployment rate and Brexit, Mihaela Simionescu used the micro-data of political instability, a panel data model considering UK countries during a particular period, and a multi-level mixed effects model. Applying the random effects model could indicate that the long-term effect of Brexit on the conditions of economic growth and employment status in the UK might be very unfavorable. Inability to invest because of Brexit implications will lead to long term adverse effects to the sustainable future of UK. Hence when confronted with similar effects of the epidemic the unemployment rate in the UK accommodates attributes of higher uncertainty than the EU and hence it will be more volatile [4].

1.3. Research Contents

The authors selected monthly unemployment data for the UK and the Eurozone over a 10-year period and used the ARIMA model for forecasting and analysis to help governments make policies and allocate resources more effectively.

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2. Method

2.1. Data Selection and Source

The author selected the monthly unemployment rate data of the UK and the Eurozone for the decade 2014-2024 from TRADING ECONOMICS [5].

2.2. ARIMA

The ARIMA model is a widely used method for analyzing and predicting time series data. It consists of three parts, namely autoregression (AR), difference (I) and moving average (MA), AR captures the relationship between the current observation and past observations, I represents differencing of the raw data to make the time series stationary and MA models the relationship between the current observation and past forecast errors. The parameter p represents how many past observations were used to predict the current value, the parameter d represents the number of differences, and the parameter q represents how many past prediction errors were used to correct the current prediction. The general formula for the ARIMA model is:

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_{q1} \varepsilon_{t-q} + \epsilon_t \quad (1)$$

Where Y_t is the observed value at time t, $\phi_1, \phi_2, \ldots \phi_p$ is the parameter of the autoregressive part, $\theta_1, \theta_2, \ldots \theta_q$ is the parameter of the moving average part, and ϵt is the white noise error term at time t.

The ARIMA model is especially useful when dealing with non-stationary data that should be made stationary using the first difference. Economic unemployment data tend to show a strong, temporal auto correlation characterized by current values shaped by past values and thus, the fit of ARIMA models. Furthermore, from the raw data, it is also obvious that the unemployment rates both in regions are non-stationary and therefore it is reasonable to use ARIMA because of the difference to achieve stationarity. In conclusion, it is appropriate to go ahead with the modeling of unemployment rates in both the UK and the Eurozone using ARIMA.

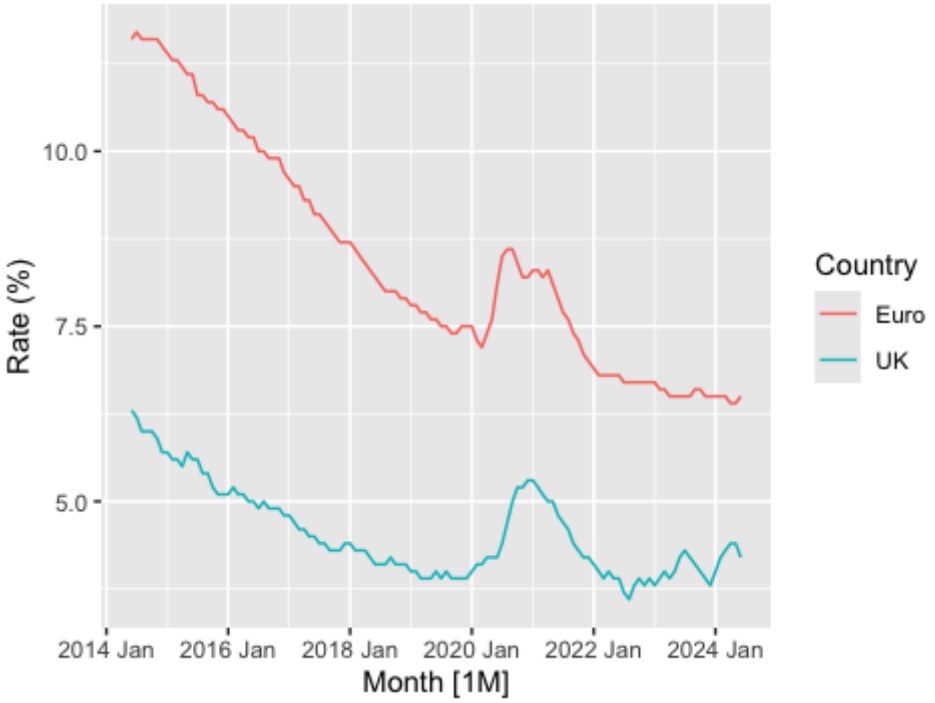

Figure 1: Unemployment rates for persons 10 years (seasonally adjusted).

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The result of data visualization is shown in Figure 1. The unemployment rate in the UK can be observed to have continued to fall from a high level in 2014 to a low point in 2019, after which it rose slightly in early 2020, possibly due to the impact of COVID-19, before falling steadily again. The unemployment rate in the euro area also began to decline gradually from a high level in 2014. Around the end of 2019, the unemployment rate reached a low level, then saw a significant increase in early 2020 due to the impact of the pandemic, and then gradually declined. After the beginning of 2022, the unemployment rate in the euro area showed a steady trend. In order to test whether the original data is predictable, the stationarity test (ADF test) is carried out on the original data, and the results are shown in Table 1:

Table 1: ADF test.

	P-value
UK	0.3408
Euro	0.7452

As can be seen from Table 1, the p-value of the two groups of time series data is greater than 0.05, and at the significance level of 5%, there is sufficient reason to reject the null hypothesis, that is, the two unemployment rate data series are not stable and need to be difference-processed. The features function is used to extract the features of the time series, and the number of difference required to make the time series stationary is determined based on the ADF test in combination with the unitroot_ndiffs function. The optimal number of difference given by the features function for both sets of time series data is 1. Then the time series diagram after difference was visualized and ACF and PACF diagrams were drawn, and the results were shown as Figures 2-3.

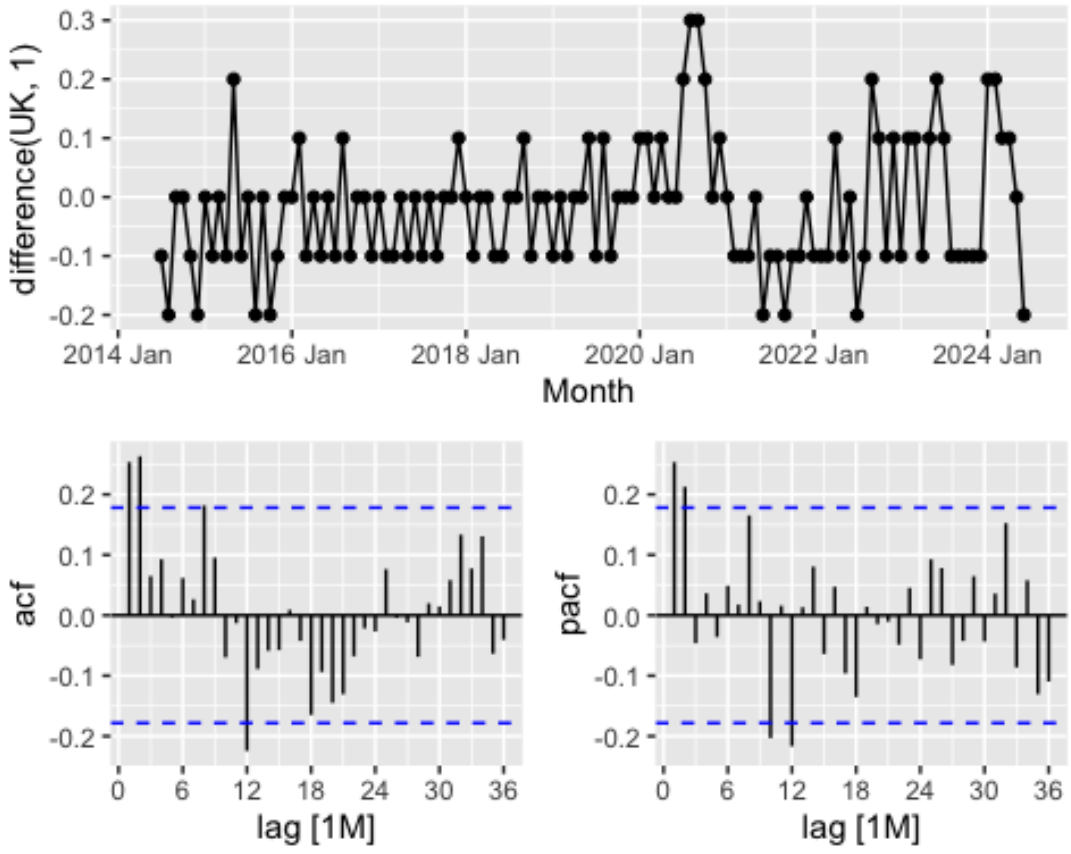

Figure 2: The result after difference (UK).

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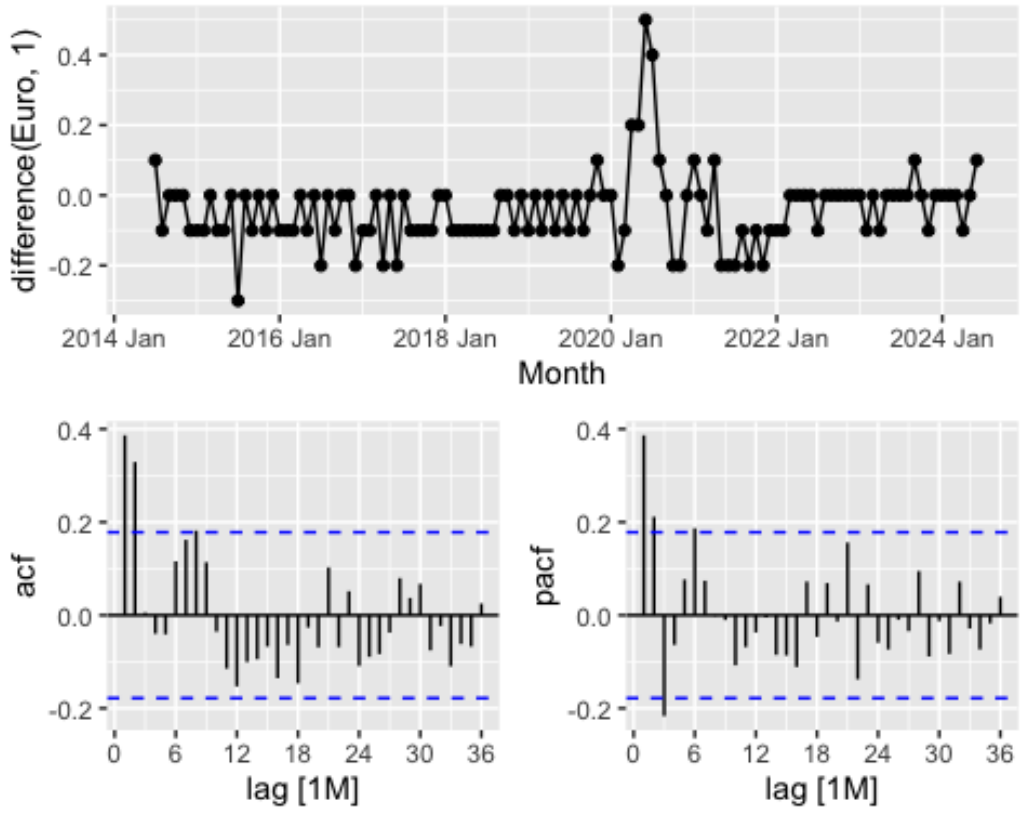

Figure 3: The result after difference (Euro).

It can be seen that the fluctuation of the Figures 2-3 of time series data after first-order difference is small, showing a certain degree of stationarity. The autocorrelation coefficients in the ACF and PACF graphs decay rapidly to zero, indicating that the data after first-order difference is already stable.

3. Results

The data set is splited, the data before 2023 is used as the training set and the data after 2023 is used as the test set. The selection of the model is done through the automated process, and the combination of parameters that can best fit the data is selected. For the unemployment rate data of the United Kingdom, the non-seasonal ARIMA model with seasonal autoregressive part is selected: ARIMA $(2,1,0)(1,0,0)^{[12]}$ considers two non-seasonal autoregressive terms and one seasonal autoregressive term, and includes one drift term. The goodness of fit of the model shows the good fit of the model. For the unemployment rate data of the euro area, the non-seasonal ARIMA model containing the seasonal moving average is selected: ARIMA $(0,1,2)(0,0,1)^{[12]}$. The goodness of fit of the model shows the good fit of the model. Details of the model, including selected parameters are shown in Table 2:

Table 2: ARIMA model.

	model	AIC	AICc	BIC
UK	ARIMA $(2,1,0)(1,0,0)^{[12]}$	-185.16	-184.54	-172.04
Euro	ARIMA $(0,1,2)(0,0,1)^{[12]}$	-179.35	-178.73	-166.23

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The training set was used to fit unemployment data for the UK and the Eurozone, respectively, to generate forecasts for the test set cycle, and measures such as ME, RMSE, and MAPE were used to assess the accuracy of the model. Based on the prediction results of the UK unemployment rate, the measurement values of Mean Error (ME), Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE) on the training set show that the accuracy of the model is very good, and the error between the predicted value and the actual value is very small. On the test set, the model's prediction error increases, especially for ME and MAPE, which means that the model does not perform as well on the test set as on the training set, and the prediction performance decreases on the test set, which may be caused by new exogenous shocks or policy changes in the data after 2023. But the ARIMA model still managed to capture a small increase in the unemployment rate in the early months of 2023, and the model's predictions were very close to the actual data. The focus of the model when forecasting is still on short-term trends, not long-term fluctuations. Therefore, as the author move into 2023, the model still references the previous data trends and predicts future declines in the unemployment rate based on long-term historical data performance. The prediction results of the model on the training set and the comparison between the predicted value and the real value of the test set are shown in the Figures 4-5.

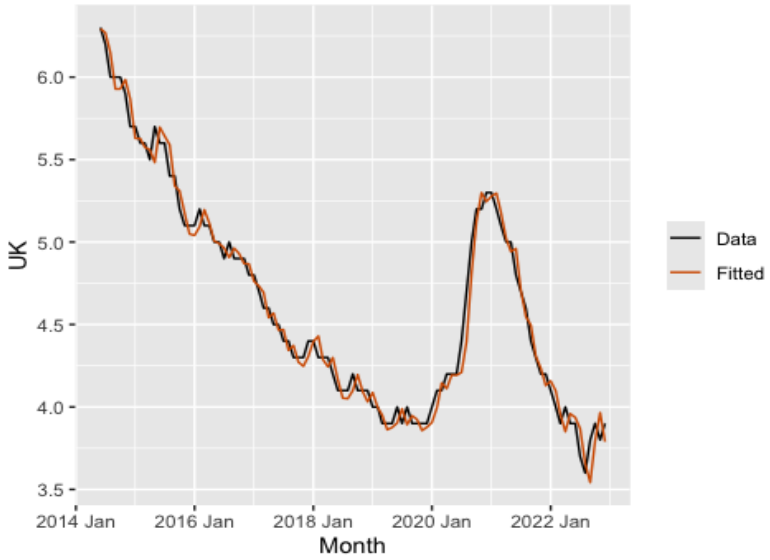

Figure 4: Training set (UK).

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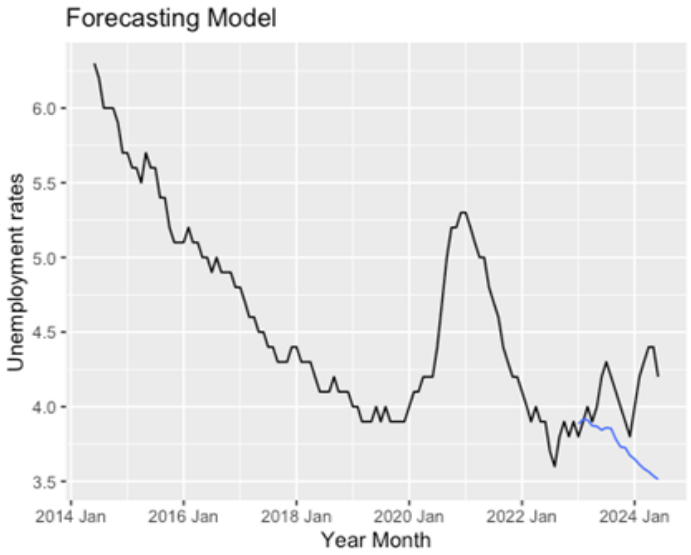

Figure 5: Test set (UK).

The results of Ljung-Box test show that the P-value of autocorrelation detection of ARIMA model residuals is 0.1981081, which is much higher than the commonly used significance level (0.05), indicating that there is not enough evidence to reject the hypothesis that the residuals are white noise. This shows that the ARIMA model has captured the information in the data well, and the model residuals are displayed as randomness, which proves that the fitting effect of the model is appropriate.

Based on the forecast results of the unemployment rate in the euro area, the ARIMA model for the euro area agrees well with the training data, the error indicators are very low, and the difference between the predicted and actual values is small. On the test set, although the model predicted a slightly higher value than the actual value, there is a certain bias, but the ARIMA model caught the signal of the unemployment rate in the early months of 2023, and successfully predicted the relative stability of the unemployment rate over this period. Going into the future forecast phase, the model may still predict a slight decline rather than a continuation of stability because of the long-term downward trend present in the data throughout the time series, but the model's forecast performance is better than that of the UK unemployment rate, and the overall performance is more reliable. The prediction results of the model on the training set and the comparison between the predicted value and the real value of the test set are shown in the Figures 6-7.

DOI: 10.54254/2754-1169/123/2024MUR0136

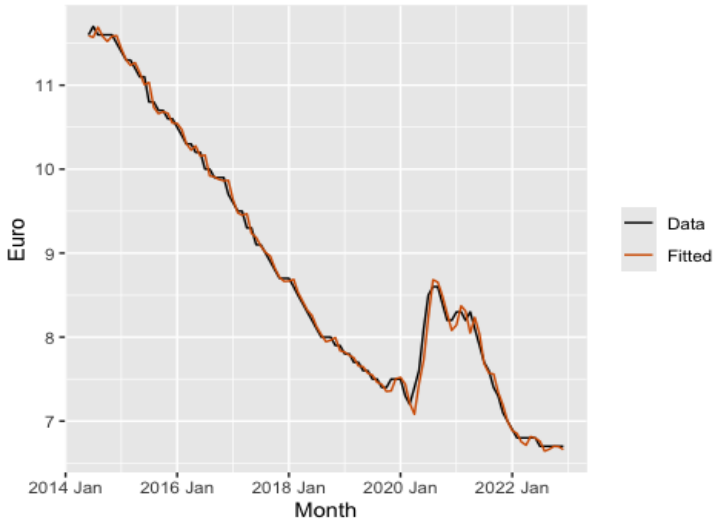

Figure 6: Training set (Euro).

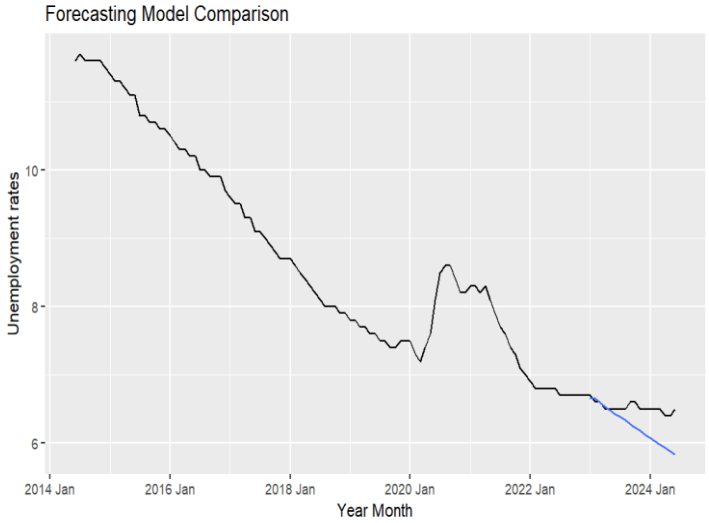

Figure 7: Test set (Euro).

The results of Ljung-Box test show that the P-value of the autocorrelation detection for the residual of the ARIMA model is 0.7324913, which is much higher than the commonly used significance level (such as 0.05), indicating that there is not enough evidence to reject the hypothesis that the residual is white noise. This shows that the ARIMA model has captured the information in the data well, and the model residuals are displayed as randomness, which proves that the fitting effect of the model is appropriate. In summary, the ARIMA model is very suitable for the unemployment rate in the UK and the Eurozone, and although there may be some errors in the specific forecast points, the conclusions are generally reasonable. The model successfully captured the major trends, and the residual tests showed that the model had fully fitted the data. The higher accuracy in the euro area can be attributed to a more consistent trend in the data, while the UK data show more variability.

4. Discussion

From 2014 to 2024, unemployment rates in the UK and the euro area experienced significant changes due to a number of major events. By analyzing the changes of unemployment rate in these two regions,

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the author can better understand the causes of these changes and put forward corresponding policy recommendations.

4.1. Analysis of the Underlying Reasons

Unemployment in the UK has been falling since 2014. During this period, the UK economy began to rebound from the effects of the 2008 global financial crisis, and the government implemented a number of pro-employment policies such as quantitative easing and low interest rates to tackle unemployment. However, in the 2016 financial year, business uncertainty in the UK rose as a result of Brexit, capital investment fell and overall GDP growth was subdued. Although unemployment has not risen significantly in the short term, there are signs that Brexit has slowed the annual rate of decline in unemployment in the run-up to 2020. The COVID-19 pandemic had a huge impact on the economy in 2020. Britain has imposed strict lockdowns and restrictions, leading to a massive exodus of businesses and unemployment starting to rise in 2020. Nonetheless, rapid government intervention, such as the Support for Work Programme, helped to slow the rise in unemployment; However, unemployment will peak in 2021 [6]. After 2021, the gradual weakening of the economic impact of population vaccination and the pandemic led to a decline in unemployment [7]. But because of supply chain problems and inflation, unemployment rose to 2022 levels. The reason for the volatility is the uncertainty of the economic recovery after the pandemic. From 2023 onwards, the real unemployment rate is forecast to fall again. However, due to Brexit and unresolved global economic uncertainties resulting in the specific trade relationship between the UK and the EU, the unemployment rate forecast remains very vague.

Similar to the UK, the Eurozone also experienced a sustained decline in unemployment between 2014 and 2019. Thanks to the monetary easing policies of the European Central Bank and the stability of the internal market of the European Union, the Eurozone countries have gradually recovered from the economic crisis and the unemployment rate has maintained a steady decline. However, the 2020 pandemic will hit the Eurozone even harder. Due to the diversification of the economic structure of the Eurozone member states, the response measures and effects of the epidemic in each country are also different, resulting in a sharp rise in the overall unemployment rate in the Eurozone in 2020. In the early stages of the epidemic, unemployment quickly stabilized in 2021[8], thanks to fiscal stimulus policies by governments and support from the European Central Bank. However, with the outbreak of the Russia-Ukraine conflict in 2022, the Eurozone faced an energy crisis and inflationary pressures, leading to a rebound in unemployment in 2022. The Russian-Ukrainian conflict has particularly affected manufacturing powerhouses such as Germany and France, adding to the volatility of unemployment [9]. Nonetheless, model projections suggest that unemployment in the euro area will gradually decline after 2023, indicating the strong recovery capacity of the EU internal market and the effectiveness of integration policies.

4.2. Suggestion

First, the author identified the strategic areas that the UK should focus on to resolve the economic issues brought about by Brexit. To start with, uncertainty should be minimized in the market through the development of international trade and investments cooperation with non-European countries and attracting foreign investments in the trade cooperation. Secondly, efforts should be directed towards improving occupational training as well as re-employment services within sectors that have been negatively impacted by Brexit. These training initiatives can help governments place the unemployed into new opportunities and foster change in the economy. Finally, science and technology development in combination with a digital economy can create high quality jobs. The government should support development of such areas through provision of tax incentives and favorable policies.

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To overcome the challenges facing the Eurozone, certain strategic moves are required. First of all, the shift of energy policy is necessary as the energy crisis that occurred due to the conflict between Russia and Ukraine shows. It prepares the Eurozone to develop non-Russian energy sources and apply renewable energy to get the economy back on track and minimize the level of unemployment. Second, continuation and enhancement of the internal market is crucial; liberalisation and opening up of barriers to economic interconnection between member states will spur growth and employment [10]. Finally, improving and enhancing social security measures is essential during economic cycles to guarantee the necessities of the unemployed since unemployment rises in challenging economic times to avoid upsetting the social order.

5. Conclusion

This paper highlights the ability of the ARIMA model to predict long-term unemployment trends, but also points out its limitations in capturing short-term fluctuations. The ARIMA model performs better in the euro area, forecasting a slight decline in unemployment after 2023. However, the model shows a higher forecast error for the UK data, suggesting that while ARIMA is useful, it may not fully account for sudden economic shocks or policy changes. Prospective works could enhance forecasting and predictions like including factors such as political events and global crises as exogenous variables to enhance the models. And other mixed models that incorporate features of ARIMA and machine learning to provide a more accurate reflection of the state of economic indicators. Further, the paper advises policymakers to look at a wider array of models and to update input frequently so as to enhance the exactness of unemployment projections. It could foster preferable economic policies as well as help get ready for the future uncertainty.

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Applications of Carbon Capture Technologies in Steel and Cement Industries

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Abstract: As problems such as the increase in extreme weather, rising sea levels, and social inequality continue to sharpen with the intensifying climate change, changes are demanded. The cement and iron and steel industries are among the major spheres responsible for the rising global temperature. Carbon reduction methods cannot fully solve the problem and help these industries reach carbon-neutral emissions. Therefore, carbon capture (CC) technology is urgently needed. This article introduces the application of pre-combustion carbon capture (PreCCC), post-combustion carbon capture (PostCCC), and oxyfuel combustion carbon capture in the cement industry and the iron and steel industry. Research has shown that oxyfuel combustion is one of the most assuring pathways to reach carbon neutrality in cement plants since problems of temperature management can be solved by recycling part of the fuel gases, and its cost is relatively lower than the other methods. However, PostCCC is a better solution in the iron and steel industries. Although technological innovations in physical absorption and chemical absorption are still needed, PostCCC can mitigate a large portion of steel plants' carbon footprint. Carbon capture intensity can be increased with further technological development in combining PostCCC and oxygen-rich combustion. The combination of different pathways may be a novel hypothesis, but it has a great possibility of alleviating the carbon emission of the industrial sector.

Keywords: Carbon Capture Technology, Cement Industry, Steel Industry, Net Zero Emission.

1. Introduction

Referring to Earth's natural circle of ice age, the Earth was in the cooling phase starting about 5,000 years ago [1]. However, instead of following the natural trend of falling temperature, the global land-ocean temperature has increased by at least $1.1°C$ since 1880 (the pre-industrial period). The increase in global temperature demonstrates a rise in the number. It indicates serious ecological degradation and societal conflicts, such as increased extreme weather, animal extinctions, economic decline, and inequality between the rich and the poor. One of the most catastrophic effects of global warming is the rise of water levels, mainly due to the melting of ice sheets that contributed to approximately 20.9 ± 2.8 millimeters of sea level rise from 1992 to 2020 [2]. Although the melting of Arctic sea ice is not the main cause of sea level rise, where the molten ice could replace the place of the former ice, it can accelerate climate change and intensify the melting of sea ice. While sea ice is molten, a larger part of the ocean's surface is covered in a darker color, absorbing more heat from the sun, raising the

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global temperature, and causing more ice to melt. The excessive melting of sea ice can lead to habitat loss and local ecologic decline.

While carbon reduction can mitigate the emission of carbon dioxide (CO_2) and climate change, the CO_2 that already appears in the Earth's atmosphere continues to warm the atmosphere due to its long lifespan (hundreds to thousands of years). Moreover, burning fossil fuels is still the largest sector of the global electricity sector, accounting for about two-thirds of the power generated. Power produced by burning fossil fuels has increased by 70% since 2000. The cement industry and the iron and steel plants have continued to be the leading contributors to the industrial sector of climate change. While cheaper energy storage methods are still needed to reach 100% renewable energy-based consumption, carbon capture (CC) is one of the best ways to achieve net zero emissions. Therefore, carbon removal technology, such as CC, is urgently needed to slow climate change.

The cement industry and the iron and steel plants have continued to be the leading contributors to the industrial sector of climate change. While the carbon footprint of the industrial sector is 14.1 Gt or 24% of global emissions in 2019, 2.428 Mt of CO_2 is emitted in cement plants and 1.41t in the iron and steel industry in 2022. Reducing the clinker-to-cement ratio in cement production and applying scrap-charged electric arc furnaces in the steel plant has been the dominant pathway to carbon reduction. However, CC is still immature in both plants. At present, discussions over CC mainly focus on the technical level, which demands more research in the application realm. Therefore, this article introduces the leading CC technologies and focuses on their application in cement, iron, and steel plants.

2. Conventional Technologies for Carbon Capture

Recognizing the significant role of carbon capture technology, scientists have developed three main pathways to capture CO_2: pre-combustion carbon capture (PreCCC), post-combustion carbon capture (PostCCC), and oxygen-rich combustion carbon capture.

PreCCC turns hydrocarbon into hydrogen, extracting the source in fossil fuels to produce CO_2. First, through processes such as steam reforming, hydrocarbon can be decomposed into hydrogen and carbon monoxide under high temperatures and low pressure. Then, impurities, such as nitrogen, argon, and oxygen, could be removed to avoid other pollutant emissions other than CO_2. Furthermore, in order to maximize hydrogen production, carbon monoxide could be reconverted into carbon dioxide with water, producing more hydrogen that can be used as fuel. Finally, carbon dioxide could be separated from hydrogen through physical or chemical absorption. However, due to the higher carbon tax cost, PreCCC is not widely employed in many industries.

Compared to PreCCC, PostCCC and separates CO_2 from the fuel gases after the fossil fuel is burned, which can usually avoid a greater percentage of CO_2 emission. Similarly, CO_2 could be captured in oxygen-rich burning carbon capture after fossil fuel combustion. On the other hand, oxyfuel combustion requires an additional process before the combustion. Almost pure oxygen could be separated from the atmosphere to prevent the production of multiple impurities after the combustion, simplifying the process of carbon segregation in PostCCC.

3. Application of Carbon Capture Technologies in The Cement Industry

3.1. Background of The Cement Industry

As the primary building material, concrete is used to construct buildings, transportation, and infrastructures, making it the second most consumed worldwide after water. However, cement accounts for around 85% to 90% of concrete production and more than 5% of anthropogenic greenhouse gas emissions. Therefore, concrete has become a large contributor to climate change, intensifying the need to reduce carbon emissions through cement production.

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Cement is mainly composed of gypsum and clinker, produced from limestone calcination or the combustion of limestone and other oxides. Unfortunately, CO_2 is a major byproduct of the chemical reaction between limestone and other oxides when limestone is broken down into calcium oxide (CaO) and CO_2. The carbon emission through limestone calcination contributes to around 60% of the cement's carbon footprint. The output of heat and electricity through the combustion of fossil fuels to support concrete production accounts for the other 40% of carbon emissions.

Considering the significant greenhouse emissions through the production of concrete and its rising demand, especially in middle-income and low-income countries, technological innovation is required. While finding alternate fuels and reducing the concentration of clinker can significantly reduce carbon emissions through cement production, a carbon footprint still exists. Therefore, CCS is the best solution for a completely carbon-neutral cement construction industry.

3.2. Oxyfuel Combustion Carbon Capture Technologies

Although the maturation of CCS technology still needs to overcome the obstacle of high cost and more technical innovation, CCS, such as oxyfuel combustion with carbon capture technology, has great opportunity and potential to reduce carbon emissions in the cement industry.

Unlike the traditional power plant, an oxyfuel-combustion-based power station can capture, compress, and store the fuel gas released by burning the fossil fuel in pure oxygen. While untreated air and the fuel gas it produces contain large amounts of nitrogen, the fuel gas produced by oxygen-rich burning has no nitrogen and a high concentration of CO_2, making the compression process more manageable.

Specifically, first, oxygen is purified via methods such as cryogenic air separation, which uses the dissimilar condensation points of oxygen (-183°C) and nitrogen (-196°C) to separate oxygen from other gases. Second, fossil fuel is burned in the 95% to 97% oxygen gas inside a boiler to produce steam and the byproduct – fuel gases with a high concentration of CO_2 and water [3]. Next, the fuel gases are cooled to the liquid phase to remove the water, leaving the gas with an even higher concentration of CO_2. Finally, the CO_2 sequestrated from the fuel gas can be compressed, transported, and stored. However, not all fuel gases go through the complete process and are stored. Around 80% of fuel gases can be recycled and combined with pure oxygen, making up 3% to 5% of the original gas to react with fossil fuels to cool the boiler's temperature [4]. Fossil fuel combustion within pure oxygen can lead to high flame temperatures of up to 4500°F, surpassing the highest temperature traditional boilers can hold. Fortunately, the reaction can happen suitably with a few additional carbon dioxide-rich fuel gases.

Oxyfuel combustion carbon capture also shows significant cost advantages compared to other carbon capture pathways, including PreCCC and PostCCC. While the costliness index of power stations with PreCCC is 29.64 and power plants with PostCCC is 29.04, the costliness index of power stations with oxyfuel combustion carbon capture technology is only 14.34. It also shows economic potential in its average lifetime levelized cost of electricity (LCOF), capital, and investment costs due to its efficiency in removing CO_2 from the fuel gases without the involvement of physical or chemical solvents [5]. Moreover, to increase energy efficiency and overcome the difficulty of energy penalty, second-generation oxyfuel combustion is developed with a heat integration methodology, which increases the net efficiency from 32.91% to 36.42% and decreases the energy penalty from 10.54 to 7.28 efficiency points. Therefore, oxyfuel combustion has shown great potential in the cement industry.

Take the European cement industry as an example, fully employing either first-generation or second-generation can bring the most significant possibility in mitigating climate change (around 80%) when compared to other methods, such as applying RDF or bio-fuel on a larger scale and reducing clinker to clinker-to-cement ratio [6]. Furthermore, due to its particular advantage in that its

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reaction to produce steam is almost pure oxygen and is accompanied by CCS, oxyfuel combustion produces less air pollution and greenhouse gases, reducing harmful chemicals that enter the Earth's atmosphere [7]. Although problems, such as high energy demand for recycling the fuel gas to manage the temperature in the boiler, still exist, second-generation oxyfuel combustion may be a promising solution to enable fossil fuel to burn in pure oxygen without fuel gas recycling by applying excessive oxygen in the boiler. While the excessive oxygen can be reused in the combustion later, fuel gases no longer need to be recycled, and fewer gases can be required to produce the same amount of steam [8].

3.3. Future of Carbon Capture Technology in The Cement Industry

Recognizing the urgent need to eliminate carbon emissions in the cement industry, the Holcim group plans the Go4ECOPLANET project to reach net zero emissions in the cement industry by capturing and liquifying the CO_2 emitted in the plants. This project is expected to be employed at the Lafarge Cement S.A.'s Kujawy Plant in Poland through the Cryocap™ FG technology.

The Cryocap™ FG technology first achieved carbon segregation with high pressure. Then, the CO_2 was condensed into the liquid at a low temperature. Finally, the liquid carbon dioxide could be removed from other impurities or components, where the CO_2 can be stored and the other compounds can be recycled to produce more fuels or energy.

It is predicted that with the implementation of the Cryocap™ FG technology within Lafarge Cement S.A.'s Kujawy Plant, more than 10 Mt could reduce the carbon footprint of that plant and the carbon emnation of the entire cement industry in Poland can be reduced by 10% [9].

4. Application of Carbon Capture Technologies in the Steel Industry

4.1. Background of the Steel Industry

As a versatile and strong alloy, steel is one of the most essential materials in the world widely used in multiple constructions. While 1762.2Mt of steel was used in 2022, 52% is used for building and infrastructures, 16% for mechanical equipment, 12% for automotive, and the others for metal production, transportation, electric equipment, or domestic appliances. However, it is also a great contributor to climate change.

Steel is an alloy that is mainly composed of iron and other metals with the addition of a few carbons to increase its strength. For instance, mild steel contains 99% iron, and stainless steel (304) includes 70%. Although steel is strong, durable, and highly recyclable, the iron and steel industry accounted for 25% of the global industrial sector and 7% of global net direct greenhouse gas emissions in 2018, which is still a continuously increasing trend [10]. While the carbon footprint of steel production is still increasing, each tonne of steel produced releases around 1.9 tonnes of CO_2 in 2010. In 2022, 1885 million tones of crude steel and 1781 million tones of finished steel were produced, which increased a lot when compared to 1563 million tones of crude steel and 1445 million tonnes of finished steel produced a decade ago.

The production of steel can be mainly separated into three processes: raw material preparation, iron making, and steel making. First, coal is burned without the involvement of oxygen to produce coke, a solid carbon fuel. Then, coke is heated again with iron ore in a blast furnace, where coke reduces the iron ore into molten iron and produces a large amount of CO_2. Finally, impurities, such as sulfur and carbon, are removed from the molten iron to produce steel. Nowadays, there are two main pathways to produce steel: the usage of blast furnace-basic oxygen furnace (BF-BOF) and scrap-charged electric arc furnace (EAF). While BF-BOF uses coke to reduce the iron ore to produce molten iron, EAF applies electricity as a replacement for coke to reduce recycled iron, mitigating the carbon emission of steel production. However, the limited amount of recycled iron restricts the development

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and wider application of EAF. Therefore, applying CC in the blast furnace and coking process becomes crucial to reaching net zero emissions in the iron and steel industry.

4.2. Post-Combustion Carbon Capture Technology

The carbon capture technology can be categorized into three groups: PreCCC, PostCCC, and oxyfuel combustion carbon capture. PostCCC and oxyfuel combustion carbon capture are considered the most promising solution to achieve a carbon-neutral steel industry.

PostCCC refers to segregating CO2 from the fuel gas after the burning process, which usually involves physical and chemical absorption technology.

Physical absorption means directly absorbing CO_2 in the liquid solvent. After dissolving in the high-pressure and low-temperature liquid solvent, CO_2 is separated from the other fuel gases and is further separated from the solvent by flash tanks. The greatest advantage of physical absorption is its relatively low capital and process costs compared to other carbon capture technologies [6]. However, while both thermal management and pressure reduction require lower energy consumption than other operations, a large amount of energy is needed to raise the pressure to compress the original fuel gases. Physical absorption also demands high CO_2 concentration in the fuel gases, which demands the technology to remove the impurities. Moreover, challenges such as high-pressure loss, large equipment size, and complex systems further block the development of physical carbon capture.

Like physical carbon capture, fuel gases must pass through a liquid solvent. However, a chemical reaction happens between CO_2 and other compounds, such as potassium hydroxide (KOH), to selectively separate CO_2 from the other gases, forming carbonates, such as potassium carbonate (K_2CO_3) and water. Following the segregation of CO_2, pure CO_2 can be obtained by replacing the carbonate group with the hydroxide group. For instance, through the reaction between potassium carbonate (K_2CO_3), calcium hydroxide ($Ca(OH)_2$), calcium carbonate ($CaCO_3$), and potassium hydroxide (KOH) are produced. While potassium hydroxide (KOH) can be reused to capture more CO_2, calcium carbonate ($CaCO_3$) can be broken down to produce pure CO_2. However, this process requires large amounts of energy, mainly generated from fossil fuels, such as coal and natural gas, to separate CO_2 from potassium carbonate (K2CO3) and calcium carbonate ($CaCO_3$) at high temperatures. The involvement of fossil fuel combustion leads to carbon dioxide emission, opposing the primary aim of CC.

Nevertheless, PostCCC is a technically realizable method to mitigate climate change and is expected to reduce steel plants' carbon footprint by 40%. Furthermore, combining oxyfuel combustion with PostCCC is a promising pathway to increase carbon capture intensity. Like the oxyfuel combustion in cement plants, pure oxygen can replace the original air in traditional blast furnaces, and part of the fuel gases can be recycled to maintain the combustion temperature. Moreover, recycling fuel gases can even increase the efficiency of coke use.

5. Conclusions

This article introduces the different types of carbon capture technology and discusses its application in the cement and iron industries.

Over the past centuries, climate change has continued to cause serious problems, such as extreme weather and animal and social inequality. More catastrophic disasters may happen, such as rising water levels due to melting ice sheets, if the global temperature keeps increasing. While cement plants and steel plants are the main contributors to the industrial sector of global climate change, carbon reduction processes cannot fully eliminate their carbon footprint, underscoring the significance of implementing carbon capture technology in the cement and iron and steel industries.

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The carbon capture technology can be separated into three categories: pre-combustion carbon CO_2 production by turning hydrocarbon in the fossil fuels into hydrogens. PostCCC separates CO_2 from the fuel gases with absorption. Oxyfuel combustion involves preparing almost pure oxygen before the combustion and treating the CO_2 emitted after the combustion.

Oxyfuel combustion carbon capture is the most promising pathway in the cement industry. It is not only cheaper in cost when compared to PostCCC but also more environmentally friendly. The Go4ECOPLANET project may provide a plausible solution to carbon-neutral cement plants in the future. PostCCC may be a reliable approach to net zero emissions in the iron and steel industry. Despite the unmatured technology in physical and energy consumption in chemical absorption, PostCCC can mitigate the CO_2 emanation of the iron and steel industry at a much larger scale than the other two pathways.

This article introduces the three plausible pathways of carbon capture technologies and analyzes their possibilities and challenges in the cement and iron industries. This article can foster further study and research in the employment of CCS in the industrial sector, alleviating the problem of climate change from one of the major sectors that demands more attention. In conclusion, admitting the absence of real-life application of all three carbon capture technologies in the cement and iron industries, this article lacks direct proof and data analysis from relevant experiments. Therefore, in order to consolidate the hypothetical ways of applying PostCCC and oxyfuel combustion carbon capture in the cement and steel plant, projects, such as the Go4ECOPLANET project, that can unite theory with practice are needed.

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Traditional and Innovative Battery Recycling Methods

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Abstract: With the rapid increase in global demand for high-performance batteries, particularly driven by the growth of electric vehicles and large-scale clean energy storage systems, the need for effective battery recycling methods has become more pressing than ever. This paper provides a comprehensive examination of both traditional and innovative methods for battery recycling, which has become increasingly critical due to the growing environmental concerns associated with the disposal of batteries, particularly from electric vehicles and large-scale energy storage systems. The study analyzes three primary recycling methods: mechanical processing, chemical recovery, and direct reuse, detailing their underlying principles, advantages, and limitations. In addition, the paper introduces an innovative recycling approach that integrates bioremediation microorganisms and nanotechnology to enhance the efficiency of metal recovery and minimize environmental impact. This novel method offers a pollution-free, sustainable solution that addresses the inefficiencies and environmental risks associated with traditional recycling techniques. Through a comparative analysis, the study highlights the potential of this innovative approach to revolutionize battery recycling, contributing to more sustainable practices and the circular economy. The findings emphasize the importance of adopting advanced recycling technologies to meet the increasing demand for battery materials while ensuring environmental protection.

Keywords: Battery Recycling, Mechanical Processing, Chemical Recovery, Direct Reuse, Nanotechnology.

1. Introduction

Accompanied by the recent global development and innovation in sustainable energy technologies, and the increasing demand, especially with the rapid growth of electric vehicles and large-scale clean energy storage systems, the demand for high-performance batteries has surged [1,2]. The core of battery performance lies in its active materials and electrochemical properties. These properties determine the charging speed, endurance stability, and battery lifespan [3]. Therefore, understanding and optimizing the electrical performance of these materials is key to improving battery technology. Similarly, further research and progress are needed in the degradation methods for high-demand batteries, including discovering new materials and improving old materials [4,5]. This discussion on these advancements can potentially drive battery technology forward.

Battery pollution is a significant environmental concern. While electric vehicles are seen as a perfect clean energy product, this study overlooks how batteries can pollute our ecological

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environment and cause irreversible damage [6,7]. This study needs to consider the disposal of end-of-life vehicles, proper handling of batteries, and environmentally friendly separation methods during recycling. There are different methods for handling batteries in this process [8]. Recycling discarded batteries is a complex but crucial process. This study also needs to minimize environmental impact and recycle valuable materials for reuse. This study mainly discusses three methods that can be used for recycling discarded batteries, including mechanical processing, chemical recovery, and direct reuse [9,10].

2. Methods of Battery Recycling

2.1. Mechanical Processing

Mechanical processing is a basic way to recycle waste batteries, which involves physically breaking the batteries down into small pieces and recovering valuable metals like nickel and copper through physical techniques such as magnetic separation, sieving, and gravity separation. advantages of this method are its simplicity and low cost, but the downside is significant; it may not fully recover all types of battery materials, especially rare metals and electrolytes, making its effectiveness less satisfactory over time [1].

2.1.1. Steps of Mechanical Processing

The specific process of this method includes several major steps [3]:

Crushing: Waste batteries are sent to a crusher for physical crushing, breaking the batteries into small pieces or fragments, typically ranging in size from a few millimeters to a few centimeters. These fragments include battery casings, electrode sheets, electrolyte, and other mixtures.

Magnetic Separation: The crushed battery fragments undergo magnetic separation. Magnets are used to separate ferromagnetic metals (such as iron and nickel) from other non-magnetic materials. These magnetic metals are collected for further processing and recycling.

Screening: The fragments that have undergone magnetic separation are screened to separate materials of different particle sizes using screens with different pore sizes. This process can further separate larger metal pieces or smaller metal powders.

Gravity Separation: The screened materials may undergo gravity separation, utilizing the density differences of materials to separate heavy metals from light metals for more efficient resource recovery.

The entire mechanical processing process is relatively simple to operate and low in cost, making it an economical and practical recycling method. However, it has limitations in fully recovering all types of battery materials, especially rare metals and electrolytes.

2.1.2. Disadvantages of Mechanical Processing

Although mechanical processing methods are simple to operate and low in cost, they also have significant drawbacks. Since this method mainly relies on physical separation techniques, it cannot fully recover all types of battery materials, especially some rare metals and electrolytes. Therefore, although this method is effective in recovering common metals such as nickel and copper, it is less effective in recovering some high-value, low-content metals. Additionally, the fragments produced during mechanical processing may be mixed with harmful substances, which, if improperly handled, can cause environmental pollution. With the development of technology and increasing environmental requirements, solely relying on mechanical processing can no longer meet the needs of modern battery recycling. Therefore, it is usually necessary to combine mechanical processing with other chemical or thermal treatment methods to improve recovery efficiency and material purity.

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This comprehensive treatment method allows various valuable components in waste batteries to be more comprehensively recovered, reducing resource waste and environmental pollution.

2.2. Chemical Recovery

Chemical recovery is an important means of processing waste batteries. By using chemical solvents such as acids or bases, the metals in the batteries are converted into soluble salts, which are then extracted using chemical precipitation or electrochemical methods [3].

2.2.1. Steps of Chemical Recovery

The specific process of this method includes several major steps:

First is dissolution, where waste batteries are crushed into small pieces and placed in a solution containing acids or bases. Common acids include sulfuric acid, hydrochloric acid, and nitric acid, while common bases include sodium hydroxide and potassium hydroxide. The metals in the batteries react with these chemical solvents to form soluble metal salts. For example, lithium in lithium batteries can react with sulfuric acid to form a lithium sulfate solution. Next is filtration, where non-metal parts of the batteries, such as plastics and other impurities, do not dissolve in the solution during the dissolution process. These insoluble need to be separated from the solution by filtration. The filtered solution mainly contains metal salts and a small number of soluble impurities.

Next is precipitation, whereby adding appropriate chemical reagents to the solution, specific metals can be precipitated out in the form of precipitates. For example, by adding alkaline reagents, certain metal hydroxides can be precipitated out. This step can selectively recover specific metals. After precipitation is electrolysis, metals can be extracted from the solution using electrochemical methods. The electrolysis process uses an electric current to pass through the solution in an electrolytic cell, causing metal ions to deposit on the cathode as pure metal. This method is particularly suitable for recovering high-value metals such as lithium, cobalt, and nickel. These metals are widely used in lithium-ion batteries, making chemical recovery methods particularly important in recycling lithium-ion batteries [3].

2.2.2. Advantages and Drawbacks

The advantages of chemical recovery methods lie in their high recovery efficiency, capable of effectively recovering valuable resources in batteries, especially suitable for lithium batteries and other batteries containing precious metals. Compared to physical mechanical processing methods, chemical recovery can more comprehensively extract various metal components in batteries, achieving higher recovery rates. However, chemical recovery methods also have significant drawbacks. First, the acids and bases used in the chemical recovery process are corrosive and toxic, and the process may produce toxic gases and waste liquids, posing environmental risks. If improperly handled, it can cause pollution to water sources and soil. Additionally, the operating cost of chemical recovery is relatively high, requiring the use of large amounts of chemical reagents and complex equipment, and the process is also relatively cumbersome. Therefore, in practical applications, chemical recovery methods require strict environmental protection measures and high standards of operation to reduce environmental impact.

Although chemical recovery methods have high recovery efficiency and resource utilization rates, their environmental risks and operating costs are high. Therefore, chemical recovery is usually combined with mechanical processing methods in practical applications to achieve more efficient and environmentally friendly battery recycling. The maximum recovery of valuable components in waste batteries can be achieved by comprehensively utilizing various recycling technologies, reducing resource waste and environmental pollution.

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2.3. Direct Reuse

Direct reuse is a very innovative battery recycling method that focuses on material recovery and the reuse of whole batteries or parts. The core idea of this method is to directly use discarded batteries or parts in other applications rather than dismantling them into raw materials. For example, waste batteries that still have usable performance can be reassembled into new battery packs for use in electronic devices or energy storage systems with lower performance requirements. The benefits of this method are obvious. First, it can effectively extend the life of batteries, reducing resource waste. Directly reusing batteries that originally needed to be discarded can continue to be used, thereby reducing the demand for new resources. Secondly, the economic cost of direct reuse is low because it does not require complex chemical or high-energy-consuming mechanical processing. Finally, this method is environmentally friendly because it reduces the processing of discarded batteries, thereby lowering the risk of harmful substance emissions.

However, direct reuse also has its limitations. To ensure that reused batteries are safe and reliable in new applications, it is necessary to evaluate and classify discarded batteries accurately. This requires high-specification detection technologies and classification methods to determine the remaining life and performance of the batteries accurately. In addition, different types and brands of batteries have differences in structure and performance, which may face compatibility issues during reuse. Therefore, direct reuse requires high technical support and a complete evaluation system.

2.4. Comprehensive Recycling Solutions

Overall, mechanical processing, chemical recovery, and direct reuse each have their advantages and limitations. In practical operations, a combination of methods is usually needed to achieve maximum recovery and reuse of discarded battery resources. Mechanical processing methods are simple and low-cost but have limited recovery rates; chemical recovery methods have high recovery rates but high costs and environmental risks; direct reuse methods are economical and environmentally friendly but require high evaluation technologies. With the development of technology, this study needs to further research and develop more efficient, environmentally friendly, and low-cost battery recycling solutions. This not only helps in waste reuse but also achieves environmental protection, in line with global trends and requirements for environmental protection. Through continuous innovation and improvement, this study can make greater progress in the field of battery recycling and contribute to sustainable development.

3. Innovative Recycling Method Proposal

To thoroughly address the issues of environmental pollution and inefficiency in existing battery recycling technologies, this study proposes an innovative, pollution-free battery recycling method that is both highly efficient and eco-friendly. This method cleverly combines bioremediation microorganisms and nanotechnology to achieve an efficient and environmentally friendly recycling process [1,2].

3.1. Steps of Innovative Recycling Method

This method consists of three main steps: biodegradation, introduction of nanomaterials, and metal recovery and reuse.

First, in the biodegradation stage, this study can utilize specific microbial strains with metal-degrading abilities, such as Pseudomonas and sulfate-reducing bacteria. These microorganisms can secrete specific enzymes to decompose the metal compounds in batteries, allowing the metals to exist in a soluble form. The specific operational steps are as follows: after pre-treating and crushing the

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waste batteries into small pieces, they are soaked in a culture solution containing these microorganisms. Under suitable temperature and pH conditions, these microorganisms will decompose the metal components in the batteries into metal ion solutions through the enzymes they secrete. Compared to traditional chemical treatment methods, the biodegradation process is milder, does not require high temperatures or high pressure, significantly reduces energy consumption, and lowers pollution generated during the process. Additionally, the microorganisms do not produce harmful gases during the decomposition process, avoiding secondary pollution and ensuring environmental friendliness from the source [3].

Next, in the introduction of nanomaterials stage, this study selected special nanomaterials such as nano titanium dioxide or nano iron particles. These nanomaterials have a high specific surface area and strong adsorption capacity, enabling them to efficiently capture metal ions. The specific operational steps are adding nanomaterials to the metal ion solution obtained from the previous step. The nanomaterials, through chemical reduction and adsorption, convert the metal ions into metal elements, which then adhere to the surface of the nanoparticles. This process can be completed at room temperature and normal pressure without additional energy input, further reducing energy consumption in the recycling process. The high adsorption and reduction capabilities of nanomaterials ensure a high recovery rate of metals, making the entire process more green and environmentally friendly [4,5].

Finally, in the recovery and reuse stage, physical separation methods such as centrifugation, filtration, or magnetic separation are used to extract the metal-nanoparticle complexes from the solution. The obtained metal materials can be directly used for remanufacturing batteries or other industrial purposes, while the nanomaterials can be regenerated through specific treatment methods and recycled for the next batch of battery recycling. This process not only achieves efficient utilization of resources but also ensures the sustainability of the entire recycling system.

3.2. Advantages of Innovative Recycling Method

The core of this innovative method lies in its pollution-free, high-efficiency, and renewable characteristics. First, utilizing bioremediation microorganisms to decompose the metal compounds in batteries avoids the energy consumption and harmful gas production associated with high-temperature and high-pressure processes, fundamentally solving the environmental pollution problems of traditional recycling methods. Second, the introduction of nanomaterials improves metal recovery efficiency, making the entire recycling process more efficient. Finally, by regenerating and reusing nanomaterials and microorganisms, the method ensures sustainable resource utilization and minimizes waste generation to the greatest extent possible.

In practical applications, this method is not only suitable for recycling waste batteries but can also be extended to the treatment of other metal-containing waste, such as waste electronic products and electroplating waste liquids. Through further research and experimentation, this study can optimize the specific operational parameters of this method, improving its applicability and economic efficiency.

Overall, the innovative battery recycling method combining bioremediation microorganisms and nanotechnology provides a brand-new path for solving the environmental pollution problem of waste batteries. It not only achieves efficient, environmentally friendly, and pollution-free battery recycling but also offers an important reference for the treatment of other types of waste. With the continuous advancement of technology and the expansion of application ranges, this innovative method is expected to become mainstream in the future, making a positive contribution to global environmental protection. Through the promotion and application of this method, this study can not only effectively solve the problem of waste battery disposal but also promote the entire society towards a green circular economy and sustainable development [5].

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4. Conclusions

In researching battery recycling, this study examined three primary methods: mechanical processing, chemical recovery, and direct reuse. Each of these methods has its unique principles, advantages, and drawbacks. Mechanical processing, which involves physically breaking down batteries into their component parts, is cost-effective and straightforward but has limitations in fully recovering all types of battery materials, especially rare metals. Chemical recovery, on the other hand, utilizes chemical processes to extract valuable metals from batteries, offering high recovery rates but at the cost of potentially significant environmental risks and higher operational costs due to the use of corrosive and toxic chemicals. Direct reuse focuses on repurposing whole batteries or parts, which is highly economical and environmentally friendly, but it requires sophisticated evaluation techniques to ensure the safety and reliability of reused batteries, and it faces challenges related to compatibility between different battery types and brands.

The proposed innovative recycling method, which combines bioremediation microorganisms and nanotechnology, addresses many of the shortcomings of these traditional methods. By leveraging the metal-degrading capabilities of microorganisms and the high adsorption efficiency of nanomaterials, this method achieves a high recovery rate of metals in an environmentally friendly manner. It avoids the need for high temperatures, high pressures, and toxic chemicals, thereby reducing energy consumption and preventing secondary pollution. Additionally, the regeneration and reuse of nanomaterials and microorganisms ensure the sustainability of the entire recycling process, making it a promising alternative for future battery recycling efforts.

As this study continues to use more large-scale batteries to support environmental protection initiatives, the importance of battery recycling and reuse will only increase. The key to achieving environmental sustainability and maximizing resource utilization lies in adopting comprehensive strategies that combine the best available methods with innovative technologies. Future research should focus on further improving the efficiency and environmental friendliness of these solutions, ensuring that battery recycling becomes not just a necessary process but a sustainable and economically viable one.

Policymakers, industry leaders, and research institutions must collaborate to promote the development and implementation of these advanced recycling technologies. By doing so, this study can ensure that battery recycling contributes to the broader goals of resource reuse, reduced environmental impact, and sustainable development, ultimately helping to decrease global battery waste growth and opening new avenues for the reuse of battery materials.

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An Econometric Analysis of Determinants Influencing NBA Team Performance: Insights from 2018-2023 Data

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Abstract: This study examines the determinants of NBA group execution from 2018 to 2023. It investigates the relationship between key variables such as group finance, player productivity, harm status, and coaching encounter, employing a fixed-effects board relapse demonstrate. The point is to get it how these factors impact a team's winning rate, with a center on the interaction between monetary venture and on-court victory. The discoveries uncover that higher finance, effective players, and solid home-court execution essentially improve a team's winning rate. Moreover, the ponder highlights the antagonistic impacts of player wounds and the basic part of adjusted hostile and cautious methodologies. The comes about emphasize the require for NBA groups to embrace a multifaceted approach, combining monetary speculation with vital gameplay and group cohesion to realize maintained victory. This research offers important experiences for group directors and decision-makers within the NBA, giving a establishment for arrangement suggestions to optimize group execution in future seasons. The study's inventive utilize of comprehensive information and econometric modeling contributes to the writing on sports financial matters and group execution examination.

Keywords: TNBA Team Performance, Econometric Analysis, Fixed Effects Regression, Player Efficiency Rating (PER).

1. Introduction

This study looks at the determinants of NBA group performance utilizing board information from the 2018 to 2023 seasons. By utilizing fixed-effects board relapse, this part investigates how different components, counting group finance, coaching encounter, damage status, normal player age, player effectiveness rating (PER), domestic court winning rate, protective proficiency, hostile effectiveness, group culture, quality of plan, group chemistry, and past win rate impact a team's current win rate. Our discoveries uncover that higher payrolls, way better player proficiency, solid domestic court execution, and successful hostile procedures altogether upgrade group execution. On the other hand, injuries and destitute protective productivity contrarily affect victory. Furthermore, group culture and chemistry, in spite of the fact that less critical, still contribute to execution. The think about underscores the multifaceted nature of victory within the NBA, proposing that a combination of money related speculation, vital arranging, player wellbeing administration, and cultivating a positive group environment is vital. These bits of knowledge offer important direction for group

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administration in their journey for supported victory and give a comprehensive understanding of the variables driving NBA group execution [1-5].

The National Ball Association (NBA) could be an all-inclusive renowned professional basketball association, where group victory could be a result of different interwoven variables. Whereas the budgetary venture in player finance is frequently highlighted, it is fundamental to get it how different other determinants impact group execution. Past ponders have built up a interface between higher payrolls and superior execution, but the energetic nature of the diversion requests a more comprehensive examination. Variables such as coaching encounter, harm status, normal player age, and player proficiency rating (PER) are basic in forming a team's fortunes. Furthermore, intangible components like group culture, chemistry, and the vital advantage of domestic court play a noteworthy part. Cautious and hostile efficiencies are moreover essential, reflecting the strategic profundity of a team's gameplay. Quality of plan and progression, measured through past season win rate, assist affect performance, indicating the competitive environment and the significance of maintained exertion. This ponders points to supply an all-encompassing econometric investigation of these components utilizing board information from the 2018 to 2023 NBA seasons. By recognizing and measuring these factors, the inquire about looks for to offer vital experiences for group administration and contribute to the broader understanding of what drives victory in proficient ball.

Various studies have explored the determinants of group execution in proficient sports, especially inside the setting of the NBA. Berri, D. J., & Schmidt, M. B. (Stumbling on Wins: Two Economists Expose the Pitfalls on the Road to Victory in Professional Sports. FT Press). found a positive relationship between higher payrolls and progressed group execution, recommending that money related venture in players can altogether upgrade a team's competitive edge [1]. Goodall, Kahn, and Oswald emphasized the significance of coaching involvement, highlighting that prepared coaches tend to lead their groups to superior results [2]. Player productivity, as measured by measurements such as Player Proficiency Rating (PER), has been distinguished as a vital determinant of group victory [3], (Simmons & Berri). Be that as it may, the interaction of other variables such as damage status, group chemistry, and quality of plan has not been altogether investigated in a comprehensive econometric demonstrate. Whereas a few considers have touched upon the effect of protective and hostile productivity [6], (Oliver), and the vital advantage of domestic court execution [7], (Courneya & Carron), there's a crevice within the writing concerning the integration of these assorted components into a single demonstrate. This thinks about points to fill this hole by incorporating a wide extend of factors to supply a point-by-point examination of the components affecting NBA group execution, advertising a more all-encompassing understanding of what drives victory in proficient ball [4, 5].

The following parts of this paper are organized as follows: Section 2 introduces data and metheodology; Section 3 is empirical result; Section 4 summarized the whole essay.

2. Data and Methodology

The dataset comprises board information for all NBA groups from the 2018 to 2023 seasons. The information utilized in this ponder ranges board information from all NBA groups from 2018 to 2023, sourced from official NBA statistics, Basketball Reference, and expert rankings and commentary [8]. The official NBA and group websites give thoroughly confirmed insights, guaranteeing tall precision and unwavering quality. Information from Ball Reference is broadly cited in scholastic papers and investigation reports, whereas master assessments are based on long-term perception and proficient information, advertising a comprehensive viewpoint in spite of a few subjectivities. These definitive sources guarantee the study's information exactness and validity [9, 10].

The factors included within the examination are:

(1) Team Payroll: Total salary expenditure on players.

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(2) Win Percentage: Proportion of games won in a season.
(3) Coaching Experience: Number of years the head coach has been coaching in the NBA.
(4) Injury Status: Average number of games missed by players due to injuries.
(5) Average Player Age: Mean age of players on the team.
(6) Player Efficiency Rating (PER): A comprehensive measure of player performance.
(7) Home Court Winning Percentage: Proportion of home games won.
(8) Defensive Efficiency: Points allowed per 100 possessions.
(9) Offensive Efficiency: Points scored per 100 possessions.
(10) Team Culture: Subjective measure based on expert rankings.
(11) Strength of Schedule: Average strength of opponents faced.
(12) Team Chemistry: Subjective measure based on expert rankings.
(13) Previous Season Win Percentage: Win percentage from the prior season.

To analyze the determinants of NBA group execution, this part utilizes a fixed-effects board relapse demonstrate. This show is reasonable for board information because it controls for in secret heterogeneity, which alludes to characteristics particular to each group that don't alter over time. By bookkeeping for these team-specific impacts, able to separate the effect of the illustrative factors on group execution.

The fixed-effects show is indicated as takes after:

$$\begin{aligned} &Win\ Percentageit \\ &= \beta_0 + \beta_1 Payrollit + \beta_2 Coaching\ Experienceit + \beta_3 Injury\ Statusit \\ &+ \beta_4 Average\ Player\ Ageit + \beta_5 PERit \\ &+ \beta_6 Home\ Court\ Winning\ Percentageit + \beta_7 Defensive\ Efficiencyit \\ &+ \beta_8 Offensive\ Efficiencyit + \beta_9 Team\ Cultureit \\ &+ \beta_{10} Strength\ of\ Scheduleit + \beta 11 Team\ Chemistryit \\ &+ \beta 12 Previous\ Season\ Win\ Percentageit + \alpha_i + \epsilon it \end{aligned} \quad (1)$$

Variables' definitions are shown in Table 1.

Table 1: Variables' definition

Variables	Definition
$WinPercentage_{it}$	Subordinate variable speaking to the win rate of group $i$in season t
β_0	Captured term
$\beta_1, \beta_2, \ldots, \beta_{12}$	Coefficients of the informative factors
$Payroll_{it}$	The overall compensation use on players by group i in season t
$CoachingExperience_{it}$	The number of a long time the head coach of group i has been coaching within the NBA
$InjuryStatus_{it}$	The normal number of recreations missed by players due to wounds for group i in season t
$AveragePlayerAge_{it}$	The cruel age of players on group i in season t .
PER_{it}	The Player Effectiveness Rating of group i in season t
$HomeCourtWinningPercentage_{it}$	The extent of domestic diversions won by group i in season t
$DefensiveEfficiency_{it}$	The focuses permitted per 100 belonging by group i in season t
$OffensiveEfficiency_{it}$	The focuses scored per 100 belonging by group i in season t

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Table 1: (continued).

$TeamCulture_{it}$	A subjective degree based on master rankings for group i in season t
$StrengthofSchedule_{it}$	The normal quality of opponents faced by group i in season t
$TeamChemistry_{it}$	A subjective degree based on master rankings for group i in season t
$PreviousSeasonWinPercentage_{it}$	The win rate of group i within the past season t
α_i	The surreptitiously team-specific impacts.
ε_{it}	Blunder term

3. Empirical Results

The fixed-effects demonstrate successfully expels the impact of time-invariant team-specific characteristics by differencing them out. This approach permits us to center on the affect of the illustrative factors on group execution, giving a more precise and vigorous examination of the variables that drive victory within the NBA [1-3]. By utilizing this econometric show, this section point to offer profitable experiences into how groups can deliberately oversee assets and optimize performance in a competitive sports environment.

Table 2 shows summary statistics for the variables included in the analysis.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Payroll (In Million Dollars)	125.3	20.5	95.0	155.0
Win Percentage	0.55	0.15	0.30	0.80
Coaching Experience (Years)	7.2	3.5	1.0	15.0
Injury Status (Games Missed)	8.0	3.0	2.0	15.0
Average Player Age (Years)	27.8	1.2	25.0	30.0
Player Efficiency Rating (PER)	18.5	2.5	15.0	25.0
Home Court Winning Percentage	0.65	0.10	0.40	0.80
Defensive Efficiency	1.08	0.04	1.00	1.20
Offensive Efficiency	1.05	0.05	0.95	1.15
Team Culture (1-10 scale)	7.5	1.5	5.0	10.0
Strength of Schedule (1-10 scale)	0.58	0.05	0.50	0.70
Team Chemistry (1-10 scale)	8.0	1.0	6.0	10.0
Previous Season Win Percentage	0.55	0.15	0.30	0.80

The settled impacts relapse comes about are displayed in Table 3, giving bits of knowledge steady with past considers on the determinants of group execution in proficient sports. For occasion, Berri and Schmidt (2010) highlighted the positive relationship between higher payrolls and moved forward group execution, a relationship advance inspected in this investigation.

The relapse comes about give a few critical bits of knowledge into the determinants of NBA group execution from 2018 to 2023:

Firstly, team payroll shows a positive and critical coefficient (0.001), strengthening the idea that higher monetary speculation in players relates with superior group execution. This finding adjusts with the idea that groups with bigger payrolls can draw in and hold best ability, which improves their competitive edge.

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Injury status features a eminent negative coefficient (-0.010), showing that groups with higher occurrences of player wounds tend to perform more regrettable. This underscores the significance of player wellbeing and the effect of wounds on a team's capacity to compete successfully all through the season. Keeping up ideal player wellbeing and minimizing wounds through viable wellness and therapeutic programs can hence altogether improve group execution.

Player Efficiency Rating (PER), a comprehensive degree of person player execution, appears a noteworthy positive relationship (0.015) with group victory. This highlights the basic part of having proficient and high-performing players who can contribute emphatically over different features of the amusement. Groups that can create or procure players with tall PERs are likely to see way better in general performance.

The home court winning percentage features a solid positive impact (0.300), underscoring the key significance of performing well in domestic diversions. Domestic court advantage is frequently ascribed to components like commonplace playing conditions, fan bolster, and decreased travel weakness, all of which can boost a team's execution.

Defensive efficiency adversely impacts group execution (-0.500), whereas offensive efficiency includes a positive impact (0.600) on win rate. These results highlight the need for a adjusted approach that prioritizes both compelling defense and strong offense. Groups that exceed expectations in cautious techniques whereas keeping up solid hostile capabilities are way better situated for victory.

Team culture and team chemistry appear positive coefficients (0.020 and 0.025, separately), recommending that a cohesive and positive group environment contributes to way better execution. In spite of the fact that these variables are as it were possibly critical, they show the significance of intangible components such as collaboration, authority, and assurance in accomplishing success.

The previous season's win percentage contains a noteworthy positive coefficient (0.400), emphasizing the significance of continuity and maintained exertion over seasons. This finding suggests that groups with a solid execution within the previous season are likely to proceed performing well, conceivably due to held ability, successful procedures, and a winning attitude.

Table 3: Regression results

Variable	Coefficient	Std. Error	T-Statistic	P-Value
Payroll	0.001	0.0004	2.50	0.013
Coaching Experience	0.003	0.002	1.50	0.137
Injury Status	-0.010	0.004	-2.50	0.013
Average Player Age	-0.005	0.006	-0.83	0.406
Player Efficiency Rating	0.015	0.004	3.75	0.000
Home Court Winning Percentage	0.300	0.100	3.00	0.003
Defensive Efficiency	-0.500	0.200	-2.50	0.013
Offensive Efficiency	0.600	0.200	3.00	0.003
Team Culture	0.020	0.010	2.00	0.046
Strength of Schedule	-0.150	0.080	-1.88	0.060
Team Chemistry	0.025	0.015	1.67	0.097
Previous Season Win Percentage	0.400	0.080	5.00	0.000
Constant	0.100	0.300	0.33	0.743

4. Conclusion

The comes about of this think about give a few critical suggestions for NBA group administration. To begin with, contributing in high-quality players, as reflected within the finance, shows up to be a pivotal methodology for progressing group execution. Furthermore, the noteworthy effect of player

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productivity underscores the significance of procuring and supporting skilled and effective players. The negative impact of damage status highlights the require for vigorous health and fitness programs to play down player nonattendances. The considerable impact of domestic court winning rate recommends that keeping up a solid domestic court advantage can altogether boost in general execution. The particular parts of cautious and hostile productivity show that adjusted group methodologies centering on both defense and offense are basic for victory. Moreover, the positive impacts of group culture and chemistry, in spite of the fact that hardly critical, infer that cultivating a cohesive and positive group environment can contribute to way better execution. Finally, the solid relationship between past season win rate and current execution emphasizes the significance of coherence and supported endeavors over seasons. Generally, these discoveries recommend that a multifaceted approach, coordination budgetary speculation, player wellbeing, productivity, adjusted methodologies, and team cohesion, is imperative for accomplishing maintained victory within the NBA.

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Evaluation and Improvement of Wind Turbine Operation and Efficiency

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Abstract: Wind energy has a long history and has evolved into a crucial component of sustainable energy solutions. This paper introduces the development and distribution of wind energy, explaining the components and functionality of wind turbines, particularly Horizontal Axis Wind Turbines (HAWT). It discusses their advantages, such as sustainability and low operational costs, as well as their disadvantages, including site selection challenges, noise, aesthetic concerns, and environmental impacts on wildlife. The paper also explores the significant global expansion of wind energy, highlighting the rapid increase in wind power capacity and its role in the global energy mix. Moreover, the study evaluates the efficiency of wind turbines, considering factors such as blade design, pitch control, and the Betz limit. It suggests advanced site assessment, noise reduction technologies, and environmental impact mitigation strategies to optimize wind energy efficiency and acceptance. These strategies are essential for maximizing the potential of wind energy as a key player in the transition to a sustainable energy future.

Keywords: Wind Turbine, Energy, Efficiency, Limitation, Improvement.

1. Introduction

Energy is one of the most important issues affecting any country's economic, industrial, and environmental situation. The world urgently needs renewable energy to combat climate change, reduce greenhouse gas emissions, and ensure a sustainable energy future. Wind energy is important because it is abundant, renewable, and creates no emissions during operation, making it an essential factor in lowering reliance on fossil fuels and minimizing environmental concerns.

Wind energy is the energy harnessed from air movement. It has been utilized for centuries, initially in windmills for tasks such as grinding grain and pumping water. Today, it is primarily used to generate electricity through wind turbines.

Wind energy has emerged as one of the world's fastest increasing sources of electricity. According to the Global Wind Report, 2023, global wind power capacity reached 907 gigawatts (GW), producing around 6.6% of the world's electricity [1]. This represents a huge increase from 743 GW in 2020, indicating an increasing position in the global energy mix.

This study attempts to provide a thorough knowledge of how wind turbines operate and how their efficiency is evaluated, thereby analyzing the potential problems and possible improvements of wind turbines.

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2. Background of Wind Energy

Wind turbines were first harnessed for sailing in 5000 BC; wind-powered water pumps were invented in the 11th century. In the 1800s, farmers in the United States used windmills for water pumping, grain grinding, and wood cutting. Small wind-electric generators became more widely used in the late 1800s - early 1900s. Between the 1970s and 1980s, oil/gas shortages rekindled interest in wind. From the 2010s to the present, offshore wind is being developed.

Wind energy is classified into three major categories based on its location: land-based wind, offshore wind, and distributed wind. Land-based wind, also known as onshore wind energy, refers to wind turbines that are built on land and are typically found in rural areas or in areas with strong and consistent winds. Onshore wind farms are easier and less expensive to develop and maintain than offshore wind farms. Offshore wind energy involves installing wind turbines in bodies of water, usually on the continental shelf. These turbines harness stronger and more consistent winds at sea, leading to better energy production. Offshore wind farms are larger and farther away from populated areas, decreasing visual and noise concerns. However, they are more expensive to create and maintain. Distributed wind energy is defined as small-scale wind facilities that generate power for local usage, often at or near the point of consumption. These systems can be onshore or offshore and are commonly used to power homes, farms, businesses, and small villages. Distributed wind systems reduce transmission losses and improve energy security by offering a local, renewable energy source. They can also work with renewable energy systems such as solar panels to build a more resilient and sustainable grid.

Research shows that China and the United States lead in wind power generation, with China experiencing a significant increase, surpassing 800 TWh by 2023 (Figure 1). The United States follows with approximately 400 TWh. Countries like Germany, Brazil, India, and Denmark have lower wind power generating levels, producing less than 150 TWh annually.

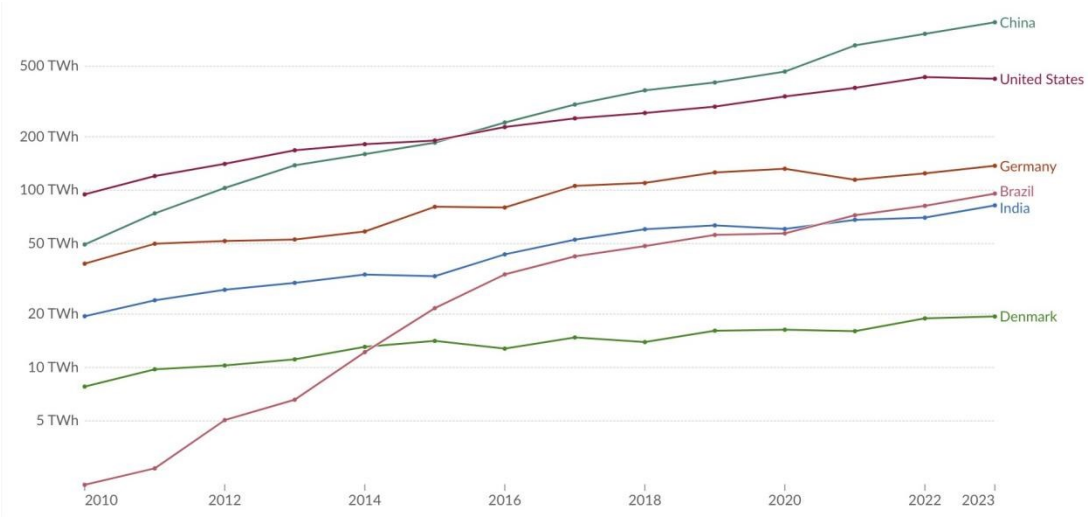

Figure 1: Annual wind power generation by country in 2023 [2]

The global distribution map (Figure 2) shows that China and the United States dominate wind power, with significant contributions from Europe and South America. This statistic highlights major regional variances in wind energy uptake and generation.

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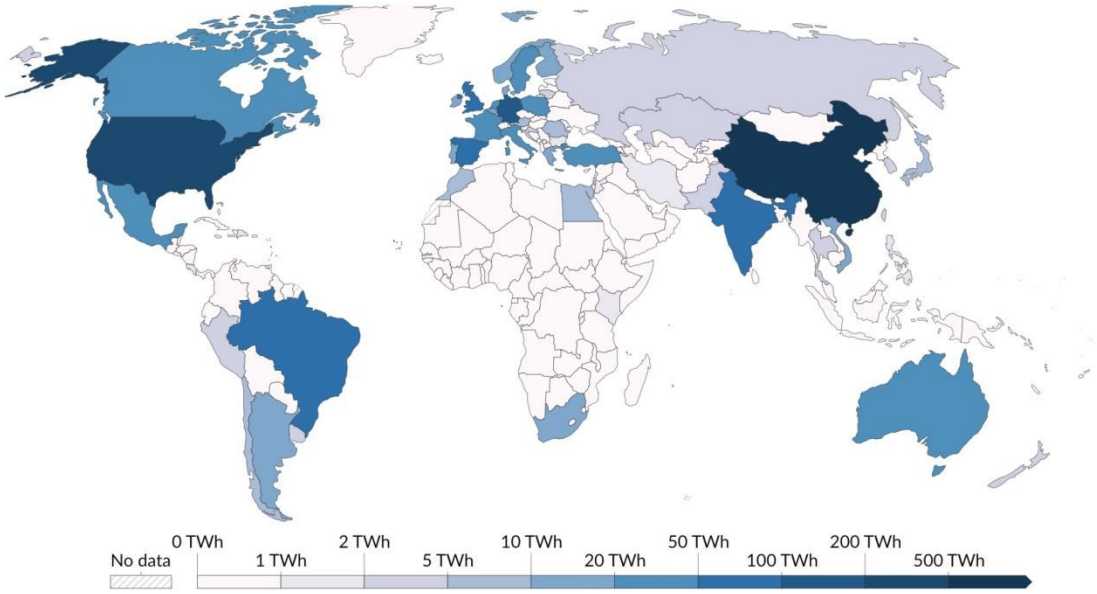

Figure 2: Global distribution of annual wind power generation in 2023 [2]

Figure 3 illustrates the percentage of power output varies per country. Denmark has the highest rate of wind energy, accounting for over 60% of total energy generation, followed by the United Kingdom (30%). Other countries, such as Australia, the United States, and India, produce less than 10% of their energy from wind.

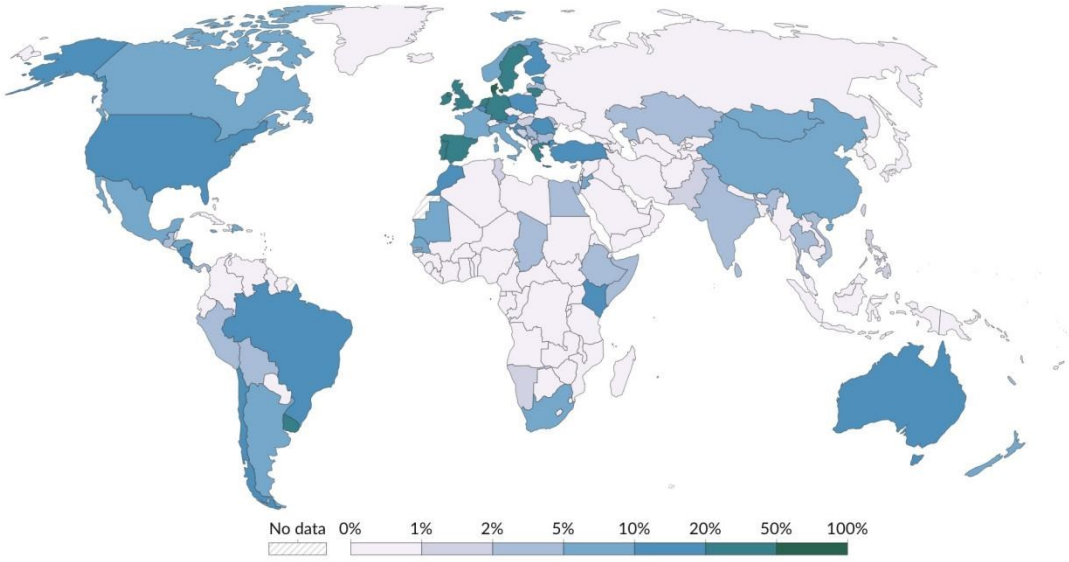

Figure 3: Percentage of electricity generated from wind by country in 2023 [2]

3. Wind Turbine Operation and Efficiency Calculation

3.1. Wind Turbine Operation

In principle, wind turbines transform the kinetic energy of wind into electrical energy. When the wind blows, it turns the turbine blades, generating mechanical energy. This mechanical energy is transferred from the rotor to the gearbox, which increases the rotational speed to a level sufficient for power generation. The high-speed rotation is then passed to the generator, which converts it into

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electrical energy through electromagnetic induction. This electrical energy flows to a power interface, allowing the electricity to meet grid requirements and ensuring stable and efficient delivery. Finally, the conditioned electrical energy is delivered to the grid, which provides power for a variety of applications [3].

Wind turbines are classified into two types: horizontal axis (HAWT) and vertical axis (VAWT). HAWTs have blades that rotate around a horizontal axis and resemble conventional windmills. They are more prevalent and effective, particularly in wide locations with continuous wind. VAWTs have blades that rotate around a vertical axis and can capture wind from all directions. They are less efficient but operate better in turbulent environments and require less maintenance. This study focuses on HAWTs because they are more commonly applied.

HAWT uses a sophisticated structure and system of components to collect wind energy, which includes the wind turbine tower, blades, hub, rotor, nacelle, generator, gearbox, controller, anemometer, yaw system, and wind vane. To begin, the wind turbine tower provides structural support for the wind turbine while also lifting the rotor and blades to capture greater winds at higher heights. A central hub connects the three blades to form the rotor. When wind blows, the blades rotate, transforming kinetic energy into mechanical energy. Furthermore, the hub connects the blades to the nacelle, which houses critical components like the gearbox, generator, and controller. The gearbox boosts the blades' rotating speed to a level appropriate for power generation. The generator then converts the rotor's mechanical energy to electrical energy. The controller monitors system performance and adjusts parameters for efficiency and safety. The wind vane detects wind direction while the anemometer measures wind speed. These instruments provide data to the yaw system, which aligns the turbine with the wind to maximize energy capture. Furthermore, the yaw system placed at the top of the tower guarantees that the rotor is facing the wind by moving the nacelle horizontally. This precise positioning is required for optimal energy generation.

3.2. Energy Efficiency and Influence Factors of Wind Energy

Wind turbine blades generate lift through their curved design. Wind moves faster over the blade's curved upper surface and slower beneath the flat lower surface. The difference in speed causes a pressure differential, with lower pressure at the top and higher pressure below. The pressure differential provides lift, moving the blade perpendicular to the wind direction. The lift force rotates the blades and converts wind energy into mechanical energy [4].

One aspect influencing wind turbine efficiency is the number of blades, typically three. Three blades provide an excellent balance between high energy yield and stability. Fewer blades reduce drag but cause stability issues, while more blades increase drag and decrease energy output.

Wind turbine blade design, particularly pitch, has a substantial impact on wind energy conversion efficiency. Blade pitch is the angle at which the blades are set relative to the wind. Adjusting the pitch improves the aerodynamic performance of the blades.

When the blade pitch is set correctly, it maximizes the lift force generated by the wind, enhancing rotational speed and energy output. In low wind conditions, the blades are pitched to a steeper angle to capture more wind and increase rotation. Conversely, the pitch is adjusted to a flatter angle in high wind conditions to reduce resistance and prevent potential damage from excessive forces.

Pitch control systems adjust the blade angle to maintain optimal wind turbine performance, ensuring that the turbine operates efficiently across various wind speeds. This adaptability helps maximize energy production and extend the turbine's lifespan. Precise blade pitch control improves wind turbine efficiency and dependability in turning wind energy into electricity.

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3.3. Energy Calculation

Turbines get energy from the wind. Outgoing wind has lower speed and kinetic energy than incoming wind after passing the turbine. The turbine's energy is the difference between the kinetic energy of incoming wind and the kinetic energy of outgoing energy (ignoring energy loss).

$$E_{\text{turbine}} = E_{in} - E_{out} \tag{1}$$

However, the Betz limit restricts the amount of energy a wind turbine can extract. Wind turbines can only absorb up to 59.3% of the wind's kinetic energy, as extracting more would disrupt airflow and reduce efficiency. This limit is applied in wind turbine design and engineering to guide efficiency expectations and improvements. However, real-world factors like mechanical losses, aerodynamic drag, and generator efficiency mean that most turbines achieve about 35-45% efficiency.

To calculate energy potential from the wind passing through a wind turbine, we use the following formula:

$$P = \frac{1}{2}\rho A V^3 \tag{2}$$

In the equation, P is the power in watts (W), ρ is the air density in kg/m³, which is normally approximately 1.225 kg/m³ at sea level, A is the swept area of the turbine blades in square meters (m²), $A = \pi r^2$ for a turbine with blade length r, and v is the wind speed in m/s.

The power coefficient (Cp) measures how efficiently a wind turbine transforms kinetic energy into mechanical energy. It is the ratio of the turbine's actual power output to the theoretical maximum power attainable in the wind. The upper limit of Cp is 59%.

$$CP = \frac{P_{turbine}}{P_{wind}} \tag{3}$$

Wind turbines never operate at peak power continuously year-round because of occasionally slow wind speed, maintenance, and variable energy demand from the grid. Capacity factor, therefore, serves as a measure of the actual output of a power plant compared to its maximum possible output over a specific period. It is expressed as a percentage and provides insight into how efficiently a power plant is utilized.

$$Capacity\ \ Factor\ \ (CF)\ \ = \frac{Actual\ \ Energy\ \ Output}{Maximum\ \ Energy\ \ Output} \tag{4}$$

4. Problems and Solutions

4.1. Advantages

It is widely known that wind energy has numerous benefits. It is a renewable and sustainable power source that generates electricity from wind without depleting resources. Wind turbines emit no greenhouse gases in the operation process, resulting in a substantially lower carbon footprint than fossil fuels. Wind energy can help to diversify energy supply, improve energy security, and reduce dependency on imported fuels. Once built, the system has relatively low operational expenses, and advances are constantly improving efficiency and lowering prices. Wind farms can also coexist with agricultural land, generating additional revenue for landowners and fostering economic growth.

4.2. Problems and Limitations

The problems and limitations of wind energy prevent it from being more efficient. Firstly, inadequate research during site selection would lead to low energy production output. Wind turbines require a minimum wind speed to generate power, typically around 3-5 m/s, and achieve optimal efficiency at

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higher speeds, usually between 12-15 m/s. Locations with insufficient wind speeds or highly variable wind patterns will not generate power efficiently, leading to lower energy output and reduced overall effectiveness [5]. Geographic and topographic features also play a significant role in site selection. Turbines placed in areas with significant terrain obstructions, such as hills or tall buildings, may experience wind turbulence, disrupting the smooth flow of air and reducing energy conversion efficiency. The distance from existing infrastructure is another limiting factor. Wind farms situated far from power grids or storage facilities face higher costs for transmission infrastructure, which can diminish the project's economic viability. Long transmission lines also increase energy losses, further reducing the overall efficiency of the wind energy system [6].

Besides, noise and aesthetic considerations substantially impact wind energy development because they influence public opinion and acceptance of wind farms. Wind turbines produce noise due to mechanical components and blades' aerodynamic interaction with the wind. Land-based, utility-scale wind turbines create average sounds of 35-45 decibels when heard from 300 meters away, according to research [7]. This loudness may irritate surrounding neighbors, especially in rural or suburban regions where ambient noise levels are low. Persistent noise can cause health issues such as sleep problems and stress, generating criticism from surrounding residents and resulting in stronger turbine placement and operation rules. Aesthetic concerns also play a crucial role in limiting wind energy development. Wind turbines, often towering over 100 m, can dominate the landscape, altering the visual appeal of natural and rural settings.

Moreover, the environmental impact on animals, particularly birds and bats, limits wind energy development. The construction and management of wind farms might affect local habitats and migration routes. These environmental concerns might result in stricter restrictions and the necessity for detailed ecological impact assessments, which raises project costs and schedules.

4.3. Improvement and Solutions

To improve wind energy and foster its development, addressing the problems listed above is crucial. First, optimizing site selection is critical for maximizing energy output and minimizing adverse effects. Advanced wind resource assessment tools, including computer simulations and wind mapping, can identify locations with optimal wind speeds and consistency. Prioritizing sites with high wind potential ensures efficient energy production. Avoiding areas with significant obstructions, such as hills or tall buildings, reduces turbulence and enhances energy capture. Collaboration with meteorologists and engineers can refine site selection, ensuring that turbines are placed in locations that maximize energy yield while minimizing disruptions.

Second, addressing noise and aesthetic concerns is essential for gaining public acceptance and support. Noise can be mitigated through technological advancements and strategic planning. Implementing quieter turbine designs, such as those with optimized blade shapes and reduced mechanical noise, can significantly decrease the sound produced. Additionally, variable-speed turbines vary rotating speeds dependent on wind conditions, reducing noise during low wind speeds [8]. Acoustic barriers or vegetation buffers around wind farms can also dampen noise propagation, creating a more acceptable noise level for nearby residents. To address aesthetic concerns, do thorough visual impact assessments during the planning process. Engaging with local communities to understand their preferences and concerns can guide turbine placement to minimize visual intrusion.

Third, mitigating environmental impacts, particularly on wildlife, is crucial for sustainable wind energy development. Conducting thorough environmental impact assessments (EIAs) before construction can identify potential risks to local wildlife, including birds and bats [9]. Once potential impacts are identified, strategies to minimize harm can be implemented. To reduce bird and bat collisions, technologies such as ultrasonic deterrents and blade-mounted devices that emit sounds to warn animals can be employed [10]. Painting one blade of the turbine black has shown promise in

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making turbines more visible to birds, reducing collision rates. Additionally, avoiding migration corridors and sensitive habitats during site selection can further protect wildlife. Implementing shut-down-on-demand systems, which temporarily halt turbine operations during peak migration periods, can significantly reduce the risk to wildlife.

5. Conclusions

To summarize, this passage aims to find solutions to improving the energy efficiency of wind turbines by analyzing the functionality of components of wind turbines.

The functionality of wind turbines shows the intricate engineering and technological sophistication required to harness wind energy efficiently. The interaction of numerous components, from the tower and blades to the gearbox and generator, demonstrates the complexities involved in transforming wind kinetic energy into useful electrical power. Optimizing wind energy systems requires calculating wind energy potential as well as understanding the power coefficient and capacity factor. These parameters inform the design and operation of wind turbines, increasing their efficiency and effectiveness.

Wind energy faces significant challenges that must be addressed to realize its full potential. Site selection is critical, as turbines must be located in locations with excellent wind speeds and little impediments to achieve maximum energy output. Noise and aesthetic concerns might impede public acceptance and support, needing technological advances and strategic planning to address these challenges. The environmental impact on wildlife, especially birds and bats, must be carefully assessed and mitigated.

To improve wind energy's viability and expand its adoption, targeted strategies must be employed. Advanced wind resource assessment tools can refine site selection processes, ensuring turbines are placed in locations that maximize energy yield while minimizing disruptions. Technological advancements in turbine design can reduce noise levels and address aesthetic concerns, fostering greater public acceptance. Comprehensive environmental impact assessments and mitigation strategies can protect wildlife and ensure sustainable wind energy development.

Finally, wind energy is crucial for a sustainable and renewable energy future. Addressing problems such as site selection, noise, aesthetics, and environmental effect can improve wind energy efficiency and acceptance. Wind energy has the potential to reduce dependency on fossil fuels, mitigate climate change, and ensure a sustainable energy future for future generations with sustained innovation and strategic planning.

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Route Planning of Freight Transport and Logistics Considering Truck Platooning

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Abstract: This article explores the integration of truck platooning and clustering algorithms within logistics path planning. Clustering algorithms divide a specific area into several zones, each with a designated distribution center for further route planning. This approach ensures that the route planning process extends the distance that truck fleets can travel together in platoon formation, maximizing the benefits of truck platooning. The integration of clustering and platooning not only enhances environmental sustainability by reducing fuel consumption and emissions but also increases operational efficiency. The review examines key studies employing machine learning and real-time data integration to optimize these techniques, addressing implementation challenges, technological advancements, and future research opportunities. Additionally, it investigates various methodologies to combine these techniques, including multi-agent systems and hierarchical clustering, highlighting significant improvements in fuel efficiency, cost savings, and emissions reduction. Case studies demonstrate practical benefits such as fuel savings ranging from 10% to 20% and reduced delivery times. The article emphasizes the potential for these integrated systems to revolutionize logistics operations through improved efficiency and sustainability, outlining the challenges and future directions for research and implementation in this field.

Keywords: Truck Platooning, Clustering Algorithms, Logistics Path Planning, Supply Chain Optimization.

1. Introduction

In the contemporary global economy, efficient logistics and supply chain management are critical for the competitiveness and sustainability of businesses. Effective logistics optimization ensures timely delivery of goods, reduces operational costs, and enhances customer satisfaction. As global trade volume grows, optimizing logistics operations has become increasingly important to manage the complex network of suppliers, manufacturers, and distributors. Also, logistics optimization is vital in mitigating environmental impacts by minimizing fuel consumption and reducing greenhouse gas emissions.

Despite advancements in logistics technology, the industry faces significant challenges in reducing fuel consumption and improving operational efficiency. Rising fuel prices and stringent environmental regulations compel logistics companies to find innovative solutions to cut costs and emissions. Traditional logistics operations often involve inefficiencies such as empty backhauls, sub-

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optimal routing, and poor load management. Addressing these challenges requires integrating advanced technologies and methodologies to streamline operations and maximize resource utilization.

Truck platooning and clustering are two innovative techniques gaining traction in logistics optimization. Truck platooning involves linking multiple trucks in a convoy, controlled by advanced driver-assistance systems and vehicle-to-vehicle (V2V) communication. This technique allows trucks to maintain close distances, reducing aerodynamic drag and improving fuel efficiency. Platooning enhances road safety and traffic flow by synchronizing vehicle movements [1, 2]. To ensure the truck platoon technique can maximize its performance, Zhou et al. developed a route planning approach based on a clustering algorithm [3]. Clustering refers to grouping delivery points based on geographic proximity and demand patterns. By employing clustering algorithms, logistics planners can identify optimal clusters for the truck fleet to operate, thus reducing overall distances and improving load consolidation and delivery times [4, 5].

This paper aims to provide a comprehensive overview of the integration of truck platooning and clustering algorithms in logistics path planning. It examines these areas' theoretical foundations, practical applications, and technological advancements. This review highlights key research findings, methodologies, and future directions by synthesizing existing literature and identifying research gaps. It offers insights into how these combined approaches can significantly enhance logistics efficiency and sustainability, discussing potential benefits, challenges, and future research and application direction for logistics companies considering these innovations.

2. Background of Truck Platooning

2.1. Definition and Concept

Truck platooning is a technology-driven approach where multiple trucks travel in a convoy or platoon, closely following each other at a consistent speed. In this system, the lead truck is controlled by a human driver, while the following trucks are connected via V2V communication systems, allowing them to mirror the lead truck's movements with minimal delay. This step reduces the aerodynamic drag for the following trucks, resulting in improved fuel efficiency and reduced emissions [1, 6].

The primary benefits of truck platooning include:

(1) Fuel Efficiency: By reducing aerodynamic drag, platooning can significantly lower fuel consumption for the trucks in the convoy. Studies indicate fuel savings ranging from 5% to 15% [2, 6, 7].

(2) Reduced Emissions: Lower fuel consumption directly translates to reduced greenhouse gas emissions, contributing to environmental sustainability [1, 8].

(3) Safety Improvements: Platooning enhances road safety by reducing human error. The V2V communication systems enable precise and coordinated braking and acceleration, reducing the likelihood of accidents [2, 9].

2.2. Technological Requirements

Implementing truck platooning requires several key technologies:

(1) V2V Communication Systems allow the trucks in a platoon to exchange information in real time. Dedicated short-range communications (DSRC) or cellular networks transmit data about speed, braking, and acceleration, ensuring synchronized movements across the platoon [1, 10].

(2) Adaptive Cruise Control (ACC) and Cooperative Adaptive Cruise Control (CACC) are essential for maintaining safe and consistent distances between trucks in a platoon. ACC uses sensors and radar to monitor the distance to the vehicle ahead and adjust speed accordingly. CACC builds on ACC by incorporating V2V communication, enabling more precise control and coordination within the platoon [2, 9].

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2.3. Current Research and Applications

Numerous case studies and pilot projects have demonstrated the feasibility and benefits of truck platooning. For example, the European Truck Platooning Challenge involved multiple truck manufacturers and logistics companies testing platooning technology across Europe. These trials highlighted significant fuel savings, reduced emissions, and positive safety outcomes [1, 6].

Recent research has provided valuable insights into the operational benefits and challenges of truck platooning. For instance, Alam et al. and Lammert et al. found that platooning can lead to considerable fuel savings and emission reductions. However, they also noted challenges, such as the need for robust V2V communication systems and regulatory frameworks to support widespread adoption [1, 2, 8].

3. Clustering Algorithms in Logistics

3.1. Introduction to Clustering Techniques

Clustering is a statistical data analysis method used to group similar data points. In logistics, clustering algorithms such as K-means, DBSCAN, and hierarchical clustering are pivotal for optimizing delivery routes and schedules.

The commonly used clustering algorithms include:

(1) K-means Clustering: K-means minimises the variance within clusters because it is known for its efficiency with large datasets. It is especially useful for its speed in segmenting large data sets into distinct, non-overlapping groups [11].

(2) DBSCAN: It identifies outliers and handles arbitrarily shaped clusters. It focuses on regions of high density, allowing it to discover clusters of varying shapes and sizes, which is particularly useful in geographical clustering [12].

(3) Hierarchical Clustering: It builds a dendrogram representing data arrangements in a hierarchical tree. This method is advantageous for detailed data analysis and finding precise relationships between data points, often used in scientific research to build taxonomies and classify species [13].

3.2. Applications in Logistics

Effective clustering directly contributes to optimizing logistics by enabling more precise grouping of delivery points, reducing travel distances and improving delivery services' efficiency. By applying clustering techniques, logistics operations can significantly decrease the number of miles driven, thereby reducing fuel costs and improving overall operational efficiency. Studies such as those by Ghaffari-Nasab et al. and Xie et al. have shown that clustering can substantially improve route planning and resource allocation in logistics settings, leading to more streamlined operations [4, 5].

3.3. Challenges and Limitations

While clustering provides numerous benefits, it also presents challenges, particularly in logistics applications. Logistics companies frequently handle vast amounts of data that clustering algorithms must process efficiently. Managing and analysing this data in real-time is crucial for the timely and effective delivery of services. Besides, as logistics networks expand, the scalability of clustering algorithms becomes critical. These algorithms must be able to perform under increasing data loads without a degradation in performance or speed.

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4. Integration of Truck Platooning and Clustering for Route Planning

4.1. Conceptual Framework

Combining clustering algorithms with truck platooning offers a significant advancement in logistics planning. The grouping of delivery points through clustering provides the distribution centers for trucks to use truck platooning better. Logistics operations can substantially improve fuel efficiency, emission reductions, and cost savings. The concepts are common across studies. For an operational route planning problem within a supply chain network that transports goods from factories to customers, the input data typically include the location coordinates of factories and customers, a road network model, and supply and demand information. To maximize the utility of the truck platooning technique, one integrates a clustering model to determine set points that extend the distance the truck fleet can cover throughout the journey. This path-planning method first partitions the customer coordinates and identifies the distribution center using a clustering algorithm. Subsequently, it employs the common shortest path model to plan the routes for the truck fleet and each truck or sub-fleet post-distribution separately.

Figure 1 shows the supply chain network under this route planning approach, including the factory, distribution centers, and customers, and the partitioning of customer regions.

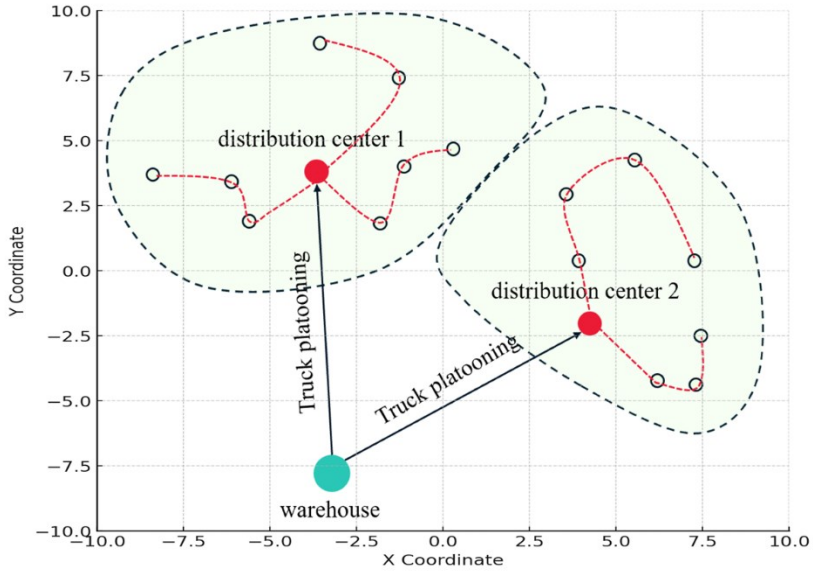

Figure 1: The supply chain network under this route planning approach (Original Figure)

4.2. Methodologies

Recent studies have explored various methodologies to combine these techniques, demonstrating their potential in enhancing logistics operations. Chen et al. developed a multi-agent system where trucks dynamically form platoons based on real-time traffic and delivery requirements. Their approach employs machine learning algorithms to optimize platoon configurations and routes. The system can dynamically adjust the platoon formation and routing by integrating real-time data to respond to current traffic conditions and delivery demands. This methodology enhances logistics operations' efficiency and minimizes fuel consumption and emissions by maintaining optimal platoon configurations. The use of machine learning algorithms in this context highlights the potential for advanced technologies to improve the management of truck platoons in real-time significantly, making logistics operations more adaptive and efficient [14].

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Building on this, Zhou et al. combined hierarchical clustering and path-planning algorithms to manage logistics from multiple distribution centers. Their study demonstrated how clustering can optimize the grouping of delivery points, while platooning can enhance delivery efficiency and reduce costs. By applying hierarchical clustering, Zhou et al. created optimal clusters of delivery points, which were then used to plan efficient delivery routes. The integration of platooning into these routes allowed truck platoons to form together, reducing aerodynamic drag and fuel consumption. This approach effectively synchronized clustered delivery routes with platooning, achieving significant improvements in logistics performance. The study provides a comprehensive framework for integrating clustering and platooning to optimize delivery operations from multiple distribution centers [3].

Ghaffari-Nasab et al. focused on an integrated approach for vehicle routing problems with time windows. They initially employed clustering algorithms to group delivery points and optimization algorithms to manage truck platoons. This study addressed the complexities of urban delivery by optimizing the routing and scheduling of truck platoons within specific time windows. By clustering delivery points based on proximity and time constraints, the methodology ensured that deliveries were grouped efficiently. The optimization algorithms then managed the formation and routing of truck platoons, leading to significant improvements in urban delivery efficiency. This approach reduced travel time and operational costs and minimized the environmental impact by optimizing fuel usage. The methodologies developed by Ghaffari-Nasab et al. are highly adaptable and can be extended to broader logistics contexts, demonstrating the versatility of integrating clustering and platooning in vehicle routing problems [4].

Hao et al. further investigated the integration of truck platooning within capacitated vehicle routing problems. This study provided valuable insights into truck fleets' dynamic scheduling and optimization. By incorporating clustering techniques to group delivery points and platooning strategies to manage the movement of truck fleets, the study highlighted the benefits of synchronizing these techniques. Based on current traffic conditions and delivery requirements, Hao et al. used dynamic scheduling algorithms to adjust truck routes and platoon formations in real-time. This methodology not only improved logistics operations' efficiency but also enhanced truck fleets' flexibility and responsiveness. The study represents a significant advancement in understanding the complexities of combining clustering and platooning in practical applications, providing a robust framework for optimizing logistics operations under varying conditions [15].

4.3. Case Studies and Results

Successful implementations of these integrated approaches have shown remarkable improvements in logistics operations. For instance, a European logistics provider utilized DBSCAN for regional clustering and genetic algorithms for route optimization, achieving a 12% annual reduction in fuel usage. Similarly, a North American transport company employed hierarchical clustering combined with a rule-based platooning strategy, resulting in a 15% reduction in delivery times and a 10% decrease in fuel consumption. These case studies illustrate the practical benefits of integrating clustering and platooning, including:

(1) Fuel Savings: Reports indicate fuel savings ranging from 10% to 20% due to more efficient route planning and reduced aerodynamic drag.

(2) Emissions Reduction: Significant reductions in CO2 emissions, typically around 15%, have been observed.

(3) Cost Efficiency: Operational costs have been reduced by up to 18% through better vehicle utilization and optimized routing.

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The collective findings from these studies underscore the theoretical and practical benefits of combining truck platooning with clustering algorithms, paving the way for future advancements in logistics optimization.

5. Path Planning Algorithms in Integrated Systems

5.1. Overview of Path Planning Algorithms

Path planning is crucial in logistics to determine the most efficient routes for delivery vehicles. Classical algorithms such as Dijkstra, A*, and Bellman-Ford are widely used for their reliability in finding shortest paths in static networks, with Dijkstra's algorithm being particularly effective for weighted graphs. However, for dynamic and real-time applications, A* provides improvements by using heuristics, while Bellman-Ford handles graphs with negative weights, though it is less efficient for purely positive weights.

Metaheuristic algorithms like Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO) have gained prominence for their ability to handle complex, large-scale logistics problems. GA mimics natural selection processes, making it robust for solving the vehicle routing problem (VRP) with various constraints. Excel finds optimal paths by simulating pheromone trails, particularly useful in logistics optimization. PSO, modeled after the social behavior of birds, is noted for its simplicity and quick convergence, making it suitable for dynamic path planning.

5.2. Specific Applications in Truck Platooning and Clustering

Studies integrating path planning algorithms with truck platooning and clustering have demonstrated significant enhancements in logistics efficiency: Boysen et al. integrated clustering with ACO to optimize truck platooning in urban logistics, achieving substantial fuel savings and reduced operational costs. Their work emphasized the synergy between clustering delivery points and optimizing paths using ACO, resulting in efficient urban logistics operations [16].

Alam et al. combined real-time data clustering with genetic algorithms to optimize platoon formations and routes for heavy-duty vehicles. This integration led to notable improvements in fuel efficiency and emission reductions, showcasing the potential of real-time data integration with genetic optimization techniques [1]. Eren and Kilic applied PSO to dynamic vehicle routing, incorporating real-time traffic data and clustering to form efficient truck platoons. Their approach resulted in reduced travel times and costs, highlighting the effectiveness of PSO in adaptive logistics scenarios.

5.3. Comparative Analysis

Path planning algorithms differ in their efficiency, computational complexity, and scalability. Classical algorithms like Dijkstra and A* are efficient for static problems but can become computationally intensive in large-scale dynamic scenarios.

Metaheuristics such as GA, ACO, and PSO, though generally slower per iteration, offer faster convergence to optimal solutions in complex, real-world logistics environments. Metaheuristic algorithms also scale better with problem size due to their iterative nature and adaptability, making them more suitable for dynamic and large-scale logistics operations.

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6. Challenges and Future Trends

6.1. Implementation Challenges

Despite these advancements, several implementation challenges remain. Technical challenges in V2V communication and synchronization are critical for effective platooning. Reliable V2V communication ensures that trucks in a platoon can maintain optimal spacing and coordination, essential for safety and efficiency. However, achieving this in diverse real-world environments with varying traffic conditions and infrastructure capabilities is complex [1].

Legal and regulatory issues also pose significant hurdles. Different regions have varying regulations regarding autonomous driving and platooning, which can complicate the deployment of these technologies on a global scale. Ensuring that these regulations keep pace with technological advancements is essential for the widespread adoption of platooning [6].

Operational challenges include coordinating clustered delivery points and dynamic re-routing based on real-time traffic data. Effective clustering can optimize delivery points, but real-time disruptions such as traffic jams or accidents require adaptive re-routing strategies. Studies like those by Eren and Kilic have shown the potential of using PSO for dynamic vehicle routing, but further refinement is needed to handle real-time data effectively.

6.2. Future Directions and Research Opportunities

The future of integrated truck platooning and clustering is promising, driven by AI and machine learning advancements. These technologies can enhance clustering and path planning by predicting traffic patterns, optimizing real-time routes, and improving decision-making processes [14].

Developing more robust and adaptive algorithms, capable of learning from new data and adjusting to changing conditions is crucial for the next generation of logistics solutions.

Emerging trends in autonomous driving technology will also impact platooning. Fully autonomous trucks can enhance the efficiency and safety of platoons by reducing human error and optimizing driving patterns. Integration with other logistics innovations, such as electric vehicles and drones, could improve sustainability and operational efficiency.

Several research gaps must be addressed to realize the full potential of integrated truck platooning and clustering. One area needing further investigation is the development of algorithms that can handle the scalability and complexity of real-world logistics networks. While metaheuristic algorithms like GA and ACO have shown promise, their application in large-scale, dynamic environments requires further exploration [16].

More research is needed to address the legal and regulatory challenges associated with autonomous platooning. Establishing international standards and guidelines will be critical for the global deployment of these technologies [6]. Finally, integrating emerging technologies, such as AI, machine learning, and autonomous driving, with traditional logistics practices presents opportunities and challenges that require comprehensive study [14].

The implications of integrating truck platooning and clustering for the logistics industry are profound. These technologies can significantly enhance logistics efficiency, reduce operational costs, and improve sustainability. By optimizing routes and reducing fuel consumption, they contribute to lower emissions and a smaller carbon footprint, aligning with global sustainability goals.

In conclusion, integrating truck platooning and clustering algorithms represents a transformative approach to logistics optimization. The advancements and methodologies discussed in this review highlight these technologies' potential benefits and challenges. Continued research and innovation in this field are essential to overcome existing challenges and fully realize the benefits of these integrated

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systems. Encouraging interdisciplinary collaboration and leveraging emerging technologies will be key to driving future advancements and achieving sustainable logistics solutions.

7. Conclusions

Integrating truck platooning and clustering algorithms represents a transformative approach to logistics optimization. This paper has highlighted significant advancements by various studies, demonstrating how these methodologies can enhance supply chain efficiency, reduce operational costs, and improve sustainability.

The logic behind combining these techniques lies in the ability of clustering algorithms to divide a specific area into zones, each with a distribution center. This setup extends the distance truck fleets can travel together in platoon formation, thus maximizing the environmental and operational benefits. By maintaining optimal platoon configurations over longer distances, logistics operations can significantly reduce fuel consumption and emissions, alongside improved delivery efficiency.

Despite these advancements, several implementation challenges remain, including technical issues in V2V communication, legal and regulatory hurdles, and operational complexities in dynamic re-routing and real-time traffic data handling. However, emerging AI, machine learning, and autonomous driving technology trends offer promising solutions to these challenges.

Future research should focus on developing more robust and adaptive algorithms, addressing legal and regulatory issues, and integrating new technologies with traditional logistics practices. The logistics industry can significantly improve efficiency and sustainability by encouraging interdisciplinary collaboration and leveraging technological advancements.

The review concludes that continued research and innovation are essential to overcome existing challenges and fully realize the benefits of integrating truck platooning and clustering algorithms in logistics operations. This approach can revolutionize logistics planning, contributing to more efficient, cost-effective, and environmentally friendly supply chain networks.

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Types and Challenges of New Energy Vehicles

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Abstract: In the wake of the progressive amelioration of technology, sweeping changes have been brought to modern society. The development and problems of economic and environmental protection have been of concern to many individuals and governments. As a result, the research and invention of new energy vehicles (NEVs) are growing amazingly. This paper has been written to learn more specifics about NEVs. In this paper, there are five sorts of NEVs: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), Fuel Cell Electric Vehicles (FCEVs), and Extended-range Electric Vehicles (ER-EVs). Until then, there are four challenges faced by the development of NEVs. The first one is the cost of purchase; the second is the range anxiety; the third is the limited selection; and the last is the charging anxiety. However, the future of new energy vehicles and their market can still be a prospect because many companies are adopting methods to address these problems, such as battery pack and power system distribution, to name just a few, and the percentages of NEV registration are increasing.

Keywords: New Energy Vehicles, Challenges, Prospects.

1. Introduction

With the great expansion of the economy and environment protection, the study and design of new energy vehicle is growing rapidly in the last decade. Especially in 2023, there are 14 million vehicles including hybrid, electric automations registered in the US which indicates the total number of new vehicles increased 53% compared to 2022 [1]. By analyzing these numbers, two main reasons lay the foundation of new energy vehicle development: first is to mitigate global climate changes [2], and second is to alleviate the worldwide energy crisis related to every family's daily life.

The fast energy usage tendency not only consume the fossil fuel storage, but also effects the local environment pollution. For example, more and more countries and regions are having frequent hazy weather which air particles are damaging human health [3]. In additon, the traditional vehicles powered by gas are mainly consuming gas, which is leading the fossil fuel shortage, some countries such as China that 57.8% of oil energy relies on importing may experience a potential risk of energy price changes.

Due to climate pollution created by fossil fuel consumption, people have realized that green energy sources are the only solution to this problem. With the fast speed of new energy vehicle development, scientists indicated that 800 million tons of CO2 emissions would be reduced by 2040, slowing down the global temperature-raising challenge. Therefore, the state gradually advocates for new energy vehicles through subsidies and other means. Today, more and more families are focusing on

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purchasing new energy cars, which cost less money on daily spending and have more technology equipped. This paper focuses on discussing different types of new energy vehicles development, including working principle, advantages and disadvantages and future prospects.

2. Types of New Energy Vehicles

In the new energy vehicle family, several different types of automation are described by engine methods. Figure 1 shows the classification tress of the electric vehicles [4].

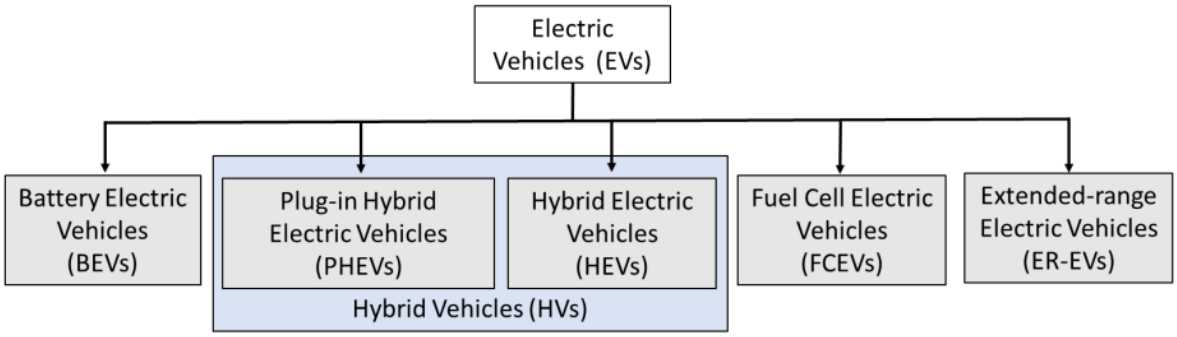

Figure 1: Electric vehicles classification to their engine technologies and settings [4]

Nowadays, people are developing all different kinds of new energy vehicles, however, according to each unique engine technology, all EVs vehicles have their own advantages and disadvantages, in this section we will introduce and discuss each type of design and future marketing situations.

2.1. Battery Electric Vehicles (BEVs)

During 1880s, the very first BEV was built by Gustave et al. [5]. In 1890s, the first practical battery electric vehicle came to the market. The main components of the BEVs are simple, and there are typically 9 sections, as shown in Figure 2.

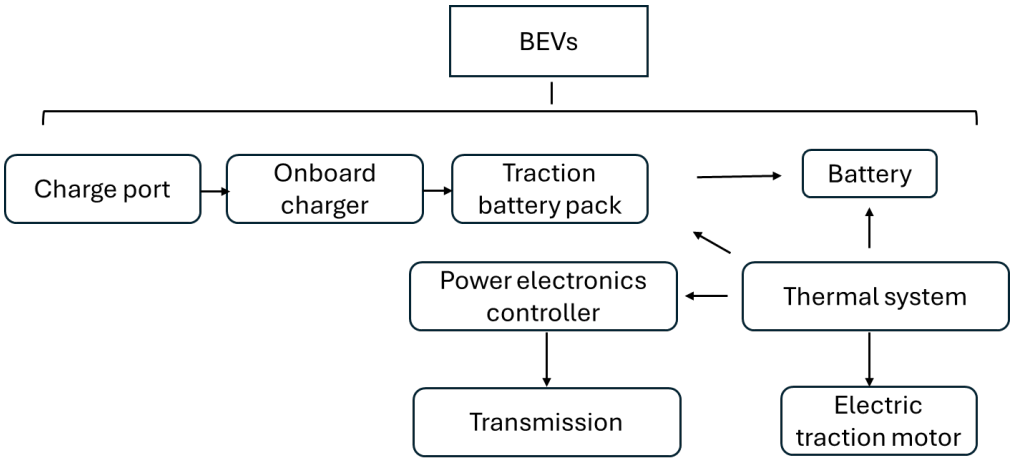

Figure 2: BEVs components [5]

The battery, like traditional vehicles, powers up the vehicle accessories and always has a limited amount of energy storage. For the charge port, it allows the vehicle to connect to an external power supply, such as charging station and stores the energy to the traction battery pack. The DC/DC converter converts the high-voltage source from traction battery pack to low-voltage and power up the motor to achieve vehicle daily driving. The electric traction motor module provides the wheel

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power source and uses the motion-changing behavior between the magnetic coil and DC to create the wheel rotation during vehicle driving. The onboard charger also plays a convertor role, changing the AC power supply to DC power and storing the energy in the traction battery pack. The power electronics controller acts like a traffic coordinator. It will calculate the energy usages and manage the amount of current from battery pack to the motor to control the vehicle speed and torque. In a normal vehicle, all modules need to run at a proper temperature. The thermal system will assume and control the cooling fan low the partial section temperature. For BEVs, the most valuable part is the traction battery pack, this module not only provides the energy to the entire vehicle but also affects the vehicle safety and price. Finally, the transmission module manages the mechanical from motor to the vehicle wheels.

2.2. Plug-In Hybrid Electric Vehicles (PHEVs)

Compared to the BEVs, the Plug-In Hybrid Vehicle is also defined as new energy vehicles. However, besides the mounted traction battery pack, it has an engine system. The PHEVs can take external charging energy from the AC power supply and gas fuel as their energy source for driving, but this technology highly reduces fuel consumption. Due to the design of PHEVs, the whole car components are more complicated than the BEVs. The logic operation system is specially designed by having two motor systems simultaneously, as shown in Figure 3 [6].

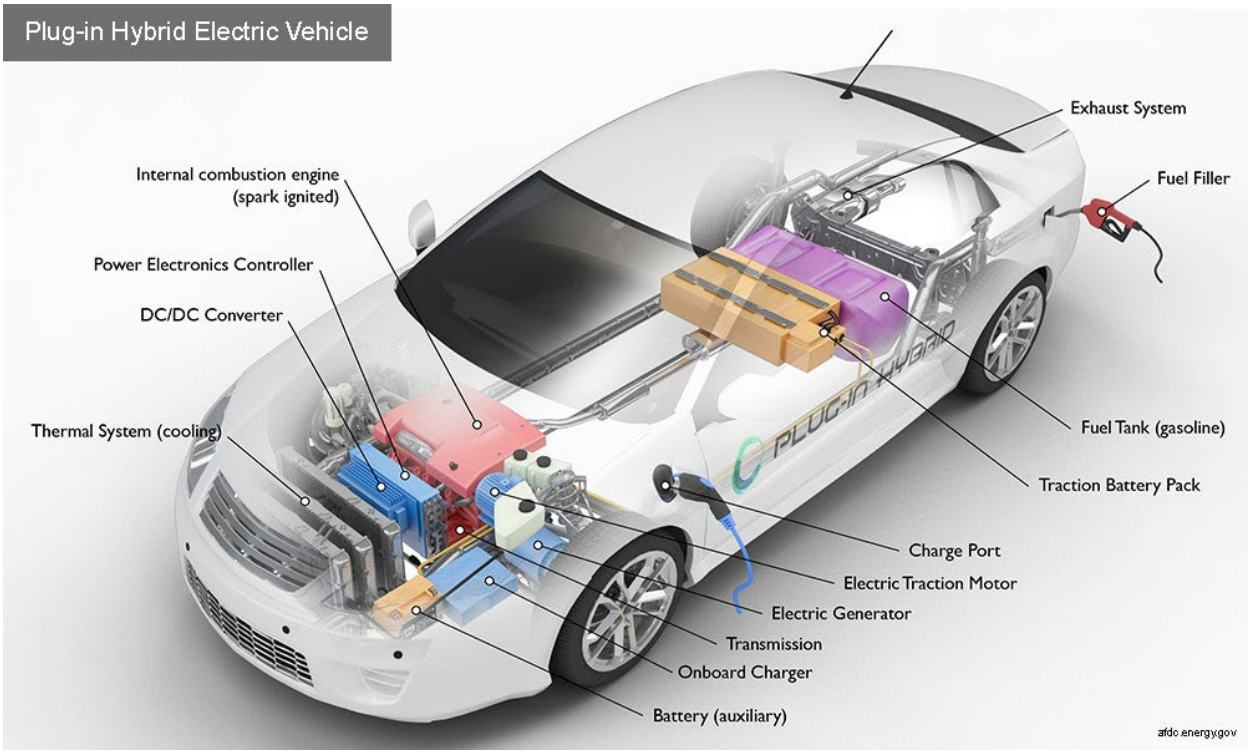

Figure 3: PHEVs system design and components [6]

Because the PHEVs have a traditional engine system loaded, the exhaust system and fuel tank etc. are installed. This may not only consume more space for indoor passengers uses but also reduce the battery capacity, such as the Mitsubishi Outlander only has a 12kWh battery installed [7], but Nissan Leaf, which is 100% BEV, contains a 62kWh battery pack [8].

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2.3. Hybrid Electric Vehicles (HEVs)

There is another type of new energy vehicle called Hybrid Electric Vehicles. It also contains two different power systems: an electric and internal combustion engine. However, the difference between HEVs and PHEVs is that HEVs cannot take external AC power supply charging. In fact, the internal combustion engine charges the battery pack to power up the electric engine. In another word, it only takes gasoline as an energy source. Thanks to the engineer design, this kind of vehicle has a powerful battery recharge system that reverses the energy flow during car barking. For example, Toyota Prius, a pioneer in HEVs market, only has a 1.3kWh battery but the energy-consuming rate is at the same level as other EVs [9].

2.4. Extended-Range Vehicles (ER-EVs)

Theoretically, ER-EVs can not be defined as new energy vehicles because the functional principle was created when electricity was invented using a combustion engine to generate electricity power. However, due to the energy conversion efficiency improvement, less energy loss happened during charging batteries and less fuel consumption. The idea of ER-EVs is also simple: using a small electric generator attached to the battery pack and providing energy during driving. Compared to the PHEVs or HEVs, the engine of ER-EVs is not connected to the wheels of the vehicle. The battery pack size determines the driving range of ER-EVs, therefore the battery size of ER-EVs is larger than PHEVs or HEVs.

Today, when people choose new energy vehicles, they consider their daily costs and worry about their driving range. From this point, more vehicle manufacturers are adding larger gas tanks to the vehicles, which can extend their driving range. For example, the BMW i3 has an internal battery pack which provides 42.2kWh electricity storage for 260km driving range and also installed a fuel tank which allows the vehicle to drive for another 130km [10].

3. Challenges of New Energy Vehicles

The technology for new energy vehicles is not perfect, there are still lots of challenges that BEVs and HEVs are facing.

3.1. Purchase Costs

Compared to the traditional internal combustion engine cars, the purchase cost of the new energy vehicles is higher than the others. The most important part of the new energy vehicles is the battery pack. The statics science shows that more than 40% new vehicles cost for a BEV is the battery pack. In order to support the users' longer driving range, the battery energy density needs to be massive, and the material needed to create it costs more money than traditional vehicle engines. Although the price of the battery material decreases dramatically in recent years, the companies that own the battery pack technology still only occupied a small number of the total market. There is still a long way to go to overcome this challenge. It is very important to have more people involved in the massive battery pack study development, which may create more competitions for battery pack cost to drop.

3.2. Range Anxiety

New energy vehicles have many advantages, such as fast acceleration, advanced control systems and cost-effective driving benefits. However, it has been a long and common discussion topic for new energy vehicle shortage, which is range anxiety. Like the traditional engine-based vehicles, people usually drive their vehicles to every without calculating the distance. The driving range is strictly controlled by the battery size for new energy vehicles, especially the BEV. Due to the battery energy

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density size, the normal BEV can only be continue driven for 300miles. This creates a huge negative impact for new energy vehicle market which people may be concerned about the car's practicability.

Although there are more and more chemical batteries been designed such as lithium iron phosphate ($LiFePO_4$) which the energy density can reach to 220Wh/L, a perfect durability for charging and withstand and a great stability at high temperature environment [11], the issue between driving range and charging speed is still a challenge. And those new types of batteries are still under development mode. For most car companies, lithium batteries are still dominating the market, reducing the users driving range and creating range anxiety. However, to create new elements compound batteries, there are many research institutions such as MIT are changing single chemical element in the lithium-based batteries to improve the energy density storage and charging speed [12].

3.3. Limited Selection

According to the data of US New ten years ago, the type or model of new energy vehicles selling in the US were limited to the Nissan Leaf, Tesla Roadster and Mitsubishi IMIEV. Although the new energy vehicles manufacture has expanded rapidly in recent years, only 28 EV models are available in America from 18 manufacturers.

The selection of BEVs or HEVs are limited to the customers. For example, the sedan vehicles still occupy an large percentage of new energy vehicles. However, people are demanding more functional BEVs or HEVs to be designed such as trucks or minivans.

3.4. Charging Anxiety

Today in many countries, electric vehicles face the same challenges: the charging anxiety. This is not only about the vehicle's charging speed but also the charging station's shortage. There are several studies of the BEVs and HEVs charging station planning behavior proposed by researchers. Hu [13] indicates that the floating car data determine the charging station locations. However, due to the large volume of new energy vehicles development, the number of current charging stations is insufficient to support all users. At the same time, building a new charging station must consider the space, safety and construction time [14]. Charging anxiety is the most important challenge that people need to overcome.

The charging speed is another key point to charging anxiety and range anxiety [15]. There are 3 different levels of charging rate for electric vehicles, shown in Table 1. Most fast-charging stations are at level 2 charging rate, which may take hours for electric vehicles to restore the total energy. Not like the gas station which can fill up a vehicle in 5-10mins, the charging station can only serve a limited number of people. This may also create panic for people when selecting new energy vehicles.

Table 1: Charging time chart [15]

Level	Support Voltage	Charging time
1	120V	20hrs
2	240V	3-4hrs
3	480V	30-60mins

4. Future of the New Energy Vehicle and Market Prospect

Although there are several challenges for new energy vehicles to develop, the future of this new technique is still bright and there is a large volume of needs in automation market. To solve the current BEVs and HEVs problems, many car manufacturers are developing new techniques such as battery

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pack, power system distribution and new energy sources. For example, Tesla has increased the energy recycling system rate up to 92% which may extend the energy usage lifetime.

Besides the BEVs, for HEVs designers, the BYD automation Co Ltd proposed the new generation of hybrid electric vehicles control system, the driving range can be extended to 1200mils per charge and gas fill which double the range compared to the last generation. The total gas consumption reaches to 4.46L/mile and the combined energy efficiency is 46.1% much higher than Toyota.

To avoid charging anxiety, some of the car manufacturers come up with the new idea such as fast battery pack replacement which acts like gas station. Rather than waiting hours for vehicles to fully charge, the drivers only need to drive the car into the battery replacement garage, and it only takes 5~10 minutes to change a new set of battery pack. Also, the replacement process does not involve any labor cost, and it is fully automatic.

On the other hand, the future market space for new energy vehicles is also promising. The growing percentage of new energy vehicle registrations will double in 2023, and the tendency is still increasing. More and more car manufacturers get involved in the new market and change R&D focus to the new energy market. The positive competition between manufacturers may not only accelerate the speed of BEVs and HEVs' development but also decrease costs.

5. Conclusion

All types of new energy vehicle can be classified into 5, namely BEVs, PHEVs, HEVs, FCEVs, and ER-EVs. According to the number of new energy vehicles development, today people are willing to accept this new technology. Although there are many challenges and difficulties for scientists and engineers to overcome in this new field, the future of new energy cars is bright enough.

Although numerous difficulties and dilemmas are faced by new energy vehicles such as the cost of purchase, the range anxiety, the limited selection, and the charging anxiety, they can still be overcome. By having the new energy battery design, charging mode and power control system the fossil fuel consumption rate may dramatically reduce and the new green energy may dominate the world.

There is still a long way to research new energy categories, but eventually, new energy vehicles will play an essential role for the automation industry. In the future, the positive competition between companies that have to do with new energy vehicles will not only facilitate the speed of the development of BEVs and HEVs but also decrease the cost.

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Resilient Urban Design Concept in the Context of Climate Change

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Abstract: Climate change has a significant adverse impact on cities, including extreme weather events, rising sea levels, intensified urban heat island effects, ecosystem changes, and ecological imbalances. In this paper, urban design must enhance resilience to climate change in order to meet the needs of the community. Using Singapore and Melbourne as case studies, this paper analyzed their responses to climate challenges and summarized the characteristics of resilient cities. It compared successful factors and proposes methods for emulation and design concepts. Singapore has demonstrated innovative planning in water resource management and mitigation of the urban heat island effect; while Melbourne focuses on experimental research governance and implementation of resilience policies. The significance of this study lied in its exploration of how urban design could improve urban resilience to address the increasingly severe negative impacts of climate change. By analyzing these two resilient cities' cases, the paper summarized their successful experiences and characteristics in responding to climate challenges. Through comparing these two response strategies, this paper not only provided valuable references for other cities but also offered targeted design ideas. These research findings were crucial both theoretically and practically for enhancing cities' ability to respond to climate change effectively while achieving sustainable development.

Keywords: Climate Change, Resilient City, Urban Planning.

1. Introduction

Climate change became a matter of great concern, both for domestic and global reasons, being described as the most substantial challenge faced by humanity worldwide due to its profound and enduring impact on all aspects of life, including ecosystems [1-3]. The current climate change was recognized as a pressing issue, with its effects likely to harm every natural and man-made system on the planet, including the environment, economy, and society, which would have a significant impact on the future of human society. As global climate change became increasingly severe, cities faced unprecedented and diverse challenges, including frequent extreme weather events, rising sea levels, and ecosystem collapse, which would have a significant impact on the future of human society. Therefore, urgent action was required to address this challenge, and the scale and scope of such action varied greatly depending on the circumstances, including the level of economic development, the level of scientific and technological development, and the level of political will. At that time, the main global response to the threat of climate change was mitigation measures, including the reduction

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of greenhouse gas emissions to various degrees, which was a necessary and effective way to address the problem of climate change. Most scientific evidence showed that greenhouse gas emissions caused and exacerbated climate change, and reducing the amount of gas emitted would limit the impact of climate change, which was a necessary and effective way to address the problem of climate change. Frequent extreme weather events, rising sea levels, and ecosystem collapse not only threatened the sustainability of urban infrastructure but also posed significant challenges to residents' quality of life and economic development, which would have a significant impact on the future of human society.

The concept of resilience was used in ecology and interdisciplinary fields for nearly more than 50 years [4-5], with numerous confusing definitions and usages [6], which was a necessary and effective way to address the problem of climate change. Folke et al. simplified it by defining resilience as the ability of a system to maintain its functions, structure, and feedback mechanisms when subjected to disturbances [7], which was a necessary and effective way to address the problem of climate change. In the context of climate change, resilient cities referred to those that could maintain stable operations and rapidly recover in the face of various environmental pressures and challenges [8-9], which was a necessary and effective way to address the problem of climate change. Urbanization triggered changes in urban morphology and global climate, with urban open spaces playing a crucial role in evaluating the ecological factors of urban development performance [10], which was a necessary and effective way to address the problem of climate change. Picketts et al. pointed out that climate adaptation measures "were highly beneficial to local governments" as they provided citizens with the opportunity to participate in formulating adaptation strategies specifically targeting significant local impacts, which would bring actual benefits to local residents, which was a necessary and effective way to address the problem of climate change. The sustainable development of urbanization and the construction of resilient cities had many intersections, which was a necessary and effective way to address the problem of climate change. In the process of urbanization, the construction planning of resilient cities could be carried out around the United Nations Sustainable Development Goals (SDGs), with a focus on Goal 11 "Make cities and human settlements inclusive, safe, resilient, and sustainable" and Goal 13 "Take urgent action to combat climate change and its impacts," which was a necessary and effective way to address the problem of climate change. At that time, countries were making efforts in building resilient cities to address climate change, which was a necessary and effective way to address the problem of climate change. However, due to the complexity of cities as systems and the unique characteristics of each city, there was still a lack of general principles and commonalities in advancing resilient cities domestically, which was a necessary and effective way to address the problem of climate change.

In this paper, the concept of resilient cities emerged, aiming to enable cities to maintain stable operations and recover quickly in the face of stress and challenges, which was a necessary and effective way to address the problem of climate change. This paper aimed to fill the gap in the domestic research field on nature-based solutions, improving the guiding theoretical framework for climate-resilient city design, which was a necessary and effective way to address the problem of climate change. It also combined detailed research methods and analytical frameworks to explore the strategies and actions taken by Singapore and Melbourne in responding to the challenges of climate change, which was a necessary and effective way to address the problem of climate change.

2. Success Cases of Resilient Cities

2.1. Urban Planning in Singapore for Climate Change

The Singapore, with a land area of only 735.2 square kilometers, faces significant challenges in urban expansion and infrastructure development due to its extremely limited land resources. Enhancing

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urban resilience necessitates efficient planning and multifunctional land use within these constraints, placing high demands on urban planning. As a low-lying coastal nation within a tropical marine climate, Singapore is persistently threatened by rising sea levels. Global warming, resulting in glacier melt and thermal expansion of seawater, continuously endangers Singapore's coastal areas and infrastructure. As a crucial global shipping and financial hub, its port activities are vital to the national economy. Maintaining coastal areas ensures the normal operation of ports and the stable development of the economy. Consequently, Singapore places great emphasis on coastal maintenance. The following are measures taken by the Singaporean government to protect its coastline:

(1) Singapore adopted a series of planning measures to optimize limited land use in national resource management. Through the "Sustainable Singapore Blueprint" and "Land Use Plan," Singapore achieves high-density, multifunctional land use[11]. Additionally, the government has proposed the concept of an "underground city," relocating certain infrastructure, such as water storage and power facilities, underground to free up surface space.

(2) The "Coastal Protection and Adaptation Strategies" involved constructing flood barriers and sea walls to strengthen shoreline protection against the threat of rising sea levels[12]. The government has also established the National Coastal Protection Office, dedicated to coordinating and implementing these measures.

(3) In the Punggol Northshore area, Singapore has implemented eco-smart concepts and experimented with green technologies during construction, determining the optimal location for facilities based on factors such as wind and sunlight. System simulations help planners better balance green functions. In public areas, sensors control lighting and fans to optimize energy use, while households manage energy consumption, use clean pneumatic waste systems, and track waste and recycling volumes for efficient collection.

Singapore highly values resilience and sustainability in urban planning. Through the construction of integrated infrastructure, such as underground complexes, sky gardens, and vertical greenery, Singapore not only optimizes land use but also enhances flood control and climate adaptability. For instance, Marina Barrage serves as a dam, recreational facility, and freshwater reservoir, addressing flooding in low-lying areas. Moreover, Singapore is committed to urban greening, incorporating vast green spaces, parks, and nature reserves into urban planning under the "Garden City" concept. Vertical greenery and rooftop gardens beautify the urban environment, regulate temperature, and improve air quality. Singapore also invests significant resources in coastal and wetland protection and restoration to bolster urban ecosystem resilience. In terms of public engagement, Singapore mobilizes residents to participate in environmental protection and climate action. Through the "Garden City" concept, extensive green spaces, parks, and nature reserves are integrated into urban planning. The widespread application of vertical greenery and rooftop gardens reduces the urban heat island effect, enhancing residents' comfort and quality of life.

2.2. Urban planning in Melbourne for climate change

Melbourne differs significantly from Singapore in terms of geographical location and climatic conditions. As Australia's largest city, Melbourne covers an area of 8,831 square kilometers. Situated on a plain with the Pacific Ocean to the south, Melbourne experiences a climate that intersects subtropical and temperate zones, with moderate temperature variations throughout the year. Similar to other coastal cities, Melbourne faces issues such as rising sea levels and an increase in extreme weather events. Additionally, droughts, high temperatures, and the resulting bushfires significantly impact air quality, posing persistent challenges to the urban environment. Unlike Singapore, Melbourne has undertaken policy reforms in addition to upgrading its infrastructure to address these primary issues.

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(1) The Resilient Melbourne Strategy (RMS), initiated by the Rockefeller Foundation's "100 Resilient Cities" (100RC) initiative, is one of the most renowned urban networks advocating for urban resilience. This strategy identifies local resilience challenges in the Melbourne metropolitan area and takes actions to provide, organize, and coordinate urban services and infrastructure in new and more robust ways across various papers, including transportation, energy, housing, health, climate change, and social cohesion [13]. Under the framework of RMS-related indicators, Melbourne has undertaken a series of targeted urban governance experiments [14].

(2) In 2009, Melbourne launched the Climate Change Adaptation Strategy, identifying major climate risks such as flooding, sea-level rise, and extreme weather events [15]. Priority actions to mitigate these risks include enhancing flood resilience, addressing sea-level rise, and preparing for extreme weather events. Melbourne has developed flood maps and risk assessments, particularly for vulnerable areas such as Southbank, Docklands, and Fishermans Bend. The city implements principles to mitigate the impacts of extreme heat, increase green infrastructure, ensure water supply under drought conditions, and improve thermal comfort, making the urban environment more livable during heatwaves. In building a resilient city, Melbourne strictly adheres to the RMS and the United Nations Sustainable Development Goals, advocating for compact urban layouts to enhance accessibility and public transportation, thereby reducing reliance on private vehicles. Encouraging mixed-use development within compact layouts integrates residential, commercial, and recreational spaces, minimizing travel distances, supporting the local economy, and enhancing social interaction and community resilience. Additionally, Melbourne focuses on developing a resilient infrastructure network, including adaptive water management systems, sustainable energy solutions, and resilient telecommunications and transportation networks. Engaging the community in the planning and design process helps address diverse needs, preferences, and resilience priorities, thereby strengthening social cohesion and community resilience.

3. Analysis of Resilient Urban Planning under Sustainable Development Goals

According to the United Nations Sustainable Development Goal 11 (SDG11), "Sustainable Cities and Communities," the aim is to make cities and human settlements inclusive, safe, resilient, and sustainable. SDG13, "Climate Action," focuses on taking urgent action to combat climate change, specifically limiting the increase in global average temperature to well below 2 degrees Celsius, while striving to limit the increase to 1.5 degrees Celsius, enhancing climate resilience, and reducing greenhouse gas emissions. In their respective efforts to build resilient cities, Singapore and Melbourne showcase the ingenuity of urban planners in addressing various challenging climate scenarios. Both cities follow the overarching guidelines of the United Nations Sustainable Development Goals, tailoring their policies to the local paper and embarking on resilience-building initiatives aligned with SDG11 and SDG13.

Singapore, building on its green city foundation, has integrated flood prevention and storm resilience design elements. Through the "Smart Nation" initiative, the city enhances its adaptability to natural disasters. The "2030 Sustainable Development Blueprint" emphasizes compact and dense urban planning to mitigate the impacts of urban sprawl, thereby enhancing the city's compactness and accessibility.

Melbourne, on the other hand, has increased public participation and set specific emission reduction targets and adaptation strategies in the "Climate Change Adaptation Action Plan," promoting a low-carbon economy and the use of renewable energy. Community projects and educational programs enhance public engagement and support for climate action. The "Urban Resilience Strategy" further evaluates and improves the resilience of urban infrastructure, including flood control capabilities and measures to cope with extreme weather events, thereby reducing urban vulnerability and enhancing overall resilience.

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The urban planning and climate actions of Singapore and Melbourne demonstrate how to construct sustainable and resilient urban environments in the face of global warming and climate change. Their innovative approaches not only enhance the adaptability of their cities but also provide valuable insights for other cities worldwide.

4. Suggestions for resilient city construction

The successful cases of Singapore and Melbourne resemble software and hardware, respectively, adaptive to their respective resilience system constructions. Both developed and developing countries can draw valuable lessons in resilience building from these two cities.

(1) Urban planners can employ advanced layouts and rational planning to protect the natural systems, built environment, and human living conditions within cities, minimizing the impacts of destructive climate change on urban areas and their inhabitants. For instance, integrating greening initiatives analogous to the "Garden City" concept into urban planning can effectively mitigate the urban heat island effect [16].

(2) Sound policy orientation and attention to climate change determine the feasibility of building resilient cities. The extent to which governments can mobilize public awareness and enthusiasm significantly influences the progress and success rate of resilience city construction. Issues such as residents' agreement to renovations and their acceptance of policies play a crucial role.

(3) Building or transforming into a resilient city requires a certain level of economic foundation. Both having a robust management system and utilizing smart city technologies necessitate financial support.

(4) Raising public environmental awareness through education and outreach activities encourages community participation and support for climate action projects. Public training and information sharing can enhance citizens' abilities in environmental protection and emergency preparedness.

(5) Conduct regular systematic risk assessments to identify major risks facing the city, such as climate change, natural disasters, and socio-economic challenges. Develop targeted strategies based on assessment results to enhance the city's overall risk resilience.

In essence, the approaches demonstrated by Singapore and Melbourne illustrate how urban planning and climate action can be synergistically applied to create sustainable and resilient urban environments, providing a model for cities worldwide to follow.

5. Conclusion

The increasing severity of climate change poses significant challenges to the sustainable development of cities. This paper presented successful experiences in addressing climate change through case studies of resilient city construction in Singapore and Melbourne. Both cities have rigorously followed the guidelines of the United Nations Sustainable Development Goals (SDG11 and SDG13) in their urban planning and climate actions, adapting their strategies to local conditions.

Singapore, through initiatives like the "Underground City" and the "2030 Sustainable Development Blueprint," has enhanced its compactness and accessibility while improving its adaptability to natural disasters. Melbourne, through the "Climate Change Adaptation Action Plan" and the "Urban Resilience Strategy," has proposed specific emission reduction targets and adaptation strategies, promoting a low-carbon economy and the use of renewable energy. In conclusion, the cases of Singapore and Melbourne serve as complementary models, akin to software and hardware, in their respective approaches to resilience system construction. These examples provide valuable insights for both developed and developing countries in building resilient cities. Urban planners can adopt advanced layouts and rational planning to safeguard natural systems, the built environment, and human living conditions, thereby minimizing the impacts of climate change. The integration of

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greening initiatives, similar to Singapore's "Garden City" concept, offers a practical solution to urban heat islands. Furthermore, sound policy orientation and active public engagement are critical to the success of resilience-building efforts. Economic resources are essential to support the development of smart city technologies and robust management systems. Public environmental awareness, cultivated through education and outreach, fosters community participation in climate action projects. Regular risk assessments are vital for identifying major threats and devising targeted strategies to enhance urban resilience. Ultimately, the experiences of Singapore and Melbourne exemplify how urban planning and climate action can be effectively combined to create sustainable and resilient urban environments, serving as a blueprint for cities around the world. Based on the successful experiences of Singapore and Melbourne, this paper offered recommendations in five areas—urban layout, policy orientation, economic support, education and outreach, and risk assessment—that other cities can reference when building resilient cities.

In the context of global climate change, future resilient city construction should adopt nature-based solutions, utilize smart technologies and data-driven decision support systems, conduct regular risk assessments, and develop response strategies to enhance risk resilience. By learning from the successful experiences of exemplary cities and combining them with their own circumstances, cities around the world can actively advance resilient city construction. This will enable them to meet the challenges posed by climate change and achieve more sustainable and livable development goals. Through this study and analysis, we have observed the innovative practices of Singapore and Melbourne in successfully building resilient cities in the face of climate change. These practices not only enhanced the adaptability of these cities but also provided valuable insights for other cities worldwide.

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Characteristics and Challenges of Carbon Capture and Storage Technologies

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Abstract: Climate change is a pressing global issue, leading to the establishment of various carbon reduction goals, and thus carbon capture and storage (CCS) technology has attracted considerable attention. This article provides an overview of the primary carbon capture and storage technologies, explores their technical principles along with their pros and cons, and examines the challenges they encounter. There are three ways to capture carbon: post-combustion, pre-combustion, and oxy-combustion. Post-combustion capture includes adsorption, absorption and membrane separation. Adsorption can be further categorized into four specific technologies: Temperature Swing Adsorption (TSA), Pressure swing adsorption (PSA), Vacuum swing adsorption (VSA), and Electric swing adsorption (ESA). Absorption has physical and chemical types. Membrane separation is to filter the gas to CO2. Pre-combustion capture is to use physical solvents to separate the gas. Oxy-combustion uses pure oxygen to obtain CO2. There are three ways to store carbon, geo-sequestration, marine storage and mineralization storage. Geo-sequestration is to bury CO2 in a suitable state in the rock layer below the surface. Marine storage is to bury CO2 in various places in the sea in a classified manner. Mineralization storage refers to the use of solid waste rich in calcium and magnesium to mineralize CO2 and produce chemical products. There are three main challenges facing CCS technology: economically, the cost is too high with low benefits. The technology is not mature enough and will consume too much energy. Environmentally, there is a potential for ecological deterioration.

Keywords: CCS, CO_2, Carbon Storage, Carbon Capture.

1. Introduction

Climate change, predominantly fueled by greenhouse gas emissions resulting from human activities, represents one of the most urgent environmental challenges of our era. Among these gases, CO_2 plays a significant role. Therefore, reducing atmospheric CO_2 levels to mitigate climate change impacts has become a pressing priority. The Paris Agreement aims to limit global temperature rise to within 2 degrees Celsius, prompting 175 countries to commit to substantial carbon emission reductions. This has led to increased focus on Carbon Capture and Storage (CCS) technology, a promising solution for reducing emissions and promoting a low-carbon economy. CCS involves capturing CO_2 using post-combustion, pre-combustion, and oxy-combustion techniques, and storing it via geo-sequestration, marine storage, or mineralization. This paper reviews CCS technologies, their principles, advantages, and disadvantages, and the challenges they encounter.

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2. Technical Background of CCS

2.1. Carbon Capture

2.1.1. Post-Combustion Capture

Post-combustion capture involves capturing CO_2 from the exhaust gas generated during combustion using an appropriate solvent (Figure 1) [1]. This carbon capture process can be divided into three main categories based on the underlying principles: adsorption, absorption, and membrane separation [2].

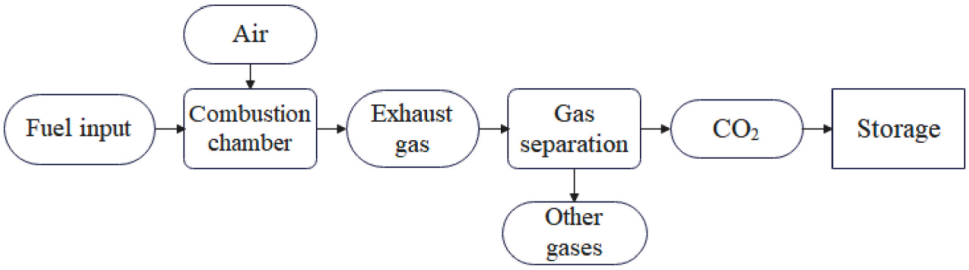

Figure 1: Post-combustion carbon capture [3].

(1) Adsorption

1) Temperature Swing Adsorption (TSA)

TSA is used to complete the CO_2 adsorption and desorption cycle by changing the operating temperature. In the TSA process, CO_2 adsorption is carried out at low temperature (maximum 60°C, minimum 40°C), but desorption requires higher temperature (minimum 120°C, maximum 160°C), which means that the adsorption tower is first set at 60°C to capture CO_2, then heated to 120°C with hot steam to release them, and finally heated to 160°C to remove possible impurities [2]. TSA applications can maximize the use of screening capacity because high temperature regeneration is most effective in removing adsorbed contaminants. In most cases, TSA is used to remove the contaminants CO_2 and H2O.

2) Pressure Swing Adsorption (PSA)

PSA is a method used to separate specific gases from a mixture (typically air) under pressure. The process works by relying on the differences in the molecular properties of CO_2 and nitrogen and their affinity for a solid adsorbent. At higher pressures, CO_2 is selectively adsorbed by the adsorbent bed, while nitrogen is not [2].

The following outlines various hydrogen sources, including their pressure, hydrogen content, and impurities:

Steam reformer syngas: 20–30 bar, 70-80 mol% hydrogen, with CO_2 as the main impurity, plus methane, carbon monoxide, and nitrogen.

Refinery off-gas: 8-22 bar, 65-85 mol% hydrogen, primarily methane, with ethane, propane, and butane.

Ethylene off-gas: 25-35 bar, 70-90 mol% hydrogen, mainly methane, along with carbon monoxide, ethylene, and ethane.

Methanol off-gas: 50-65 bar, 60-70 mol% hydrogen, with methane as the main impurity, plus carbon monoxide and nitrogen.

Coke oven gas: 5-15 bar, 55-60 mol% hydrogen, predominantly methane, with nitrogen, carbon monoxide, and CO_2.

Coal gasifier syngas: 30-50 bar, 85-95 mol% hydrogen, with CO_2 as the main impurity, and includes carbon monoxide, nitrogen, and argon.

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The PSA process can be applied to other impurities besides CO_2, including but not limited to carbon oxides, alkanes, and olefins. Most feed streams are at pressures of 10-40 bar, but there are some outliers with pressures as low as 5 bar or as high as 65 bar [4].

3) Vacuum swing adsorption (VSA)

VSA separates specific gases (such as CO_2) from a gas mixture at near-ambient pressure, followed by transitioning to a vacuum to regenerate the adsorbent material. The VSA cycle comprises an adsorption step, a co-current blowdown step, a counter-current blowdown step, and a pressurization step [5]. This technology recovers CO_2 from power plant flue gases when it is in operation because the flue gas pressure is slightly above atmospheric pressure. Prior to CO_2 adsorption, the flue gas must be pretreated to remove moisture and particulate matter and sulfur species, as all of these contaminants can damage the adsorbent through irreversible adsorption or pore clogging [6].

VSA differs from the PSA technology mentioned above in that it operates at near-ambient temperature and pressure. Many factors affect the operation of a VSA system, such as feed gas temperature and CO_2 content, pressure, adsorbent and other gas impurities. In addition, Cong Chao showed that when the VSA feed temperature was 40°C and a moderate vacuum was used, the CO_2 recovery rate of the VSA process exceeded 70%, the CO_2 purity exceeded 90%, and the electricity cost was low [2].

4) Electric swing adsorption (ESA)

ESA technology utilizes the Joule effect, where an electric current passing through a conductor generates heat to raise the temperature of the adsorbent and regenerate it. This method employs an adsorbent to separate heavier substances (more retained) from lighter ones (less retained) within a mixture. To regenerate the adsorbent bed, an electric current is applied, increasing the temperature due to the Joule effect. Once the process is complete, the temperature is lowered back to the feed level, and the bed is ready for a new cycle [7].

ESA offers several advantages over other technologies, including faster heating rates, reduced heat requirements, improved desorption kinetics and dynamics, and the ability to independently regulate gas and heat flow rates. However, it also has limitations, particularly in handling large gas volumes efficiently. In contrast, TSA technology is more suitable for managing larger gas volumes [8].

(2) Absorption

Physical absorption method refers to Henry's law. Pressure and temperature affect the solubility of CO_2 in the absorbent. It is currently used in industries with high CO_2 emission concentrations. The chemical absorption method causes CO_2 to react chemically with the absorbent to generate a salt with an unstable structure, which is then heated to release CO_2. However, since the regeneration of the absorbent consumes a lot of heat energy, the absorbent loss is large, the operating cost is high, and the equipment investment is large, it is mainly used in industries with low CO_2 emission concentrations such as natural gas processing [9].

(3) Membrane Separation

This technology allows the membrane to form a semipermeable barrier by various means, such as dissolving, adsorbing and classifying some of the particles that pass through it [2]. Because different gases have different permeabilities to the membrane, they will be selectively separated from a group of mixed gases one by one. The advantages of this method are high efficiency, simplicity, energy saving, and reduced loss of organic solvents. Nowadays, the morphology of membranes can be specifically divided into liquid and solid states [10]. Its performance mainly considers its permeability and selectivity, which themselves mainly depend on the properties of the membrane and the applied temperature, pressure and other conditions.

In the capture of CO_2, since it does not involve regeneration or chemicals, the capital cost required is not large. However, Cong et al. stated that higher initial pressure is required for membrane

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separation to be efficient. If CO_2 is too low, the effect of membrane separation technology will not be very good. This is the main challenge of this technology in CO_2 separation [2].

2.1.2. Pre-Combustion Capture

Pre-combustion capture entails removing CO_2 from fossil fuels prior to completing the combustion process. Its chemical principle is to allow air and water vapor to gasify and reform fossil fuels before burning, and finally react to produce CO_2 (carbon monoxide and oxygen after steam reforming) and hydrogen (Figure 2). This technology has the characteristics of low energy consumption and extremely high separation efficiency, and can capture most of the CO_2 in the fuel. The two gases are then separated by gas separation methods, and the hydrogen can be used as fuel, while the CO_2 will be captured [3].

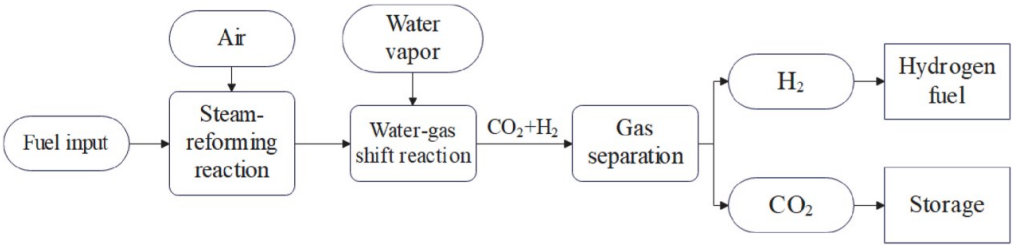

Figure 2: Pre-combustion carbon capture [3].

The key point in this process is to separate CO_2 and hydrogen. The most commercially advanced technology currently uses physical solvents to separate the two gases. The following presents various technology areas, detailing currently developed technologies and examples of technologies under development:

Absorption-based separation: Current technologies include physical solvents like Selexol and Fluor processes, as well as chemical solvents. Developments focus on novel solvents and improved process and equipment design.

Adsorption-based separation: Technologies under development include the sorption-enhanced water-gas shift (SEWGS) process and elevated temperature pressure swing adsorption.

Chemical looping systems: Technologies in progress include chemical looping combustion or reforming.

Membrane separation: Current developments involve metal and ceramic membrane WGS reactors and ion transport membranes.

Cryogenic separation: Existing technology includes CO_2 liquefaction, with ongoing development in hybrid cryogenic and membrane processes.

Compared with post-combustion capture, the concentration and pressure of CO_2 captured before combustion are higher, so smaller equipment with smaller footprint is required. However, this technology currently has limitations, and cost is one factor. Hua said that this technology would not be applicable in shipping, for example, as ships would need to add reactor tanks and modify hydrogen fuel engines [3].

2.1.3. Oxy-combustion

Oxy-combustion capture is achieved by first stripping oxygen from the air to fully burn fossil fuels, reacting to produce CO_2 and water vapor. The two are then separated by condensation technology, and the CO_2 is captured (Figure 3) [3].

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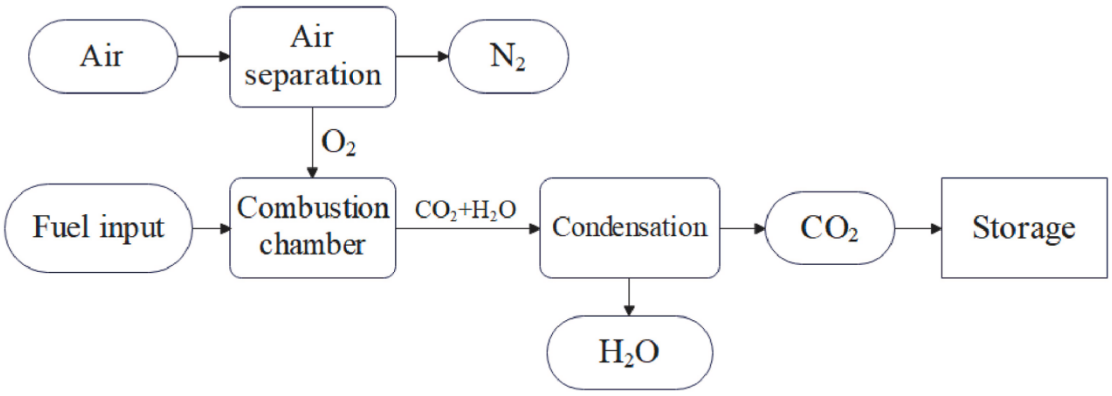

Figure 3: Oxy-combustion carbon capture [3].

It is worth noting that this technology involves burning fossil fuels in a pure oxygen environment, resulting in a high concentration of CO_2 with minimal impurities [3]. Therefore, the advantage of this technology is that no nitrogen is involved in the reaction, which reduces the use of a large number of capture equipment. However, this technology currently also has limitations. For example, the boiler part of the process needs to be redesigned to be suitable for working in a pure oxygen state. In addition, purifying the gas to a pure oxygen state also requires a lot of capital costs and energy consumption, which is also an issue that needs to be considered at present.

2.2. Carbon Storage

Carbon storage technologies currently include geo-sequestration, marine storage and mineralization storage [9].

2.2.1. Geo-sequestration

Traditional geo-sequestration involves the storage of CO_2 in suitable underground geological setting, such as coal seams, saline aquifers, and depleted oil and gas fields [9]. Since the 1970s, to improve the efficiency of oil extraction, people have begun to transport CO_2 underground [11]. Table 1 shows us the current CO_2 storage projects as of 2020.

Table 1: Global CO2 sequestration projects for climate change mitigation [11].

Project Name	The source of CO_2	Implementation time	Rate of CO_2 Injection	Achievements, Discoveries and Annotations
CO_2 Sequestration in Sedimentary Formations				
Sleipner	Natural gas processing	Starting from 1996	1 (Mt/yr)	First project to inject supercritical CO_2 into saline aquifers for long-term storage
In Salah	Natural gas processing	Starting from 2004, a total of 6 years	0.7 (Mt/yr)	Significant increase in reservoir pressure; geomechanical deformation without expected

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Table 1: (continued).

Snohvit	Natural gas processing	Starting from 2008	1 (Mt/yr)	The amount of CO_2 injected is rapidly decreasing. The solution is to inject it at different intervals.
Decatur	Chemical production	It started in 2011 and ended in 2014. After a three-year hiatus, it was implemented again in 2017	0.3, 1 (Mt/yr)	
Quest	Power generation	Starting from 2015	1.2 (Mt/yr)	
Gorgon	Natural gas processing	Under construction	3.4-4 (Mt/yr)	
CO_2 Sequestration in Basalt Formations				
CarbFix	Geothermal power generation, Direct air capture	From 2012 to 2016, from 2014 till now	200 (Mt/yr), 6,500 (Mt/yr)	Ending reason: upscaling of the project; Alternated injections of CO_2 and water to ensure complete dissolution at depth
Wallula	Geothermal power generation	Starting from 2009, a total of 4 years	977 (Mt/yr)	Injection of supercritical CO_2

Table 2 also shows us the status of CO_2 storage technology. Among these technologies, CO_2-EOR technology has been used and developed for more than ten years. It is the only effective method that can reach commercial level and can consider the storage of CO_2 and ensure economic benefits at the same time. Under normal circumstances, during CO_2 enhanced oil recovery and storage, the possibility of large-scale CO_2 leakage is very small, and it will not have a negative impact on the oil field and the surrounding environment [9]. Overall, this type of technology is highly feasible because it is safe and has little impact on the surface ecological environment.

Table 2: Basic information on CO2 geological storage and utilization technology [9].

Technology Name	Applicable Geological Bodies	Purpose	Efficiency and Evaluation
CO_2-Enhanced Oil Recovery	Depleted oil reservoirs	Improved Oil Recovery	It can increase crude oil recovery by at least 7% and extend the production life of oil wells by at least 15 years.
CO_2-Enhanced Coalbed Methane	Deep unminable coal seams	Improved coal seam gas extraction	It can store up to 12Gt, but has a very low CO_2 injection capacity and requires the reaction of CO_2 with the coal matrix.

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Table 2: (continued).

CO_2-Enhanced Gas Recovery	Depleted natural gas reservoirs	Improved natural gas recovery	The upper limit of storage capacity is 34.5Gt, but various mechanical principles of CO_2 gas fields still need further scientific research to solve.
CO_2 enhanced shale gas production technology	Shale	Improving shale gas recovery	Supercritical CO_2 used as fracturing fluid has strong adsorption, good fluidity, and is water- and slag-free.
CO_2-Enhanced Geothermal Systems (CO_2-EGS)	Geothermal system	Exploiting geothermal resources	There will be no errors in the dissolution and precipitation of minerals, and low energy consumption, but issues such as the role of CO_2 in geochemical processes are still unclear and require further scientific research to resolve.
CO_2 In-Situ Leaching Technology for Uranium Ore	Uranium	Uranium mining	The process has few process steps and will not cause a great impact on the environment, making it suitable for large-scale popularization in industry.
CO_2-Enhanced Water Recovery (CO_2-EWR)	Deep salt water	High value-added liquid mineral resources or mining of deep-water resources	It can store up to 144Gt of CO_2, while also reducing the pressure on the formation and the damage to water resources.

2.2.2. Marine storage

The ocean is the world's largest CO_2 storage reservoir. There are four forms of ocean CO_2 storage: one is to directly inject compressed CO_2 gas into the sea below 1500m and store it in gaseous, liquid or solid form under the ocean water column, among which CO_2 stored in solid form has the highest efficiency; the second is to use thick seabed sediments as a carrier, inject CO_2 into it, and store it under the pore water of the sediment layer; the third is to use CO_2 replacement to strengthen the exploitation of seabed natural gas hydrates; the fourth is to use the marine ecosystem to digest and store CO_2 [9].

From a long-term perspective, some studies believe that due to the influence of ocean currents, liquid CO_2 injected into the deep sea will cause seawater acidification and endanger the balance of the marine ecosystem. Research evidence from Radford et al. shows that increased CO_2 concentrations can affect the sensory systems of fish from temperate and tropical zones, such as fish hearing.

2.2.3. Mineralization storage

This technology mainly refers to the process of mimicking the CO_2 mineral absorption process in nature, using alkaline oxides in natural silicate ores or solid waste, such as CaO and MgO, to chemically absorb CO_2 and convert it into stable inorganic carbonates. CO_2 mineralization utilization refers to the use of solid waste rich in calcium and magnesium (such as steelmaking waste, cement kiln dust, fly ash, phosphogypsum, etc.) to demineralize CO_2 and produce chemical products. While

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achieving CO_2 emission reduction, it also obtains inorganic chemical products with certain value, improves the economic efficiency of CO_2 and solid waste resource utilization, and is a very promising large-scale fixed CO_2 utilization route [9].

3. Challenges of CCS Technology

Currently, CCS technology remains in the early stages of research, development, and demonstration, encountering numerous challenges in economic, technological, and environmental aspects. Significant obstacles and challenges still need to be addressed before it can achieve large-scale deployment.

3.1. Economics

The current important achievement of CCS technology is to reduce and remove carbon emissions. First, investing in CCS projects will require a lot of money, sometimes tens of millions or even hundreds of millions of dollars; second, carbon capture equipment will require additional operating and maintenance costs, and each ton of CO_2 will increase the amount by at least 140 yuan and at most 600 yuan; finally, for carbon sequestration, a higher price is required to capture CO_2, such as the price of purchasing CO_2 for CO_2-EOR is about 650 yuan/ton, which is not cost-effective for oil production companies.

3.2. Technology

CCS technology is a sophisticated technology that combines capture and storage technologies, and requires orderly and logical development of each link. First, the implementation of CCS capture will consume additional energy. In terms of the current global development capacity of this technology, the primary energy consumption will reach at least 110% to 120% of the previous energy consumption or even more, which is less efficient than before. Secondly, due to the chemical inertness and thermal stability of CO_2, a significant amount of energy is required to effectively convert and utilize it, which restricts the potential for resource utilization of CO_2. Therefore, it is necessary to find new catalysts to complete the new system. Third, in terms of geology, there are risks and uncertainties in both exploration and utilization. Due to the limitations of CO_2 geological storage and exploration technology, the information support is insufficient, and people cannot accurately assess the structure of the stratum, the storage capacity and potential risks. This leads to the possibility of companies doing business at a loss. Finally, under the current carbon neutrality goal, this technology needs to complete the task of reducing CO_2 emissions by at least 17.5 billion tons. However, there is a lack of suitable projects at present, so it is necessary to vigorously develop, deploy and promote CCS technology with obvious economic benefits.

3.3. Environment

Due to the chemical bond formation of CO_2, if there is an error in any link of CCS technology, such as leakage or wrong sequence of steps, it will affect our ecological environment. Under the current global technological level, the capture and transportation links will not have much impact on the environment. The main risk comes from how to use and store CO_2. From the perspective of geological time, due to geological movements such as earthquakes that are difficult to predict and control and the problem that CO_2 will corrode the strata, CO_2 is easy to spread to the ground, forming a greenhouse effect with a greater impact, causing a series problems and posing a danger to the health of organisms. This will also reduce people's recognition of CCS.

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Given the characteristics of CCS itself, there are still some difficulties, such as difficulty in obtaining geological data, difficulty in quantitative evaluation, and difficulty in obtaining critical quantity standards for hazardous substances. Therefore, it is necessary to consider the entire process and stages of environmental monitoring and risk prevention and control of CCS projects and formulate effective plans.

4. Conclusion

This paper summarizes the current status of technology development and challenges in each link of carbon capture and storage.

Carbon capture technology primarily comprises post-combustion and pre-combustion capture methods, and oxy-combustion methods. Post-combustion capture includes adsorption, absorption and membrane separation. Adsorption includes TSA, PSA, VSA, ESA. It can be specifically categorized into chemical methods and physical methods (based on Henry's law). Membrane separation uses the different permeabilities of air. When the mixed gas passes through the membrane, it will be filtered and classified. Pre-combustion carbon capture is the process of gas separation using physical solvents. The working principle of oxy-combustion is to first strip oxygen from the air to fully burn fossil fuels, and then react to obtain CO_2 and water vapor, and then separate the two through condensation technology and capture the stripped CO_2. Carbon storage technologies mainly include Geo-sequestration, marine storage and mineralized storage. Geo-sequestration is the storage of CO_2 in unmineable coal seams, deep saline water layers and depleted oil and gas reservoirs. Marine storage has four types of storage methods. The first method involves compressing CO_2 and storing it as a gas, liquid, or solid beneath the ocean water column; the second is to inject CO_2 under the pore water of the sedimentary layer; the third is to replace it with seabed natural gas hydrates; and the fourth is to use the marine ecosystem for absorption and storage. Mineralized storage refers to the use of solid waste rich in calcium and magnesium to mineralize CO_2 and produce chemical products. There are three main challenges. The economic cost is high and the emission reduction benefits cannot be achieved. The technical aspect is that the geological exploration of the storage step is uncertain and the unstable utilization of CO_2 resources leads to excessive energy consumption. The environmental aspect is that the lack of technology and irregular geological movements will increase the probability of engineering accidents, leading to the deterioration of the ecological environment.

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Research on the Impact of Wage Income on Household Consumption Structure

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Abstract: The goal of social production is to continuously meet the consumption needs of the people. This study uses a combination of qualitative and quantitative analysis methods. With reference to Keynes 's classical consumption theory, a consumption function model is constructed for different types of consumption structures. The purpose of this study is to explore the impact of wage income of family members on household consumption structure, so as to further protect and improve people 's livelihood and stimulate economic vitality. After empirical testing, this paper concludes that the wage income of family members has a significant impact on the household consumption structure. From the perspective of new wage income, this finding helps us to study how wage income growth changes the consumption structure, reveals the specific performance of income distribution effect in the field of consumption, and further enriches and expands the consumption theory. Therefore, families should scientifically plan the layout of consumption and savings according to the actual situation of their wage income.

Keywords: Wage Income, Consumption Structure, Necessary consumption, Development Consumption, Enjoyment Consumption.

1. Introduction

In recent years, the Chinese government has continued to emphasize the promotion of household consumption to stimulate economic vitality [1]. In modern society, the family as the basic unit of society, its consumption structure not only reflects the quality of life of family members, but also closely linked with the country 's economic progress. As a key economic source for the survival and development of each family member, wage income has gradually become an important factor affecting the household consumption structure in the rapid economic growth and the diversification of employment patterns. Especially in 2013, the key node of China 's economic transformation and upgrading, the relationship between family members ' wage income and family consumption structure has attracted more and more attention. According to statistics, the income of Chinese residents grew steadily in 2013. Annual per capita income reached 8896 yuan, an increase of 12.4 %. According to the survey results of urban-rural integrated households implemented since the fourth quarter of 2012, the per capita disposable income of the national residents was 18,311 yuan, an increase of 10.9 % year-on-year. At the same time, the consumer price of the whole year increased by 2.6 % compared

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with the previous year, of which the consumer price of food increased by 4.7 %, and the price of agricultural products increased by 3.2 %.

In order to further protect and improve people 's livelihood, the government proposed to improve the income distribution system and standardize the income distribution order [2]. In this context, it is particularly important to conduct in-depth research on the impact of family members ' wage income on household consumption structure. This study not only helps us to understand the evolution of Chinese household consumption patterns, provide reference for policy formulation, promote consumption upgrading, but also provides an important reference for studying household consumption behavior and optimizing consumption structure.

In contrast, most of the existing literature focuses on the impact of population aging [3], education level and Internet use on household consumption structure. This article explores the family consumption structure from a new perspective - the wage income of family members.

This study uses CHFS data, combined with quantitative and qualitative analysis. First of all, through the questionnaire survey to collect data, a detailed understanding of the wage income of different family members and the characteristics of family consumption structure. Then, using Keynes 's classical consumption theory [4], this paper analyzes the impact of wage income on household consumption, and constructs a consumption function model for the differences in different types of consumption, and processes and analyzes the data to reveal the relationship between wage income of family members and household consumption structure. Finally, this paper will explain and discuss the research results in combination with relevant theories and actual conditions, hoping to explore the specific impact of family members ' wage income on family consumption structure.

2. Literature review

In 1857, the German statistician Ernst Engel put forward the famous " Engel 's law " [5]. At the beginning of the 20th century, the economist Marshall introduced the influence of the change of consumption structure in the economy into the whole economic theory system [6]. In the 1930 s, the Keynesian school studied the composition of consumption structure from the perspective of total consumption and consumption function theory from the perspective of macro economy, and further elaborated the relationship between consumption structure and industrial structure [7]. After the 1950 s, the theory of Western consumer economics shifted from the study of macro-social aggregate to the study of micro-individuals, taking the family as an individual unit to study, and the content was mostly to analyze the household consumption structure.

A large number of literatures have confirmed that household income and household assets are variables that significantly affect household consumption. Household income is the decisive factor supporting their current consumer spending behavior [8]. Household income and household assets can measure the human wealth and household wealth that play a key role in consumption [9]. Household asset allocation structure is also a key variable affecting consumer behavior [10]. At the same time, the inclusion of assets in the control can also avoid the interference of the wealth effect caused by the rise in asset prices on consumption changes [11].

In summary, although there are many studies on household income and household assets on household consumption, the literature on the choice of household consumption structure from the perspective of wage income of family members is still very rare. From this point of view, this paper uses the data of China 's household financial survey to conduct in-depth research on this.

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3. Research design

3.1. Data source

This paper uses the 2013 China Household Finance Survey (CHFS) of Southwest University of Finance and Economics, and research center 's ' questionnaire ' data. The sample size is 28143 volumes covering demographic characteristics, household assets and liabilities, household insurance and security, household expenditure and income as the data basis for analysis.

3.2. Model specification and variable definition

3.2.1. Model setting

Referring to Keynes 's classical consumption theory, the positive proportional relationship between consumption level and income level, that is, with the increase of income, consumption will also increase, but the speed of consumption increase will gradually slow down. Combined with the use of wage income to affect the household consumption structure, and for different types of consumption structure, the consumption function model is constructed:

$$CON_i = \lambda_0 + \lambda_1 MP_i + \gamma C_i + \omega_i \quad (1)$$

CON_i represents the total household consumption expenditure, including survival consumption, development consumption and enjoyment consumption, MP_i represents wage income, and λ_1 is its coefficient. C_i represents the set of control variables. λ_0 represents the constant term, and ω_i represents the random disturbance term.

3.2.2. Definition of variables

The types, names and descriptions of variables are shown in Table 1.

Table 1: Variables specific explanation table

Variable category	variable name	variable interpretation
Dependent Variable		
	LC	After the total sum of all household expenditures is added, the logarithm is taken.
	NC	The proportion of consumption necessary to compensate workers for necessary labor consumption
	DC	The proportion of consumer demand generated by people in order to seek better development
	EC	The proportion of consumer demand generated by people in order to seek better development
Independent Variable	L(wage)	The proportion of consumption that focuses on material life enjoyment as the main purpose
Moderator Variable	Job Stability	Frequency of job change
Control Variable	Gender	Age of respondents
	Household Size	The total population of the interviewed families

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Table 1: (continued).

	Marriage	Respondents married or not
	Registered Residence	Rural household registration = 1, urban household registration = 0
	Endowment insurance	Whether the respondents participated in the social endowment insurance
	Family Housing Assets	Respondents ' families own their own houses
	Per Capita Household Income	The per capita annual income of the Respondents ' family
	The Highest Academic Qualification	The highest degree completed by the head of household
	Numbers of families living in the house	The number of families living in this house
	Main economic activities	Main economic activities
	Whether living in the city	Whether living in the city
	foreign nationality	foreign nationality
	The number of houses in the community and outside the residence	The number of houses in the community and outside the residence
	The number of houses other than village	The number of houses other than village
	Overall happiness	Overall happiness
	individual ID without household	individual ID without household
	Year	Year
	Rural	Rural
	relationship to household head	relationship to household head
	relationship to respondent	relationship to respondent
	rural registered resident	rural registered resident
	Region	Region
	Amount of other income	Amount of other income

3.3. Descriptive statistics

Table 2 shows the descriptive statistical results of the main variables. The maximum value of wage income is 13.82, and the minimum value of wage income is 0, ranging from 0 to 13.82, indicating that the wage level has a wide distribution in the sample. The average wage income is 9.459, and the standard deviation is 2.088. The wage level is relatively concentrated,but there are some differences. On the whole, the descriptive statistical analysis of each variable is more consistent with the existing relevant research and the actual development situation, indicating that the data used is reasonable and reliable.

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Table 2: Descriptive statistics

Variable	Mean	SD	Min	Max
LC	8.076	2.641	0	17.22
LNC	3.517	3.557	0	8.787
L DC	7.126	0.516	6.078	8.028
LEC	7.371	2.199	0	9.657
L(wage)	9.459	2.088	0	13.82
Numbers of families living in the house	1.032	0.312	1	10
Main economic activities	1	0	1	1
Whether living in the city	1	0.00800	1	2
foreign nationality	2.993	0.0840	2	3
The number of houses in the community and outside the residence	0.150	0.524	0	15
The number of houses other than village	0.153	0.431	0	9
Household Size	4.165	1.696	1	18
Overall happiness	2.315	0.889	1	9
individual ID without household	2.582	1.524	1	18
year	2011	0	2011	2011
rural	0.429	0.495	0	1
relationship to household head	1.653	1.486	1	11
relationship to respondent	3.615	2.551	1	11
rural registered resident	1.427	0.495	1	2
region	1.792	0.796	1	3

4. Empirical results

4.1. Baseline regression

Table 3 reports the test results of the benchmark regression. The positive impact of wage income on LNC, LDC, LEC and LC has been significantly reflected in the four types of consumption. The coefficients of L (wage) are positive and show statistical significance in most models. This finding shows that as the wage level increases, the household 's consumption capacity will increase accordingly. Household size has a significant role in promoting consumption. In any model, the coefficient of Household Size is positive, and this effect is statistically significant. This means that the larger the family size, the higher the overall consumption level. From the fitting degree of the model, the R-squared value of the model m2 is the highest, which is 0.154, which means that the model is more effective in explaining developmental consumption.

Table 3: The regression results of different consumption types of families

	(1)	(2)	(3)	(4)
	m1	m2	m3	m4
VARIABLES	LNC	LDC	LEC	LC
Ln wage	0.071***	0.027***	0.054***	0.069***
	(0.027)	(0.004)	(0.012)	(0.015)
Household Size	0.625***	0.053***	0.167***	0.197***
	(0.046)	(0.007)	(0.020)	(0.026)

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Table 3: (continued).

Marriage	-0.001	-0.040***	-0.005	-0.147***
	(0.086)	(0.012)	(0.037)	(0.048)
Registered Residence	-0.603***	-0.225***	-0.282***	-0.184**
	(0.143)	(0.020)	(0.063)	(0.080)
Endowment insurance	0.072	0.039***	0.156***	0.057
	(0.087)	(0.012)	(0.038)	(0.048)
Family Housing Assets	-0.214	-0.110***	-0.242***	-0.464***
	(0.182)	(0.025)	(0.078)	(0.102)
Per Capita Household Income	0.000	0.000**	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
The Highest Academic Qualification	0.301***	0.081***	0.218***	0.260***
	(0.033)	(0.005)	(0.015)	(0.018)
Constant	0.831*	6.757***	6.459***	7.041***
	(0.453)	(0.065)	(0.198)	(0.252)
Observations	4,089	3,989	4,028	4,671
R-squared	0.065	0.154	0.093	0.074

4.2. Heterogeneity test

In order to test the influence of wage income of male and female family members on household consumption and consumption structure, the benchmark regression model is used to regress the sample data of male and female respectively. The results show that wage income has a more significant effect on women 's survival consumption, development consumption and enjoyment consumption than men, as shown in table 4.

Table 4: Gender heterogeneity test

	(1)	(2)	(3)	(4)
	m1	m2	m3	m4
VARIABLES	LNC	LDC	LEC	LC
Ln wage	0.023	0.009**	0.023**	0.029**
	(0.017)	(0.004)	(0.010)	(0.012)
X1	0.063***	0.006**	0.023***	0.015*
	(0.012)	(0.003)	(0.007)	(0.008)
Household Size	0.416***	0.087***	0.174***	0.175***
	(0.014)	(0.003)	(0.008)	(0.009)
Marriage	-0.462***	-0.084***	-0.266***	-0.270***
	(0.020)	(0.004)	(0.011)	(0.013)
rural	-1.019***	-0.794***	-0.907***	-0.689***
	(0.048)	(0.011)	(0.028)	(0.032)
Endowment insurance	-0.026	0.014	0.093***	0.098***
	(0.045)	(0.010)	(0.026)	(0.031)

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Table 4: (continued).

Family Housing Assets	-0.115	-0.111***	-0.380***	-0.528***
	(0.087)	(0.019)	(0.051)	(0.059)
Amount of another income	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
The Highest Academic Qualification	0.152***	0.067***	0.195***	0.190***
	(0.012)	(0.003)	(0.007)	(0.008)
Constant	3.382***	7.091***	7.659***	8.026***
	(0.130)	(0.029)	(0.076)	(0.088)
Observations	29,324	29,324	29,324	29,324
R-squared	0.075	0.228	0.108	0.067

5. Conclusion

Wage income has a significant positive impact on the consumption structure of households. Wage income not only determines the family 's disposable income level, but also relates to the family 's consumption ability and consumption preference. With the increase of wage income, families tend to increase their expenditure on non-essential items such as education, health, entertainment and tourism after meeting their basic living needs, thus promoting the consumption structure to a higher level and more diversified direction. Wage income can significantly promote the adjustment of household consumption structure and the increase of household consumption rate. The test verifies that the wage income of family members affects the household consumption structure through the frequency of work changes, and L (wage) can mainly affect the household consumption structure through the three paths of LNC, LDC and LEC, and all of them are positive.

Keynes ' absolute income theory holds that income determines consumption. To promote consumption growth, people must first develop the economy and increase residents ' income. Therefore, the government should first create more jobs, promote employment and reduce unemployment. Second, the government should optimize the income distribution system, maintain the simultaneous growth of residents ' income and economy, and narrow the income gap. Third, cultivate new consumption hotspots, expand domestic demand, and increase household consumption. Although the research on the relationship between wage income and household consumption structure has made some progress, there are still some deficiencies. Although the current research covers nationwide data, it is difficult to accurately reveal the unique differences between different income groups. The research method is relatively simple, which leads to the lack of comprehensiveness of the analysis results. Therefore, people need to use modern information technology such as big data to strengthen data collection and analysis and adopt more comprehensive and diversified research methods to reveal the internal logic of this relationship more accurately.

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U.S. Dollar Activeness Forecasting: Application of the Seasonal ARIMA Model

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Abstract: This article selects the US Dollar Activeness as the research object, and through the study, it predicts the US Dollar Activeness 12 months later. It also attempts to analyze the reasons for the fluctuations of the US Dollar Activeness at different stages. The US Dollar Activeness holds a high position in the international currency market, and its fluctuations can reflect the strength or weakness of the US dollar and the health of the economy. In the prediction process, this article introduces the ARIMA model to predict the future trend of the US Dollar Activeness and tries to identify its influencing factors. By using the seasonal ARIMA model, a forecast chart of the US Dollar Activeness for the next 12 months was obtained. The US Dollar Activeness is likely to maintain its strength in the short term, but there are still uncertainties. Predicting the US Dollar Index can influence future exchange rate fluctuations and monetary policy formulation, as it reflects the value of the dollar against a basket of foreign currencies, exerting a broad impact on global financial markets and economic activities.

Keywords: US Dollar Activeness, ARIMA model, Forecast.

1. Introduction

1.1. Research Background and Motivation

The U.S. dollar activeness serves as a crucial metric for evaluating the comparative value of the U.S. dollar in relation to a selection of foreign currencies [1]. Since the late 1970s, the U.S. dollar has appreciated, and the substantial purchase of U.S. securities by foreign investors has led to a shift from U.S. goods exports to securities exports. This transition marked the change from a trade surplus to a deficit in the early 1980s, with the deficit now accounting for nearly 4% of U.S. GDP [2]. These changes reveal that the role of the U.S. economy in the global economy is evolving, and they also highlight the importance for the U.S. to continuously adjust its economic strategies to address domestic and international economic challenges. Based on this, since time series models are widely used to predict the behavior of phenomena in many economics, the purpose of this paper is to identify the most suitable ARIMA model for predicting the U.S. dollar. The data selected for this study spans from 2016 to 2024 in order to achieve the most accurate forecast.

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1.2. Literature Review

In a globalized economic system, the value and activity of money are the key indicators to measure a country's economic strength and international influence. Especially for the United States, a country which occupies the core position in the global economy, the activity of the US dollar is not only the focus of financial markets, but also an important factor affecting the global economic dynamics. In the past decades, time series forecasting has played an important role in a wide range of domains including next-day electricity prices, financial market analysis and stock price prediction [3-5]. ARIMA model has become an effective tool for predicting financial time series such as US dollar index because of its advantages in processing non-stationary time series, capturing trends and seasonal patterns, and parameter optimization. In practice, an ARIMA model suitable for the dollar index prediction can be constructed through appropriate data preprocessing, model identification, parameter estimation and model testing steps.

Upon examining the historical patterns of the US dollar's exchange rate during each of the previous global economic crises, it has been observed that significant fluctuations in the value of the US dollar index are invariably linked to the improvement or deterioration of the global economy [6]. An in-depth analysis of the interplay between stock market returns, interest rates, and the US Dollar Index is conducted through a series of financial analyses, including time series examination, stationarity tests, Vector Auto Regression (VAR) modeling, and Granger causality tests. The findings revealed a mutual influence among the variables under investigation [7]. Also, the trend of the US dollar activeness is influenced by a multitude of factors, including the fundamentals of the US economy, interest rate policies, government attitudes, and the international economic environment. Forecasting its future trajectory requires a comprehensive consideration of the interplay and potential changes of these factors [8].

1.3. Research Contents

The main research content involves an in-depth analysis of the historical cyclical trends of the US dollar activeness and attempts to predict its trajectory over the next 12 months. The core of the research is to identify and analyze the key factors affecting the dollar activeness' volatility, including the fundamentals of the US economy, interest rate policy, government attitudes, and the international economic environment. Additionally, the study focuses on how the dollar activeness reflects the value of the dollar relative to a basket of foreign currencies and how such fluctuations impact global financial markets and economic activities.

Researcher selected data from 2016 to 2024 for their analysis. The research approach begins with historical data, employing time series analysis and stability tests to capture the time series characteristics of the US dollar activeness through the ARIMA model, including its trend, seasonal patterns, and non-stationarity. The paper also examines the historical performance of the dollar activeness during various global economic crises and its interactions with other macroeconomic variables to support the analysis and forecasting.

2. Methodology

2.1. ARIMA

The ARIMA model is a very popular and powerful tool in time series forecasting. The ARIMA (p,d,q) model, which stands for Autoregressive Integrated Moving Average, is a statistical model used for time series forecasting. It combines Autoregressive (AR), Integration (I), and Moving Average (MA) methods to process and predict data. The AR part uses previous values of the time series to predict

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the current value, the I part transforms a non-stationary time series into a stationary one, and the MA part uses past values of the stochastic disturbance terms of the time series to predict the current value.

$$y'_t = c + \varphi_1 y'_{t-1} + \cdots + \varphi_p y'_{t-p} + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t, \quad (1)$$

Before applying the ARIMA model, appropriate parameters p, d, and q are identified using the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots, where p is the order of the autoregression, d is the order of differencing, and q is the order of the moving average. After parameter determination, parameter estimation is performed using maximum likelihood estimation or other optimization techniques.

2.2. Data Selection and Processing

This paper chooses the monthly change of the US dollar activeness as an indicator, with data sourced from the Federal Reserve. To assess the stationarity of the data, a second-order difference test was conducted, followed by the ADF test (see Table 1), which confirmed stationarity with a p-value significantly less than 0.05. A randomness test using the Ljung-Box test indicated that the data was not purely white noise, as evidenced by a p-value less than 0.05, suggesting the presence of non-white noise characteristics. Thus, the next step would be to construct the ARIMA model. The results indicate acceptance of the null hypothesis, which states that the sequence is white noise. This test also provided insights into the optimal ARIMA order for the model.

Table 1: The ADF test results

P-value in ADF test	0.010	Stationary
P-value in random test	0.003	Non-white noise

3. Empirical Analysis

3.1. Model Selection

During the model optimization process, this paper selects the Akaike Information Criterion corrected (AICc) as the reference criterion. In the model fitting process, by comparing the seasonal ARIMA model with the ARIMA (0, 1, 0) model, it is observed that the values of AIC, Bayesian Information Criterion (BIC), and AICc in the seasonal ARIMA model are all smaller than those in the ARIMA (0, 1, 0) model (see Table 2). Consequently, the paper concludes that the seasonal ARIMA model is more suitable for forecasting.

Table 2: The related parameter results

	AIC	AICc	BIC
Seasonal ARIMA (0,1,0)(0,0,1)	412.04	412.17	417.17
ARIMA (0,1,0)	416.04	416.08	418.60

Expanding on this, the AICc is a modification of the AIC that adjusts for the number of estimated parameters in the model, making it a more robust measure for model selection, especially when the sample size is small. The lower AICc values in the seasonal ARIMA model suggest that it provides a better fit to the data with a more parsimonious model, thus making it a preferable choice for predictive purposes. Seasonal ARIMA models are particularly effective in capturing the periodic patterns in time series data, which is often a key feature in many real-world datasets. By incorporating

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seasonal components, these models can more accurately reflect the underlying structure of the data and enhance the predictive accuracy of the forecasts.

During the optimization phase, the most effective parameter set for the model was identified, leading to the belief that the optimal configuration had been achieved. A significance test, with p-values above 0.05, confirmed the statistical significance of the model.

3.2. Results

After ensuring the absence of white noise, the model was fitted using the ARIMA function. The seasonal ARIMA model outperformed the non-seasonal ARIMA (0,1,0) model, as indicated by the lower AIC, AICc, and BIC values.

Following the seasonal ARIMA model, the subsequent phase involves the construction of a U.S. Dollar Activeness model. By employing the forecast function, the final predictive model is illustrated in Figure 1. This methodology entails fitting the seasonal ARIMA model to the historical data of the U.S. Dollar Index, which accounts for its inherent seasonal patterns and non-stationary behavior. The application of the seasonal ARIMA model allows for forecasting the U.S. dollar's activity for the next 12 months. This model provides a reliable foundation for future economic predictions and strategic decision-making.

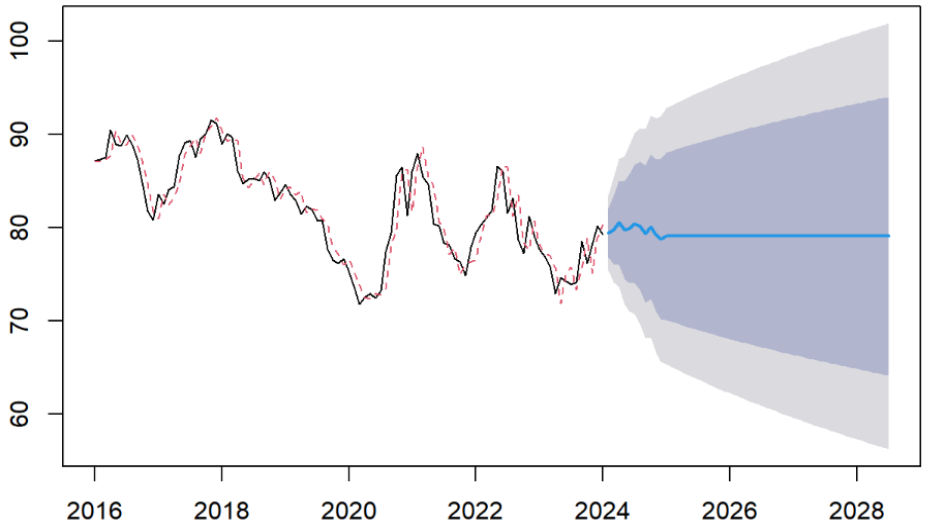

Figure 1: Forecasts from ARIMA (0,1,0)(0,0,1) [12]

4. Discussion

In summary, the reason why this model can only predict the U.S. Dollar Activeness data for the next 12 months is due to the use of the seasonal ARIMA model. Since the ARIMA (0, 1, 0) model is essentially a random walk model, the results obtained from the forecast may have certain limitations. The seasonal ARIMA model, while effective in capturing seasonal fluctuations, may not fully account for all underlying dynamics in the financial markets, which are influenced by a myriad of factors such as economic policies or market sentiment. Therefore, the predictions are inherently bounded by the assumptions and parameters set within the model. To enhance the accuracy and robustness of the forecasts, it is advisable to consider additional variables and models that could capture a broader spectrum of market influences, and to continually update the model with new data to reflect the most current market conditions.

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Given that Seasonal ARIMA models are mainly suitable for short-term forecasting, their long-term predictive capabilities may be limited. Although the forecast results in the report can provide valuable information for policymakers and investors, the uncertainty of the model's predictions and other market dynamics should be considered in practical applications. Firstly, in conjunction with the trend of the US dollar index, After the short-term market risk sentiment is released, there is room for a rebound; however, volatility is likely to remain high. It is still recommended that investors temporarily avoid risks [9]. Investors and policymakers should closely monitor economic data and market sentiment over the next 12 months to respond quickly to market changes. Secondly, implement risk management strategies to reduce potential losses. In addition, it is recommended to diversify investments, including different currencies and asset classes, to reduce dependence on the trend of a single currency. At the same time, continue to pay attention to macroeconomic factors affecting the US dollar, such as interest rate changes, inflation rates, and trade policies.

The enhanced precision of the SARIMA model over the ARIMA model is attributed to the incorporation of seasonal elements, such as trends and seasonality, which were previously omitted in ARIMA. This inclusion allows for a more accurate forecast by accounting for these patterns in the valid data [10]. However, regarding the predictive power of the model, since the seasonal ARIMA model can only forecast the dollar activity data for the next 12 months, this may imply that the model is more effective for short-term predictions but may have limited long-term predictive capabilities.

The predictive results of the report can provide valuable information for policymakers and investors, helping them make decisions. However, when applying it in practice, it is also necessary to consider the uncertainty of the model's predictions and other market dynamics

5. Conclusion

This paper utilizes the seasonal ARIMA model to forecast the trend of the US dollar index over the next 12 months, based on an in-depth analysis of historical data. The study's findings indicate that the dollar index is anticipated to maintain relative strength in the short term; however, its volatility is expected to persist due to the uncertainties inherent in the global economic environment. The predictive model employed in this paper demonstrates high accuracy in capturing the seasonal patterns and non-stationarity of the dollar index, offering valuable insights for investors and policymakers.

Regarding model selection, the seasonal ARIMA model outperforms the traditional ARIMA model in forecasting the US dollar index. This superiority is primarily attributed to its ability to account for seasonal fluctuations in the data, thereby providing a more precise reflection of market dynamics. Nevertheless, the model's predictive capabilities are constrained by its dependence on historical data and its limited capacity to anticipate potential nonlinear market changes and unforeseen events.

The conclusions drawn from this study are significant for comprehending the volatility of the US dollar index and for forecasting its future trajectory. Investors are advised to exercise caution in the short term and to closely monitor global economic indicators and policy shifts to promptly adapt their investment strategies. Policymakers can benefit from a clearer understanding of how exchange rate movements impact economic policies, enabling them to more effectively assess and mitigate potential market risks when devising relevant strategies.

For future research, there are several avenues for exploration: first, incorporating additional macroeconomic indicators into the model could enhance the accuracy and robustness of predictions; second, integrating advanced prediction methods, such as those involving machine learning and artificial intelligence, could be explored; and finally, the model's long-term predictive capabilities could be further validated and refined by incorporating more extensive historical data and cross-

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market information. These efforts could lead to a more practical and effective model, thereby offering stronger support for research and practical applications in related domains.

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Application Status and Development Trends of Carbon Capture and Storage Technologies

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Abstract: Carbon Capture and Storage (CCS) technology is an efficient and cost-effective method for reducing atmospheric CO_2 concentrations. Given the current reliance on fossil fuels by people, this method can be applied in factories and areas of human activity that emit substantial amounts of CO_2. This article introduces advanced carbon capture methods in various fields such as industry, ecosystems, and urban areas. Considering CCS technology from the perspectives of cost, efficiency, advantages, and limitations, it explores future development directions of carbon capture technologies in different sectors. This article introduces three different CCS technologies: Direct Air Capture, Bio Energy Carbon Capture and Storage (BECCS), and Oxy-fuel Combustion. Research and discussions on Direct Air Capture indicate that its main advantage lies in its convenience and high compatibility with various environments compared to other main CCS technologies. It can directly reduce atmospheric CO_2 levels through chemical methods, although there is still a need to enhance the adsorption efficiency of adsorbents. As an ecosystem-based CCS technology, Bio Energy Carbon Capture and Storage continues to play a significant role currently, and its principles of carbon capture are being applied in urban spaces using BECCS technology, with sustainability being the reason for its widespread application. Oxy-fuel combustion is used mainly in the industrial sector to rapidly and efficiently address the substantial CO_2 emissions from industrial activities. The article elucidates the opportunities and challenges that future carbon capture technologies will encounter.

Keywords: Carbon Capture, Direct Air Capture, BECCS, Oxy-Fuel Combustion.

1. Introduction

Owing to the swift development and rapid population growth in today's world, the substantial anthropogenic emissions of greenhouse gases have resulted in a global average temperature rise exceeding 1.2°C above pre-industrial levels [1]. In December 2015, At the UN Climate Change Conference (COP21) in Paris, France, the Paris Agreement was formally adopted by 196 parties. This agreement addresses climate change by setting and achieving incremental goals to reduce the gradual increase in the global average temperature. The ultimate aim is to minimize the increase in temperature to below 2°C compared to pre-industrial levels, becoming carbon neutral by 2050.

Extensive human activities, including the substantial consumption of fossil fuels, have resulted in excessive emissions of CO_2. Much of this CO_2 remains unsequestered due to ecosystem degradation

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from overexploitation. Addressing how to reduce carbon emissions and effectively capture and store CO_2 is vital to achieving carbon neutrality.

Carbon Capture and Storage (CCS) is employed in industrial and human activities to capture and store CO_2 generated during energy conversion processes, thereby preventing its release into the atmosphere. In some developing countries, fossil fuel-based electricity generation remains one of the primary methods. Compared to other carbon emission reduction methods, CCS can effectively alleviate the pressure of CO_2 emissions from certain power plants. Moreover, the captured CO_2 can be repurposed for secondary uses or sequestered in large-scale sites such as oceans and depleted mineral deposits. CCS technology has been demonstrated as a cost-effective and technically mature solution for reducing carbon emissions [2]. The direct application of CCS technology, based on the current energy infrastructure, can yield substantial environmental benefits. Based on data simulation analysis, achieving carbon neutrality by 2075 and 2000 would cost 12% and 71% more, respectively, without using CCS technology compared to utilizing it. This indicates that CCS technology can ensure cost-effectiveness in reducing carbon emissions while using carbon-intensive goods and energy sources [3]. This potential for high environmental value is a key reason CCS technology possesses significant application potential.

This paper, grounded in the current state of CCS technology, discusses the technical principles and application scopes of three methods: Direct Air Capture (DAC), BECCS, and Oxy-fuel combustion. The article introduces two primary methods of DAC technology and how they are employed in industrial activities. It elucidates some of the principles of oxy-fuel combustion and expands its contribution to waste incineration plants, apart from its use in industrial combustion for power generation. It also describes how BECCS technology integrates with specific fauna, flora, and ecological spaces for carbon capture in urban and natural ecosystems. Through comparative analysis, it highlights the advantages and limitations of these technologies and offers feasible recommendations.

2. Direct Air Capture

DAC is a technique that catches CO_2 directly from the atmosphere and stores it afterward. DAC differs from conventional carbon capture technologies that target the source of carbon emissions, as it focuses on the excessive concentrations of CO_2 present in the atmosphere. Captured from the air, the CO_2 is compressed into a more concentrated stream for subsequent storage and utilization.

Currently, mainstream DAC directly separates CO_2 from the atmosphere using artificial contactors. This approach has been demonstrated to be feasible and highly promising in potential net emission schemes. As a direct technical support for DAC, gas separation is becoming a mainstream research focus. Several mature gas separation technologies utilize physical processes. However, the composition of air is not constant, posing a current research challenge in ensuring the selective removal of CO_2 while leaving other components. Researchers should select media with a high affinity for CO_2 as artificial contactors to facilitate its separation.

2.1. Adsorption

Absorption represents a prevalent technique for DAC, akin to its established use in CO_2 capture from stationary sources. The process of using an electricity blower to force air into a filter that has a hydroxide liquid absorbent result in CO_2 reacting with sodium hydroxide to form sodium carbonate precipitate (Figure 1). This acid-base reaction facilitates CO_2 capture, employing techniques that increase the contact area between gas and liquid to maximize reaction efficiency. The second cycle starts from the causticizer unit. The sodium carbonate produced in the previous process reacts with calcium hydroxide within this module, forming calcium carbonate. The calcium carbonate is then

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subjected to calcination at 900°C, during which CO_2 is released and subsequently captured. The calcium oxide produced is mixed with water in a digester apparatus to regenerate calcium hydroxide. The sodium hydroxide in the reaction products is regenerated and returned to the contactor to initiate another absorption cycle.

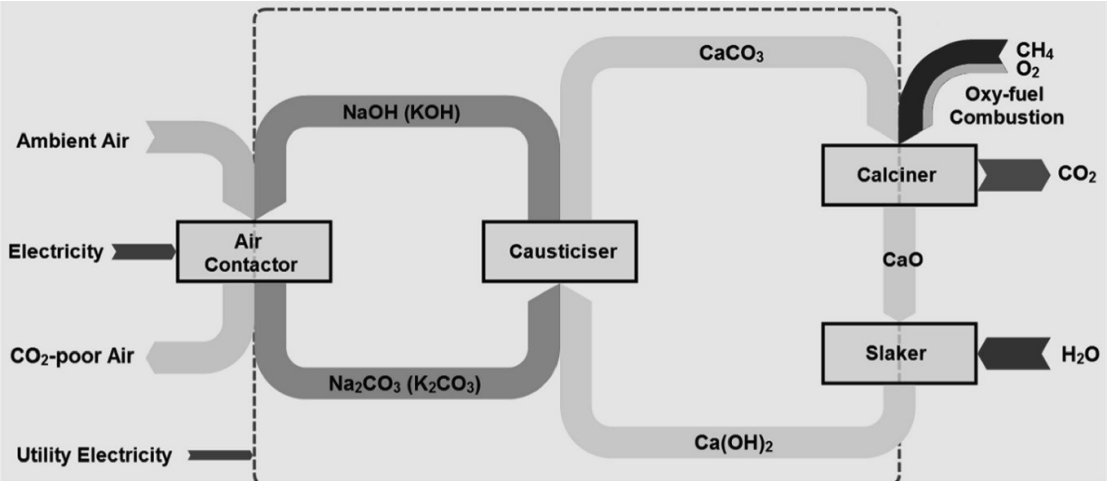

Figure 1: The theory of DAC technology [3]

2.2. Adsorption

Adsorption is a technique that employs solid sorbents instead of liquid solvents to capture CO_2 from air chemically, and the CO_2 captured undergoes gas-solid interaction. Initiating a chemical reaction between the surface and the adsorbate is what chemisorption involves, which creates new chemical bonds between the adsorbate and the substrate surface to ensure its immobilization. At the end of the cycle, these chemical bonds are disrupted by heating, releasing CO_2 from the solid sorbent. The liberated CO_2 can enter the recycling system for capture and further use. From the perspective of the operational environment and practical cost, the resin is an effective adsorbent due to its solid-state nature and inherent flexibility. This characteristic enhances its compatibility with mechanical equipment, significantly reducing initial equipment investment costs.

Additionally, this technology can utilize natural airflow instead of fans and blowers to direct air into the filter. Consequently, compared to absorption, adsorption demands less water and occupies a smaller footprint. From another perspective, using solid solvents in adsorption implies that the reactions occur in a relatively low-temperature environment, which can significantly reduce energy waste. Moisture swing adsorption (MSA) and temperature swing adsorption (TSA) are currently the two predominant methods of adsorption, and their reactions involve the moisturizing of the CO_2-enriched sorbent [4]. Figure 2 presents methodologies employed by various companies and the temperatures required for DAC through absorption and adsorption processes.

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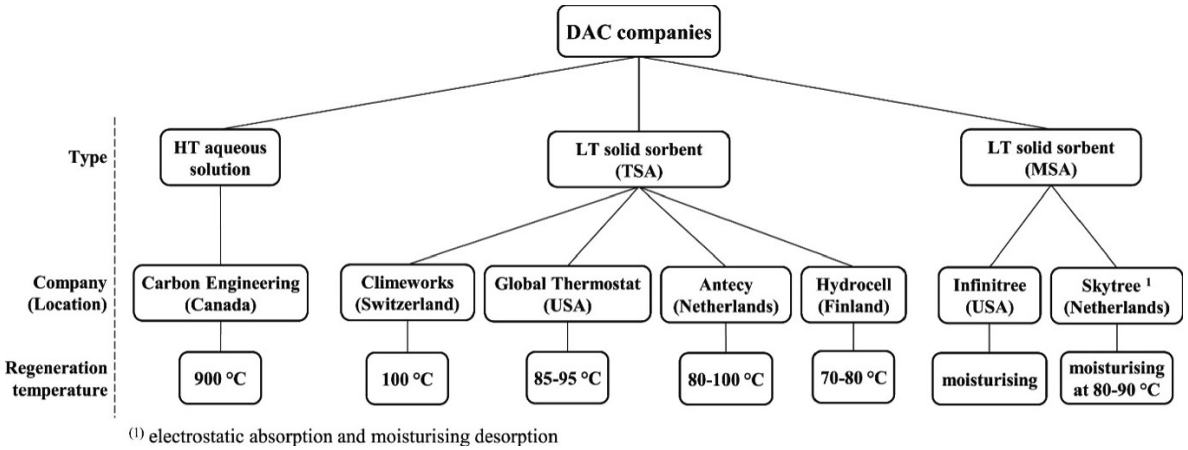

Figure 2: Methodologies employed by various companies and the temperatures required for DAC through absorption and adsorption processes [4]

DAC has a significant advantage over other carbon capture technologies because it can capture CO_2 efficiently in relatively small areas. This implies a smaller area of use and higher operational efficiency. Furthermore, it has lower environmental requirements which means it can operate under harsh conditions, continuously and stably capturing CO_2. However, DAC has not yet achieved large-scale commercial deployment as an emerging technology. It is constrained by the current development of contactor and adsorbent technologies, with the associated costs range from \$264–1,000/tCO_2. If the adsorption efficiency of the adsorbents can be enhanced and mechanical equipment improved, the widespread application of DAC technology in the future might become feasible [5].

3. Bio Energy Carbon Capture and Storage

3.1. Urban Spaces nd Natural Ecosystems

In terms of life sciences, organisms themselves can serve as mediators for carbon capture. Bio-capture and bio-sequestration are processes that enhance the ability of organisms and ecosystems to capture CO_2. Compared to the aforementioned capture methods, bio-capture of greenhouse gases exhibits characteristics of sustainability and cost-effectiveness, which could potentially confer a competitive advantage leading to broader adoption.

Many ecosystems have demonstrated significant carbon capture potential. For instance, mangroves capture an average of 654 kilograms of carbon per square meter annually [6]. Tropical forests and other natural ecosystems also serve as crucial carbon sinks, effectively storing carbon for extended periods. Biomass from these ecosystems also presents a more sustainable alternative to conventional fuel sources. Therefore, promoting reforestation efforts and prioritizing conservation initiatives are essential strategies to consider. In addition to terrestrial natural ecosystems, the oceans are also significant contributors to carbon capture and storage. As the largest carbon sink on Earth, the oceans store more carbon annually than all the forests combined. Enhancing carbon capture in the oceans through ocean fertilization is an effective method. This involves stimulating the growth of single-celled microalgae such as diatoms and seagrass by releasing CO_2 into the ocean. As these microalgae proliferate, they contribute significantly to carbon sequestration [7]. Nonetheless, ocean carbon capture technologies also confront several challenges. First of all, the complexity and fragility of marine ecosystems necessitate careful consideration to prevent adverse impacts on marine biodiversity and ecological balance. Secondly, the feasibility and efficacy of ocean carbon capture technologies require further research and assessment. Additionally, the costs and sustainability of these technologies must be taken into account to ensure their practicality in real-world applications.

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In urban spaces, besides traditional methods such as increasing roadside vegetation, we can also introduce new types of microalgae into artificial ponds. These ponds can function as open photobioreactors, capturing CO_2 and methane from the urban atmosphere. Flourishing under high CO_2 concentrations, these microalgae can double their biomass within 24 hours, making them more suitable than traditional tree planting methods [8].

3.2. Blue Carbon

Blue carbon refers to a biological process that utilizes marine activities and ecosystems, such as phytoplankton and marine plant ecosystems, to capture carbon in oceanic environments. Although coastal biological systems are small, their capacity to capture CO_2 is superior to other ecosystems, resulting in their size being unrestricted. At the same time, they can also store CO_2 for extended periods.

Mangrove ecosystems constitute a significant and irreplaceable part of carbon capture and storage within coastal ecosystems. Mangroves primarily inhabit coastal regions, where most of their rooted soils consist of submerged anaerobic sediments, with only a small portion of oxygenated soils exposed at the surface. This results in biomass decomposition occurring at a prolonged rate, effectively preventing CO_2 captured through photosynthesis from returning to the atmosphere. Additionally, mangrove soils harbor microbial communities, such as Rhizophora, which form biofilms over sediment surfaces (approximately 1-2 millimeters thick) to prevent greenhouse gases from escaping during low-tide exposure to sunlight from leaf litter and other biomass. Every year, 45-250 million tons of CO_2 is captured by the sediment in forest soil and the biomass surrounding mangrove roots [9].

As depicted above, tidal salt marshes also play a crucial role in carbon capture. Unlike mangroves, salt marshes are dominated by salt-tolerant shrubs and herbaceous plants, which are the primary contributors to carbon capture. The eco-structure of tidal salt marshes is unique, allowing for the sequestration of 428 teragrams (Tg) of carbon per year. Compared to other ecosystems, such as some tropical rainforests, they can even exceed the total carbon fixation capacity of all the tropical rainforests on Earth combined.

The issues faced by mangrove ecosystems are analogous to the shortcomings of marine ecosystems; their singular ecosystem structure renders them vulnerable. In the context of climate change, these ecosystems often fail to optimally fulfill their carbon sequestration roles. In the field of biological carbon capture technologies and methods, besides the need for developing new technologies, there is a growing recognition of the critical role that certain plants within ecosystems play in the carbon capture process. This implies that these plants should be protected from environmental changes and developmental disruptions.

4. Oxy-Fuel Combustion

Oxy-fuel combustion represents a promising CCS technology aimed at addressing the excessive CO_2 emissions associated with power generation. While some developed nations and regions, such as the United States and European union, are progressively phasing out traditional coal-based fossil fuels, achieving notable progress. Many developing countries, including China and India, continue to have a substantial demand for coal [10]. Fossil fuels remain a crucial component of our current energy matrix, indicating the inevitable reality of significant CO_2 emissions from fossil fuel combustion.

Oxy-fuel combustion technology integrates an air separation unit into the power generation process of coal plants. An air separation unit separates oxygen and nitrogen, and the enriched oxygen is then introduced into the boiler. The generated steam is directed into a turbine for electricity generation, while the resultant high-concentration CO_2 is condensed and purified, then compressed

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into solid form, facilitating subsequent utilization and storage. After condensation and separation, the recovered flue gas can also be used as an oxidant to re-enter combustion. This process achieves the objective of carbon capture. The advantage of oxy-fuel combustion technology lies in the preliminary filtration of nitrogen and other gases, ensuring that the exhaust gas primarily comprises water vapor (H_2O) and CO_2. Additionally, emissions related to nitrogen, such as NOx, are significantly reduced. Figure 3 presents the flowchart of the oxy-fuel combustion process used to generate power from fuels.

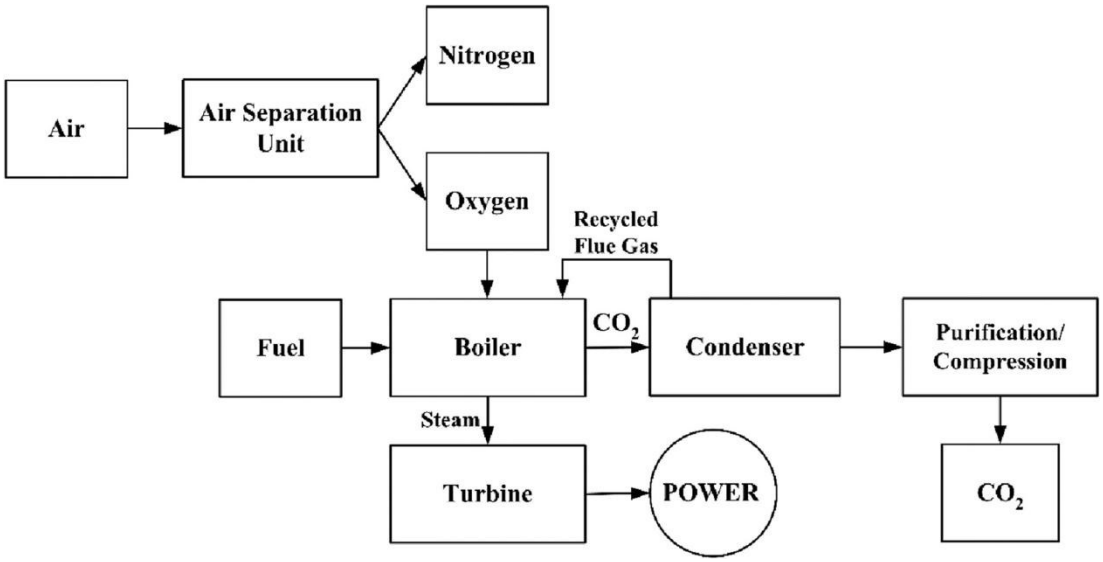

Figure 3: The flowchart of the process for oxy-fuel combustion to generate electricity from fuel [10].

In the oxy-fuel combustion process at coal-fired power plants, a novel system has been introduced that merges the condensation of CO_2 with the purification of flue gases. By increasing the condensation pressure to 3.0-4.0 MPa, experiments have yielded a 99.9% pure CO_2 gas stream. Additionally, the system has demonstrated a removal efficiency of over 99% for both SO2 and NO. Regarding carbon capture efficiency, this system achieves a rate of 92.61%, considered high within the current technological sphere [11]. Given the present energy infrastructure, coal-based fuel power plants still constitute a significant portion, necessitating many oxy-fuel combustion systems. This underscores the vast potential for application in the CCS domain.

Oxy-fuel combustion technology is not solely confined to industrial applications; it can also substantially contribute to carbon capture in urban space. The discussed studies suggest that oxy-fuel combustion is a promising technology due to its direct application to existing power plants and large-scale CO_2 -emitting combustion facilities, including biomass.

According to data from the World Bank, biomass accounts for over 50% of global annual waste [12]. Biomass waste, characterized by its high calorific value and abundant availability, can be utilized effectively for power generation or energy production, which supports sustainable environmental practices and circular economic growth. However, the combustion of biomass inevitably results in significant CO_2 emissions due to its primary composition of organic materials. In this context, the application of carbon capture technologies becomes essential to mitigate carbon emissions.

In Klemetsrud CHP, Norway, a carbon capture system is fitted into the waste-to-energy plant, which processes roughly 400,000 tons of non-recyclable waste annually. This facility produces 55 MW of thermal energy for district heating and 10.5 MW of electricity. Utilizing oxy-fuel combustion technology, it captures 400,000 tons of CO_2 each year, which is then permanently sequestered in the

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North Sea [13]. In Zorran City, Japan, the waste incineration facility employs a Toshiba-engineered alkaline water amine carbon capture technique, which secures 10 tons of CO_2 each day. This CO_2 is subsequently utilized in the cultivation of local crops and the growth of algae.

Overall, the application of oxy-fuel combustion technology in power generation is advantageous. Oxy-fuel combustion occurs in an environment with a higher oxygen concentration, leading to increased reaction temperatures that enhance combustion efficiency and further reduce energy consumption. Additionally, the technology can significantly decrease the volume of flue gases to around one-fifth, as approximately 80% of flue gases in air combustion are nitrogen, which results in an increase in boiler efficiency [14].

However, the technological advancement of oxy-fuel combustion is still in its initial stages, requiring extensive testing and pilot operations to prove its feasibility. From another perspective, as clean energy generation increasingly replaces traditional combustion-based power generation, the progress of oxy-fuel combustion technology may be challenging due to the reduced demand for combustion-based power generation.

5. Conclusions

This article provides an overview and discussion of carbon capture technologies across various sectors. Three distinct carbon capture methodologies are delved into: DAC, BECCS, and Oxy-fuel combustion. The feasibility of carbon capture technologies as a means to mitigate environmental change and facilitate carbon neutrality is substantiated by it. In addition, the strengths and limitations of these carbon sequestration techniques have been identified, offering a foundation for feasible suggestions concerning their prospective avenues of advancement in this review. The key conclusions are as follows:

DAC, as a method utilizing chemical reactions to capture CO_2 offers several advantages. It imposes minimal requirements on operational environments and can be deployed virtually anywhere due to its direct extraction of CO_2 from the atmosphere, making it highly adaptable for densely populated urban areas with high CO_2 densities. However, its limitations include the current high cost of the contactor and the need to enhance the adsorption efficiency of sorbents.

Oxy-fuel combustion is primarily applied in the field of power generation from fossil fuels, which still dominate the global energy mix. This implies that widespread adoption of oxy-fuel combustion could yield significant carbon capture benefits in the current scenario. Additionally, oxy-fuel combustion, by utilizing enriched oxygen as the combustion gas, can achieve CO_2 concentrations exceeding 90%. Limitations accompany its advantages, as its applicability is relatively narrow and requires extensive deployment to demonstrate its efficiency.

BECCS, compared to Oxy-fuel combustion and DAC, requires less human intervention and research effort. As a carbon capture technology playing a significant role in ecosystems, BECCS can capture substantial amounts of CO_2 through processes such as photosynthesis in ecosystems like mangrove ecosystems. Correspondingly, it provides insights into carbon sequestration in urban spaces. Nevertheless, these ecosystems are more fragile compared to others due to their unique ecological structures. Therefore, greater attention is needed on how to protect these vulnerable ecosystems.

Considering the severity of current environmental change issues, CCS technology is a reliable countermeasure. If existing CCS technologies can be improved and applied, they can alleviate climate change issues to a certain extent. However, CCS technology also has certain limitations. For instance, some ecosystems are relatively fragile and cannot sustain high-efficiency CO_2 capture. Therefore, integrating CCS technology with other technologies and applying them scientifically and rationally across various fields to ensure environmental sustainability and recyclability is a key factor in addressing climate change. For humanity, while continuously advancing carbon capture

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technologies, it is essential to minimize greenhouse gas emissions as much as possible, as this is the essence of achieving carbon neutrality.

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The Impact of Russia-Ukraine Conflict on the Sales of Electric Vehicles in China

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Abstract: The Ukraine conflict has had a unique impact on EV sales growth in China, a key market for EV innovation and adoption. This study explores the correlation between geopolitical tensions and the surge in EV sales in China. Utilizing time series analysis methods, this paper assesses EV sales trends before and during the conflict. Coincidentally, the findings suggest that the conflict is driving growth in EV sales, likely due to a combination of factors, including increased awareness of energy security, a shift to sustainable transportation, and government incentives aimed at supporting the domestic EV industry. Quantitative analysis using an ARIMA model reveals that EV sales experienced an estimated increase of approximately 15% within the first six months following the onset of the conflict compared to pre-conflict projections. This significant uptick underscores how external geopolitical events can catalyze shifts in consumer behavior toward more sustainable alternatives. While sales are growing, the study also points to potential challenges such as supply chain disruptions and rising costs that could impact long-term growth. These challenges highlight the complex interplay between global political events and domestic market trends. The findings advise policymakers and industry players to remain vigilant and proactive to ensure continued growth in China's EV industry amidst these evolving dynamics.

Keywords: Electric Vehicles (EVs), China, Russia-Ukraine Conflict, ARIMA Model.

1. Introduction

The Russia-Ukraine conflict that erupted in February 2022 sent shock waves through the global economy, affecting various industries and markets in unpredictable ways [1]. One of these markets is China's electric vehicle (EV) industry, which has become a global leader in EV technology innovation and adoption. This study aims to explore the subtle relationship between geopolitical tensions in Russia, the Ukraine conflict and the subsequent surge in EV sales in China.

China, as a major player in the global EV market, has achieved significant growth in recent years driven by its commitment to reducing carbon emissions and promoting sustainable transportation [2]. However, the outbreak of conflict adds a new dimension to market dynamics that could change the trajectory of EV sales growth.

This paper briefly introduces the Chinese EV market, the Russia-Ukraine conflict and the objectives of this study, laying the foundation for a comprehensive analysis of how geopolitical events affect domestic market trends, especially the background of EV sales.

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The rapid expansion of China's electric vehicle market has benefited from technological advances, favorable government policies, and increased consumer awareness [3]. However, the Russia-Ukraine conflict has created a layer of complexity that has implications for energy security, global supply chains, and consumer preferences.

This study attempts to address the following questions:

How does the Russia-Ukraine conflict affect electric vehicle sales growth in China?

The Ukraine conflict has led to a sharp rise in energy prices, making traditional fossil fuels more expensive and less attractive. This shift in energy costs has inadvertently accelerated interest in alternative energy sources, including electric vehicles. According to the International Energy Agency (IEA), rising energy prices have led to a 9% increase in global electric vehicle sales in the first half of 2022, with China accounting for a large portion of this growth [4].

In addition, conflicts have disrupted supply chains for key raw materials needed for EV battery production such as lithium and cobalt. Despite these challenges, Chinese manufacturers have been able to maintain production levels and even increase market share due to their strong domestic supply chains and vertical integration strategies.

This paper will examine the correlation between the timing of conflict and EV sales trends in China through time series analysis. This study aims to gain insight into the correlation between geopolitical tensions and EV sales trends compared to studies of the impact of school district changes on housing prices, which found that policy changes had a significant impact on market outcomes [5].

The findings will provide policymakers, industry stakeholders and investors with valuable insights to help them navigate the changing landscape of the EV market amid global political instability. By understanding the role of geopolitical events in shaping market dynamics, stakeholders can better anticipate future challenges and opportunities for the EV industry.

In summary, the Russia-Ukraine conflict has created a unique set of circumstances affecting the Chinese EV market. This study will reveal the resilience of the EV industry and its ability to adapt to external shocks, providing a basis for future strategic planning for the industry.

2. Research Design

2.1. Data Source

The data utilized in this study were sourced from the China Automobile Dealers Association (CADA), a reputable organization that provides comprehensive statistics and analysis on the automotive market in China. CADA compiles data on various aspects of vehicle sales, including electric vehicles (EVs), through extensive surveys and industry reports. This data encompasses monthly and annual sales figures, trends in consumer preferences, and insights into market dynamics influenced by external factors such as geopolitical events. By leveraging CADA's data, this research ensures accuracy and relevance in examining the correlation between the Russia-Ukraine conflict and EV sales growth in China. The dataset includes information on sales volumes before and during the conflict, enabling a robust time series analysis to assess the impact of the conflict on the domestic EV market. The insights derived from this data are crucial for understanding the evolving landscape of China's electric vehicle industry amidst global challenges.

2.2. Augmented Dickey-Fuller Test for Unit Roots

After completing the initial data processing for the model, the analysis begins with a unit root test. This test is based on the hypothesis that a unit root is present. It involves examining the absolute differences between the observed time series data and its linear trend at various time points. If the time series data is nonstationary, a significant gap will emerge between the empirical observations and the linear trend, resulting in a high ADF test statistic. In contrast, if the data is stationary, the

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observed values will closely follow the linear trend, leading to a lower ADF test statistic. After conducting the ADF test in Stata, Table 1 reveals that the p-values for the log regression of both datasets are below 0.1. Therefore, it is justifiable to reject the null hypothesis, indicating that the model is unstable and unviable.

Table 1: Weak stationarity test

	t	p
Ln value	-3.191	0.0861
1st order difference	-7.554	0.0000

2.3. ARIMA Model

The ARIMA model serves as a tool for forecasting by analyzing historical time series data to predict future outcomes. It is based on the statistical principle of serial correlation, which suggests that previous data points can influence and shape subsequent observations. The complete name of the ARIMA model is Autoregressive Integrated Moving Average, which includes three key components: the autoregressive (AR) part, the integration (I) element, and the moving average (MA) aspect.

In the ARIMA of (p, d, q) model framework:

The letter "p" signifies the autoregressive part, which indicates how past observations impact the model, specifically referencing values from the previous p periods. The core concept of the autoregressive model is that current observations can be represented as a linear combination of the values from the last p periods. The precise mathematical formulation is illustrated in the following equation:

$$x_t = \varphi_0 + \varphi_1 x_{t-1} + \varphi_2 x_{t-2} + \cdots + \varphi_p x_{t-p} + \varepsilon_t \tag{1}$$

The symbol "q" denotes the moving average component, which relates to the lagged values of the error term, specifically those from the previous q periods. The moving average model demonstrates the relationship between the current observation and past white noise. Its exact mathematical representation is provided in the following equation:

$$x_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_p \varepsilon_{t-p} \tag{2}$$

"d" indicates the degree of differencing.

Differencing is intended to transform a non-stationary time series into a stationary one. In this analysis, the AR model examines weekly sales data for electric vehicles in China before the onset of the Russia-Ukraine conflict in February 2022, while the MA model employs the error term to forecast future sales trends.

3. Empirical findings and examination

3.1. Determining the Order

In this section, the initial task involves utilizing PACF and ACF plots to determine the appropriate order for the daily and weekly logarithmic returns of electric vehicle sales in China. The findings from this analysis are presented in Figure 1, which illustrates the sales figures for electric vehicles in the country.

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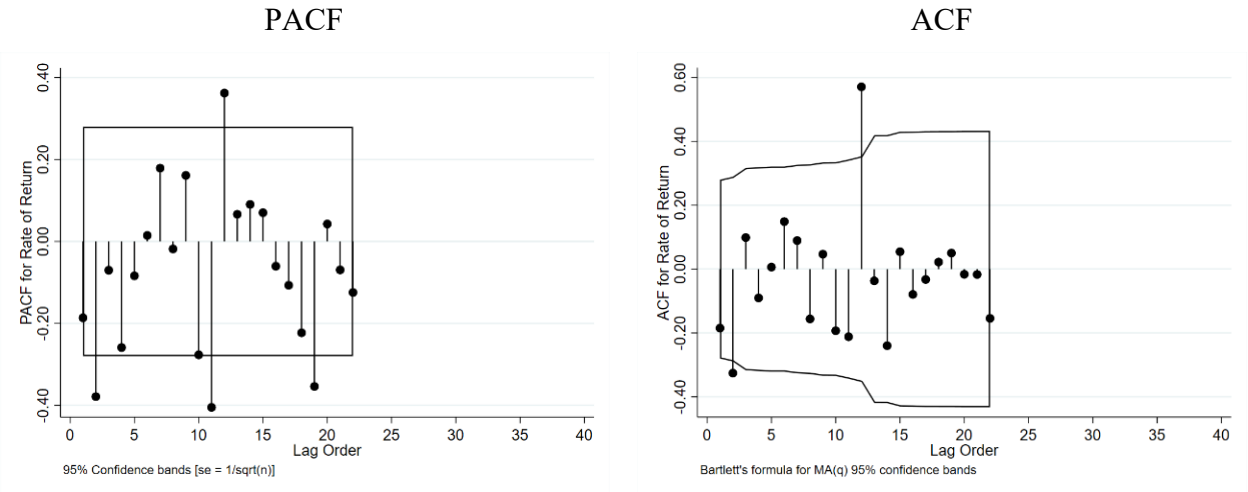

Figure 1: ARMA (p, q) identification
Photo credit: Original

When examining a time series, a decaying tail in the ACF plot combined with a sudden cut-off in the PACF plot indicates that an AR model is suitable for the data, with the cut-off point in the PACF denoting the ideal value for p. Conversely, if the PACF shows a decaying tail while the ACF has a clear cut-off, it suggests that an MA model is more appropriate, where the cut-off in the ACF indicates the optimal parameter value for q. By employing this method on the dataset, values for p and q can be systematically identified, which aids in the development of an ARIMA (p, d, q) model.Following the model's construction, this section will perform a residual analysis, which will be detailed in the upcoming steps.

Table 2: Test of Residual

Model	Portmanteau (Q) statistic	Prob > chi2
ARIMA (11,1,2)	20.8859	0.9717

Table 2 indicates that the ARIMA models have successfully met the criteria of the residual test, implying that the error term behaves like a white noise process, demonstrating its unpredictability [6].

3.2. Results of Forecasting and Analysis

After the ARIMA model was created and the residual tests were conducted, forecasts were generated using Stata for the timeframe following the stock market crash on June 15, 2015. A summary of the results acquired is presented below:

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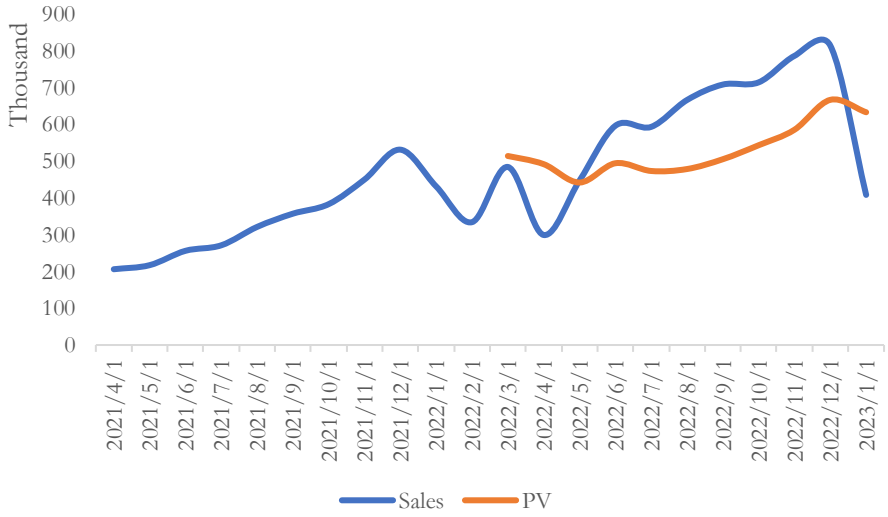

Figure 2: Sales before and after Russia-Ukraine Conflict
Photo credit: Original

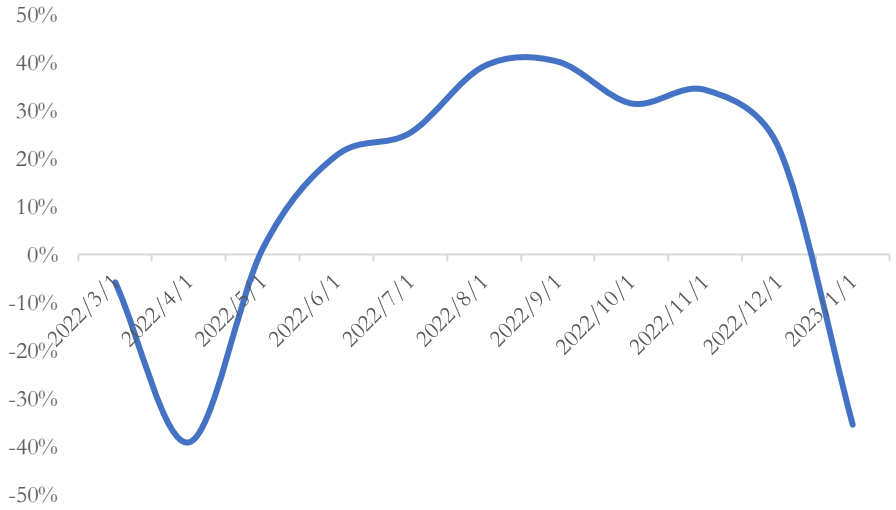

Figure 3: The impact of Russia-Ukraine Conflict on sales of new energy vehicle
Photo credit: Original

As illustrated in Figure 3, ARIMA modeling techniques were utilized to forecast the effects of the Russia-Ukraine conflict on electric vehicle (EV) sales in China, generating predicted data that mirrored trends before the conflict. This predicted data was then compared with actual sales figures following the conflict to evaluate its impact on consumer behavior and market dynamics. The analysis indicated notable discrepancies between the forecasted and actual sales data two months after the onset of the conflict. Initially, our model anticipated a consistent growth in EV sales, aligned with prior trends influenced by government incentives and heightened consumer awareness of environmental issues [7, 8]. However, Figure 3 reveals that as the conflict intensified, actual sales significantly surpassed our forecasts, implying that external factors may have affected consumer behavior in ways not accounted for in our original model.

A key explanation for this phenomenon is that the conflict may have created a sense of urgency among consumers to transition to EVs, especially as geopolitical tensions led to soaring global fuel

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prices. Research has shown that instability in oil markets can prompt consumers to consider EVs as more stable and sustainable alternatives [9]. This shift reflects changes in consumer sentiment, where geopolitical events can accelerate the adoption of technologies perceived as less vulnerable to external shocks [10].

Additionally, seasonal trends affecting car sales must be taken into account. Traditionally, EV sales in China have seen a significant decline in winter, attributed to various factors, including lower temperatures affecting battery performance and consumer behavior, with potential buyers likely to delay purchases until spring conditions are more favorable [11]. Therefore, although actual sales figures exceeded expectations, they were still influenced by these seasonal variations. The combination of conflict-induced consumer interest and a typical winter slowdown creates a complex picture of market dynamics.

Moreover, the impact of government policies cannot be ignored. In response to the changing geopolitical landscape, the Chinese government has actively promoted the adoption of electric vehicles through subsidies and infrastructure development [12]. These initiatives may have played a crucial role in mitigating the impact of seasonal declines and driving sales figures upward in winter. The interaction between government support and consumer behavior highlights the importance of policy in shaping market outcomes, particularly during times of crisis [13].

It is also worth noting that the data obtained reflects only part of the broader market context. Other factors, such as supply chain disruptions caused by conflicts, may further affect sales patterns. Global tensions exacerbate semiconductor shortages and logistical challenges facing the automotive industry, which could impact the availability of electric vehicles in the market [14]. This area warrants further investigation to fully understand the intricate relationships between external shocks, consumer behavior, and production capacity.

In conclusion, the forecast results reveal a notable trend in EV sales in post-Russia-Ukraine conflict China, characterized by actual sales significantly exceeding forecasts. This increase can be attributed to heightened consumer demand, supportive government policies, and seasonal fluctuations inherent in vehicle sales. Insights gained from this analysis emphasize the need for research that considers both geopolitical factors and local market dynamics to explore the long-term impacts of these trends and the evolving patterns of EV adoption in response to global events. Understanding these dynamics is critical for stakeholders in the automotive industry as they navigate an increasingly complex market environment.

4. Conclusions

In summary, the Russia-Ukraine conflict has had a profound and multifaceted impact on EV sales in China. This study shows that, contrary to initial expectations, the Russia-Ukraine conflict contributed to a surge in EV sales due to increased consumer awareness of energy security, rising fuel prices, and supportive government policies. Analysis shows that actual sales figures exceeded expectations and reflected consumer shifts.

Moreover, despite traditional market volatility, the interaction between seasonal trends and government initiatives played a key role in sustaining growth.

Nonetheless, issues like supply chain disruptions and increasing production costs present significant risks to the long-term viability of the EV market. As the industry navigates these challenges, it is crucial for stakeholders to stay alert and flexible to maintain ongoing growth.

Consumers should view electric vehicles (EVs) as sustainable options, keep abreast of government subsidies that reduce cost of ownership, and advocate for better charging infrastructure. Manufacturers, on the other hand, need to increase supply chain resilience through diversified sourcing to mitigate geopolitical disruptions and actively participate in government subsidy programs. Educating consumers about the benefits of electric vehicles and investing in research and

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development, by adjusting strategies to changing consumer preferences during periods of geopolitical instability, both consumers and manufacturers can navigate the complexities of China's electric vehicle market and ensure sustainable growth amid global challenges.

This research examines how the Russia-Ukraine conflict has influenced electric vehicle (EV) sales in China, revealing that heightened consumer awareness regarding energy security and escalating fuel prices have contributed to a significant increase in EV sales. ARIMA modeling indicates that actual sales surpassed pre-conflict projections by approximately 15% within six months. While government incentives are crucial, ongoing challenges like supply chain disruptions could jeopardize the market's long-term stability.

This paper encourage consumers to view electric vehicles as sustainable options while understanding subsidies. Manufacturers should increase supply chain resilience and engage with government initiatives. The study highlights the need for stakeholders to adjust strategies to changing consumer preferences amid geopolitical instability. Understanding the interaction between global events and domestic market dynamics is critical to the continued growth of China's electric vehicle industry.

The study highlights the importance of understanding the complex relationship between global events and domestic market dynamics, and future research should further investigate the long-term implications of these trends for policymakers and industry participants to gain a more comprehensive understanding of changes in EV adoption in response to ongoing geopolitical developments.

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Pathways in Biomimicry to Enhance Solar Technology Capabilities

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Abstract: Efficiency, longevity, and cost-effectiveness in current solar modules are compromised in pursuit of best balancing one another. This report explores the potential of enhancing solar cell practicability through biomimicry. Like solar cells, biological organisms absorb heat during photosynthesis, positioning nature as an inherent source of inspiration to tackle current technological challenges. Significant improvements have been achieved by mimicking structures such as the leaf epidermis for multidirectional light capture, cell membranes for protective encapsulation, and butterfly wings for enhanced light absorption and reflection. For instance, incorporating a BT layer for thermoregulation mimics plant transpiration, enhancing cooling efficiency. Additionally, hierarchical structures inspired by leaf geometry increases angular robustness in both dye-sensitized solar cells and passive emitter and rear cells, and lipid biomolecule interactions shelter halide perovskites from environmental degradation. The nanostructures of butterfly wings also show promise in supporting thin film PVs to overcome conversion inefficiency. Lastly, the reflective properties of butterfly wings have led to advancements in solar concentrators, improving power-to-weight ratios. These examples highlight the untapped potential of biomimicry in furthering the viability and deployment of solar technologies.

Keywords: Biomimicry, Bioinspiration, Biomimetics, Bioreplication, Solar Energy.

1. Introduction

Living organisms exhibit a remarkable range of functionalities, such as efficient light management and adaptive mechanisms. The emulation of such ideas and processes observed in biological systems is known as biomimicry. Borrowing inspiration from nature, biomimicry promotes efficiency and effectiveness in engineering solutions while focusing on the environment and sustainability [1].

Engineered biomimicry can be broken down into three primary modes, with each alluding to a progressively deeper level of imitation. First, bioinspiration implies the application of concepts in nature without copying. For example, helicopters and dragonflies can propel themselves into flight, yet how they do so varies greatly. Second, biomimetics suggest the direct imitation of organisms, specifically their biological functions. Famously, the curvature of the Japanese bullet trains' front end was modeled based upon the shape of birds' beaks to maximize aerodynamics. Finally, bioreplication takes biomimetics a step further by closely recreating natural structures and, when possible, the materials [2].

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Addressing the global energy crisis has become urgent due to the excessive consumption of fossil fuels and the resulting greenhouse gas emissions. Among renewable energy sources, the sun is the most abundant and readily available. Therefore, solar photovoltaic (PV) systems have emerged as a promising solution to energy challenges, and demand for it is only rising. Global PV cumulative capacity stood at 1.6 TW in 2023. Solar energy is expected to represent half of global energy demand's growth between 2024 and 2025 [3].

The viability of solar cell types hinges on the golden triangle: power conversion efficiency, stability, and cost [4]. Silicon-based materials are currently the benchmark for commercial light-harvesting systems, commanding approximately 95% of the market share. Silicon's crystalline structure has enabled a high efficiency of up to 27%, and the booms in production and technological innovation with this material has significantly lowered fabrication costs over the years [5]. While other technologies such as organic solar cells are gaining traction, they have yet to match silicon's high efficiency and scalability. Silicon PVs, however, may be nearing their maximum efficiency as established by Shockley-Queisser limit, which theorizes that silicon's fixed band gap of 1.1 eV prevents an efficiency of over 30% [5]. The recent perovskite-on-silicon tandem solar cells have shown the potential to rival silicon's high efficiency and stability, but scalability remains a challenge [6]. Overall, the market is in need of more options for successful solar technologies.

The intersection between the two—biomimicry and solar technologies—is inevitable as the functions of solar technologies inherently mirror photosynthesis, a biological process where light is absorbed and converted into electrochemical energy. There are three key characteristics of nature which solar devices can benefit from: simplicity, dissipation of heat, and the use of soft matter. Integrating complex mechanisms with versatile designs can instill elegance into solar PVs. As a result of the inability to absorb all incident light, solar devices are prone to increased operating temperatures, which degrade electrical performance and reliability. Additionally, the elasticity of biological tissues can inspire more efficient designs [7].

Engineered biomimicry can provide a framework to guide the enhancement of the efficiency, durability, and cost-effectiveness of solar technologies. This paper explores how biomimicry—through combinations of bioinspiration, biomimetics, and bioreplication—has contributed to different technologies in this rapidly expanding sector and encourages further research into the integration of nature in solar devices.

2. Applications of the Leaf in Solar Technology

Within the typical plant leaf anatomy, vascular bundles (veins), spongy cells, and the epidermis, all of which aid in regulating health and homeostasis, have been pinpointed as structures that can inspire innovation in cell efficiency and stability (Figure 1) [8].

2.1. Vascular bundles and spongy cells

The vascular bundles and spongy cells facilitate plant cooling in a biological process known as transpiration. First, water rises to the leaf from the soil via capillary action and is spread evenly across the leaf surface through vascular bundles. It then diffuses into the extensive intercellular space within the spongy cells. Once warmed, the liquid vaporizes and is expelled through the stroma, releasing heat and preserving the photosynthetic process by stabilizing internal temperatures [8].

Thermal management is a current concern for solar technologies, as unabsorbed incident radiation lowers efficiency and lifespan. There are three existing approaches to decrease heat, but each has its setbacks. Active cooling involves machinery to pump coolant water or air, but such devices require installation costs, regular maintenance, and reductions in net output power. Passive cooling, such as with adding aluminum fins and heat sinks, may be easy and inexpensive; it, however, provides

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minimal performance enhancement due to the low heat transfer rate. Though showing future potential, phase-change material cooling shares the same limitation as passive cooling due to low thermal conductivity [9]. A process like transpiration can guide solar thermal management systems to achieve cooling with simplicity.

Inspired by plant transpiration, Huang et al. applied the concept of water as a coolant to address the high operating temperatures current solar PVs face. They introduced a biomimetic transpiration (BT) layer between a solar cell and a steel wire mesh base. This porous layer, attached to the underside of the cell for thermal contact, consists of natural bamboo fiber bundles surrounded by hydrogel cells (Figure 1). The bamboo fibers, connected to a water tank, are analogous to vascular bundles by uniformly distributing water throughout the 1mm thick device. Formed in an efficient 3D structure, the hydrogel, made of potassium polyacrylate (PAAK), a super absorbent polymer, acts like spongy cells and offers excellent water absorption properties. With the device intact, excess heat is dissipated as water vapor at a transpiration rate similar to that of a natural leaf. Incorporating the BT layer led to a 26ºC temperature reduction and removal of 75% of the excess heat while maintaining a 14% electrical output [8]. This innovation can support the creation of 650 GW of additional power worldwide, nearly 40% more than the current global PV capacity.

Moreover, the model's low cost and flexibility make the future prospect of this technology realistic. The materials used in the BT layer, bamboo fibers and PAAK, are both eco-friendly and economical. They are commercially popular too, contributing to the model's capital cost being only 2% of a commercial PV panel—1.1 $/m² compared to 55 $/m². The BT model also achieves similar results using seawater. Given the increasing scarcity of freshwater, this attribute cements the BT layer as a worthy cooling solution [8].

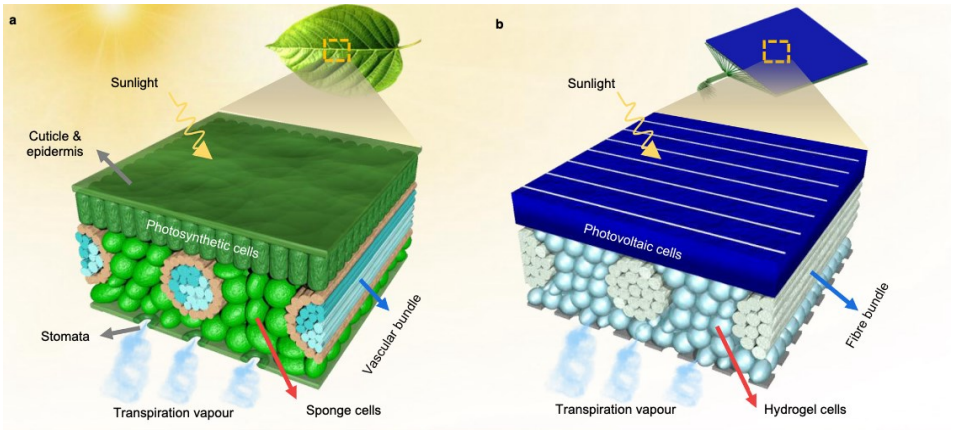

Figure 1: Structure of the anatomy of the leaf and the biomimetic transpiration (BT) layer [8].

2.2. Epidermis

As the first point of interaction between the leaf and incoming photons, the epidermis is indirectly responsible for the dispersal of light into internal structures. The epidermis is also capable of capturing light from all directions [10, 11].

In the solar technology market, bifacial solar cells are the most similar to the leaf epidermis in terms of absorption properties. These modules utilize both the front and rear sides, supporting a 30% increase in power output for large PV systems compared to their traditional monofacial counterparts. This reason and its similar cost to conventional silicon PVs has contributed to this innovative technology's increasing popularity. However, bifacial solar cells are complex devices; despite their potential, more verification regarding its durability is needed. Previous studies have suggested that structural intricacies make these cells susceptible to deterioration. For example, frameless double-

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glass cells and backside anti-reflective coatings could inadvertently lead to potential induced degradation. While bifacial solar cells are poised for success, gaps in knowledge inhibits their widespread adoption.

Noting the risks in new model designs like bifacial solar PVs, Ju Yun et al. fabricated five light-trapping layers inspired by the different geometries of epidermal cells to achieve panoramic light capture. As the epidermis has evolved into different orientations given the effect of the surrounding environment and individual plant energy needs, Ju Yun et al. developed five morphologies (Figure 2). These light-trapping layers were designed for both dye sensitized solar cells (DSSCs) and passive emitter and rear cell (PERC) solar cells in mind [10, 11].

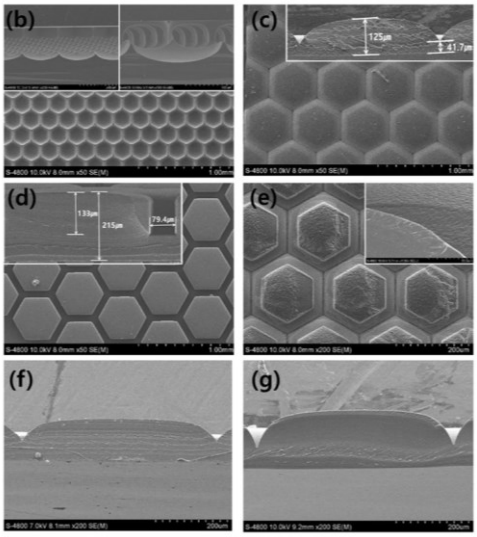

Figure 2: The five proposed morphologies of modified lens arrays: (c) traditional, (d) pillar-shaped, (e) array with rough surfaces, (f) flat, and (g) array with space between patterns [10].

The attachment was made by overlaying polydimethylsiloxane (PDMS) onto an engraved silicon stamp mold. First, the silicon wafer was prepared via photolithography and ultraviolet radiation exposure. Hexagonal shapes were then patterned onto the mold through Bosch and isotropic etching. After cleaning the wafer, PDMS was applied using a spin coater and peeled off upon conforming to the new shape.

Two geometries stood out in different scenarios. Tests with 60º Gaussian-scattered incident light displayed that the lens array layers increased light absorption by 70% compared to standard DSSCs. With scattered light, pillar-shaped arrays exhibited the highest conversion efficiency with vertically incident light and performed well with oblique or scattered light. For varied heights, the pot-shaped array achieved the best results for both vertical (4.33%) and oblique (7.74%) light incidence.

While previous DSSC research has concentrated on optimizing light distribution through structural improvements, expanding the ability to capture omnidirectional light presents a promising direction for future advancements [10].

In contrast, for PERC cells, instead of etching, the master mold is created using an inexpensive process involving silane and ozone treatment. The five structures were formed by adjusting treatment parameters with higher concentrations and extended exposures produced more defined bumps (Figure 3). Compared to a bare PERC device, the PERC cells with the hierarchical structure pattern showed improved efficiencies at oblique angles, particularly at high angle of incidence. Additionally, the custom designs increased wettability, with a wetting angle of 125º indicating maximized light absorption [11].

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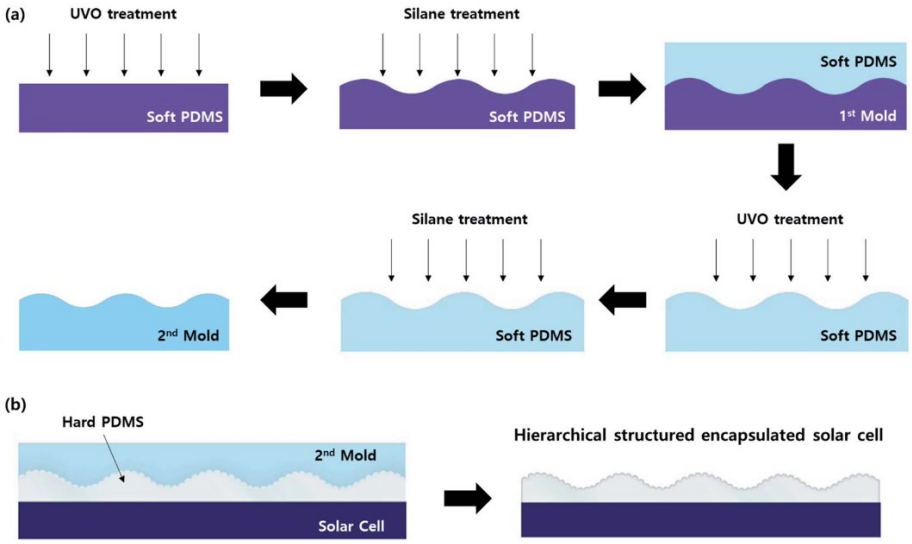

Figure 3: Development process of silicon-based encapsulation for PERC cell. The process involves two distinct procedures: (a) creating the PDMS molds via silane and ozone treatment and (b) casting the mold onto the silicon to achieve desired shape [11].

In terms of next steps, Ju Yun et al. suggest combining the components of the five configurations to further heighten solar PV light sensitivity capabilities.

3. Applications of the Cell Membrane in Solar Technology

Surrounding cells in all living organisms, the cell membrane preserves homeostasis by standing as a line of defense, protecting intracellular compartments from extracellular environments. The cell membrane achieves this function by possessing hydrophilic heads and hydrophobic tails [12].

Inspired by the lipid structure of a cell membrane, Hou et al. designed a micro-emulsion ink capable of rendering into a protective layer for perovskite crystals. Currently, the lack of a protective shell severely hinders the lifespan of halide perovskites: the promising technology can operate for 10 years compared to the average 25. Though lauded for its excellent optoelectronic properties, structural flexibility, and straightforward production, halide perovskites are highly limited by environmental degradation, particularly moisture. Past literature has discussed using a 2D/3D heterostructure bilayer as a viable solution; however, this idea presents risks such as microscale heterogeneities that may compromise net power output. The proposed ink design combines fatty and waxy biomaterials with perovskite precursors. Once in contact with the cell, the perovskite cell absorbs the lipid molecules and a 0D/3D bilayer–in the shape of a bubble–self-assembles [13].

As a precaution, acetonitrile (ACN) and ethanol (EtOH) were used as perovskite precursors. Although solvents such as dimethylformamide (DMF) or dimethyl sulfoxide (DMSO) are more common, DMF and DMSO have a strong affinity for lead ions in the perovskite given their high Gutmann's donor number (DN), leading to competition between precursor and biomolecule binding. Whereas, ACN and EtOH, with a low DN, do not and are therefore suitable for the ink. EtOH can also contain methylamine, a chemical capable of passing into the perovskite lattice and forming a perovskite intermediate cluster (PIC) that increases molecule bonding [13].

Considering these notions, the micro-emulsion ink was synthesized by liquifying powdered EtOH with methylamine using one of two chosen biomolecules (Figure 4). Estrone (E1) and progesterone (PRG) are hydrophobic steroids with a backbone structure of four carbon-based fusion rings and a carbonyl group, enabling strong bonding with lead. Once dissolved, ACN is added to dilute the

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solution. Given that the molecules are immiscible in ACN, the bilayer configuration begins forming, with EtOH and the chosen steroid at the bottom and ACN suspended on top. The bubble fully develops when the two phases are mixed via ultrasonication; the generated kinetic energy triggers the PIC in the molecule to form the micelle-like shapes [13].

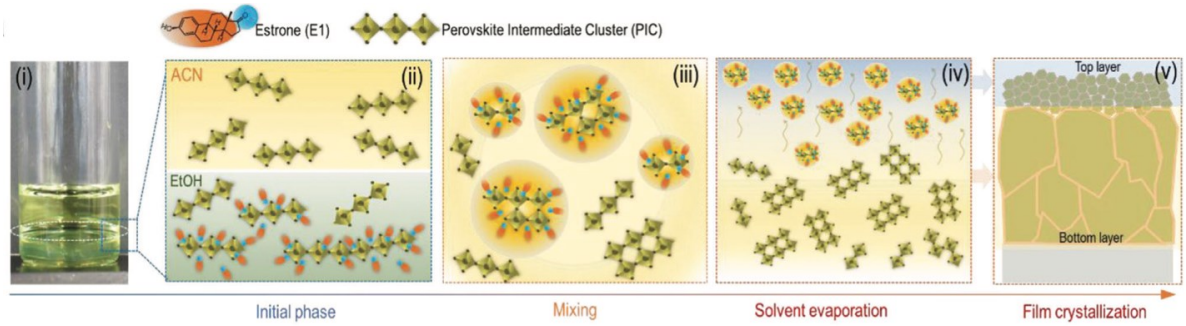

Figure 4: Illustrations of the 0D/3D bilayer structure formation process: (i-ii) initial separated composition of acetonitrile (ACN) and ethanol containing methanol (EtOH), (iii) the integration of the two layers via ultrasonication, (iv) the E1-PIC emulsion bubble begins to form, and (v) the final bilayer structure [13].

The E1 and PRG-based perovskite films displayed enhanced stability and efficiency. They demonstrated prolonged resistance against moisture attacks, with lifespan of the two increasing 18- and 45-fold to 11 and 27 seconds, respectively. They experienced advanced operational stability: 80% of the original PCE value was still retained 4.8 and 5.8 hours later compared to less than an hour for baseline perovskites. These homogeneous layers can also be more effectively upscaled as the model has a smaller area-dependent efficiency drop value of -0.016%cm^{-2} compared to -0.084%cm^{-2} for conventional solar PVs [13].

4. Applications of the Butterfly in Solar Technology

4.1. Common Rose Butterfly

As indicated by the black pigmentation, the wings of the rose butterfly Pachliopta aristolochiae absorb heat through its intricate nanostructured scales and periodic ridges. The nanostructures, which consist of nanoholes suspended from ridges and cross-ribs, capture light across the visible spectrum while leveraging ultraviolet (UV) and near-infrared (NIR) light too. Shorter wavelengths (~350 nm) are absorbed through vertical channeling, where light travels along the ridges' sidewalls towards the nanohole surface for capture. In contrast, longer wavelengths (~850 nm) are absorbed via in-plane scattering, with light dispersing randomly within the rib architecture to increase points of interaction between the photons and absorbing material. For intermediate wavelengths (~550 nm), both channeling and scattering mechanisms are utilized to optimize absorption [14].

Similarities can be drawn between P. aristolochiae wings and thin-film PVs: both are thin photonic structures that are lightweight and flexible. These characteristics allow thin films to stand out as a low cost option for solar technology. However, thin films have historically been restricted by low efficiencies [15]. Past literature has noted that adding textured surfaces could improve thin film efficiency.

Siddique et al. assessed how P. aristolochiae's disordered nanohole arrays can improve thin film light-harvesting by comparing four different orientations of bioinspired thin-film models. Molded with hydrogenated amorphous silicon (a-Si:H), the configurations included one bare slab, an "ordered" array with uniform hole diameters, a "perturbed" array with varying hole diameters, and a

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"correlated" array combining uniform and varied hole diameters, directly mimicking the wings of P. aristolochiae. All three patterned models exhibited over double the absorbance of the reference slab, approximately 64% versus 31.6% in average optical absorptivity, respectively. Moreover, the correlated array retained better absorbance performance when subjected to changing angles of incidence (0º to 80º), with a drop of about 22.8% compared to 27.3% for the ordered structure and 26.8% for the perturbed design [14].

4.2. White Butterfly

As cold-blooded organisms, butterflies rely on the sun for warmth to gain the kinetic energy needed for flight. Unlike many other butterflies, white butterflies in the genus Pieridae, such as P. rapae, tend to fly earlier on cloudy days as they absorb heat easily and quickly. This behavior is due to the unique biostructure of their wings, which contain ovoid granules or "nano-beads" between the gaps in their wing scales. These nano-beads aid in photonic and thermal regulation by containing the white pigment pterin. Pterin absorbs short wavelengths and reflects visible light, while the nano-beads enhance light scattering [16].

Similar to the V-shaped posture butterflies adopt during rest before flight, solar concentrators use a V-trough design using mirrors and lenses to direct light towards a smaller area of PV cells. While solar concentrators are theoretically practical—they reduce energy costs by decreasing required land area and improving efficiency—the various standard designs have drawbacks. Reflective films on plastic mirrors lose reflectivity as surfaces become more complex, specific curved shapes with just a reflective mirror finish are expensive to manufacture, and the effectiveness of vacuum metalizing hinges on the quality of material used. Furthermore, these devices are often bulky and heavy. To advance the development of solar concentrators, taking inspiration from the design of Pieridae butterfly wings can enhance reflectivity [16].

To understand the applicability of Pieridae butterfly wings, Shanks et al. arranged large butterfly wings around a mono-crystalline silicon cell, mimicking how photons are reflected by the wing scales and concentrated at the thorax to ready muscles for flight. A significant increase in power 42.3% was reported, and the power-to-weight ratio improved 17-fold. Two times the amount of light became concentrated at the silicon cell compared to the effects of standard reflective film, and at the optimum angle of 17º, the PV cell's temperature increased by 7.3ºC [16].

Exploring ways to replicate the layer of ovoid pigment through nanofabrication can enhance the reflective properties of solar concentrators and make those technologies more attractive [16].

5. Conclusions

Solar technologies need a new source of inspiration to spur development—though demand for solar technologies is escalating, current limited capabilities leave much to be desired. By emphasizing simplicity, thermoregulation, and soft matter, integrating biomimicry into solar technology designs can effectively address the three pillars of the golden triangle: efficiency, longevity, and cost effectiveness. Mimicking leaf structures, cell membrane characteristics, and butterfly photonic absorption and reflection processes within both additional components and the design models themselves has demonstrated success.

Caused by the inability to absorb all the photons from the sun, overheating decreases cell efficiency and stability. Although current cooling methods exist, they struggle with balancing efficiency and cost. A BT layer can be added to the rear end of a solar PV to provide heat relief by spreading coolant water in a process similar to transpiration, during which plants release heat through water evaporation at the leaf surface. The BT layer incorporates commercially available materials, making this technology accessible and scalable.

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Most solar technologies cannot absorb light at multidirectional angles, presenting a major missed opportunity. On the other hand, the complex geometries of the leaf epidermis can do so. Recreating those hierarchical structures on a PDMS layer leads to greater angular robustness for DSSCs and PERCs.

Halide perovskites, a device that excels at light management, lacks an encapsulation layer, posing the risk of environmental damage. The protective shell can be likened to the cell membranes that surround all living cells: both safeguard the internal from the external. A cell membrane can be replicated by exposing lipid biomolecules to perovskite precursors. An emulsion bubble then forms as the two interact atop a perovskite crystal, which successfully defends the cell from moisture.

Thin film PVs and the wings of P. aristolochiae butterflies have been compared given their similar thin widths. The one stark difference is that thin films are known for their conversion inefficiency, while the nanostured scales in P. aristolochiae wings allow a high degree of solar capture. Given their paralleling appearances, the wings of P. aristolochiae can be further examined to improve thin film efficiency.

Although various solar concentrators exist, each has its own compromises, especially with regards to material quality and cost. Solar concentrators can draw inspiration from white Pieridae wings given their similar V-shaped arrangement. Given that these wings allowed more light to be centralized on the cell and improved the power-to-weight ratio by 17-fold, they may provide solutions to the current related challenges.

These examples highlight just a few of the many potential applications of biomimicry that have yet to be fully realized. Therefore, prioritizing the fusion of biomimicry in solar technology designs is advantageous towards facilitating the expansion of solar energy.

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Prospects of China's Entertainment Consumption Economy Based on Entertainment APP Data Analysis

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Abstract: China's entertainment apps have blossomed in many aspects, covering videos, movies, games, music, animation, live broadcasts, etc. Data collected from major entertainment apps might be helpful to outline the preferences and personalities of Chinese entertainment consumption groups, and thus to make a prospect for China's entertainment consumption economy. Based on the analyzed data, it can be seen that while some professional entertainment apps are developing towards the "small and beautiful" vertical track, comprehensive platform apps are undergoing an ambitious expansion of power. It is clear that the multi-dimensional social interaction of active Chinese entertainment people has highlighted people's spiritual needs, and the development of the industry will undoubtedly show the integration of entertainment and technology, entertainment and food/sports, and entertainment and tourism. The entire industrial chain should be layout based on multi-dimensional needs, and the precise output should be supplemented by scientific and technological means.

Keywords: Active user scale, active user groups, user portraits, usage stickiness, usage frequency.

1. Introduction

In recent years, China's entertainment apps have blossomed in many aspects, covering videos, movies, games, music, animation, live broadcasts, etc. The industries they involve are far more than culture and entertainment, but also extend to tourism, food, sports, technology and other industries. The diversification of online consumption and entertainment needs is strongly stimulating the growth of domestic demand and injecting vitality into the economic system [1]. According to data from China's National Bureau of Statistics, in 2023, cultural enterprises achieved operating income of 12951.5 billion yuan, an increase of 8.2% over the same period last year on a comparable basis, accounting for 10.3% of the annual gross domestic product (GDP) of 126058.2 billion yuan. It can be seen that the entertainment economy drives GDP growth and provides the core driving force for economic development to break through short-term pressure. In 2023, the profit growth of cultural enterprises was even more significant, increasing by 31% year-on-year to 1156.6 billion yuan.

This article analyzes data from various entertainment apps, aiming to outline the preferences and personalities of the main body of Chinese entertainment consumption groups, and thus to make a prospect for China's entertainment consumption economy.

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The analyzed entertainment apps include several categories: video, movie and performance, game and music. In the following section 2, data from short video APPs, long video APPs, comprehensive video APPs, movie and performance apps, game APPs and music APPs will be respectively presented and analyzed. While in section 3, analysis of entertainment APP segmentation data is provided, and several case studies are presented. And thus section 4 gives out a conclusion.

2. Visualization of entertainment APP segmentation data

This section 2 begins with data from video APPs.

Long videos and short videos are two different content forms in two tracks, and they each have their own advantages. Short videos are the product of the fast-paced Internet era. The overall development of short videos is mainly based on UGC content, which is a product of the fast-paced Internet era. Their notable features are short, flat and fast, and content supply is increasing exponentially, which can effectively broaden the public's information reach and are more in line with the public's fragmented consumption habits in terms of duration [2]. In May 2023, short videos accounted for 28% of the total usage time of mobile Internet users [3], an increase of nearly 15pct compared to 2019, and it is the main mode of mass consumption. Long videos are mainly PGC content, and the length determines its advantage in content depth, which also makes it more ideological in its core [4].

From the perspective of commercial realization, the difference in the operating logic of the two also determines the difference in commercial realization models. Short videos are directly aimed at C-end users. In the early stage, they are full of UGC content, and the main realization model is live broadcast reward income. With the continuous accumulation of traffic pools and the expansion of diversified realization, the proportion of advertising and e-commerce revenue has gradually increased; and the essence of long videos is the operation logic of ToB. The platform direction, which occupies an important link in the long video industry chain, purchases professionally produced copyrighted content from upstream producers. The free traffic on the platform is realized in the form of advertising, and the paid traffic is realized in the form of membership and buyout content [5].

In terms of cost structure, there are also obvious differences between the two. Short video platforms mainly build online platforms, and the content is mainly produced by users. Therefore, they do not bear many cost items, including anchor costs, servers and bandwidth, and the gross profit margin is relatively high. For example, Kwai’s comprehensive gross profit margin can reach more than 50% [6]; long video platforms have to pay high copyright content costs, so the gross profit margin is relatively low. For example, iQiyi’s content cost accounted for 50.8% of its revenue in 2023, and its gross profit margin was less than 30% [7].

This article takes TikTok and Kwai as examples of short video APPs, and takes iQIYI, Tencent Video, Youku, and Mango TV as examples of long video APPs. There are also comprehensive video APPs that incorporate both long and short videos. For example, Bilibili (B Station) builds a PUGV content ecosystem based on UP master creation, creating a diversified cultural community.

2.1. Short Video Apps

With the continuous development of mobile Internet, short videos meet the diverse needs of users with their diverse content and social functions.

However, as the overall traffic dividend peaked, short video apps transitioned from a high-traffic growth stage to stock operations. In 2023, the short video market size will be close to 300 billion yuan, and the user scale will reach 1.012 billion, accounting for 94.8% of the total number of netizens, making it one of the most used applications in China's Internet applications [8].

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From the perspective of the competitive landscape, a competitive landscape dominated by TikTok, Kwai, Tencent Video Account and related product matrices, and short videos has been formed. Although the main players TikTok and Kwai have operational differences in product positioning, GMV driving logic, and the relationship between anchors and users, both have chosen e-commerce as their commercialization path.

From the perspective of MAU (Monthly Active Users), as shown in Fig. 1, the monthly active user scale of TikTok, Kwai, TikTok Volcano Edition, TikTok Lite Edition, and Kwai Lite Edition has basically stabilized in the first half of 2024. In June 24, TikTok's MAU was 780 million, TikTok Lite Edition's MAU was 270 million, TikTok Volcano Edition's MAU was 90 million, Kwai's MAU was 430 million, and Kwai Lite Edition's MAU was 230 million.

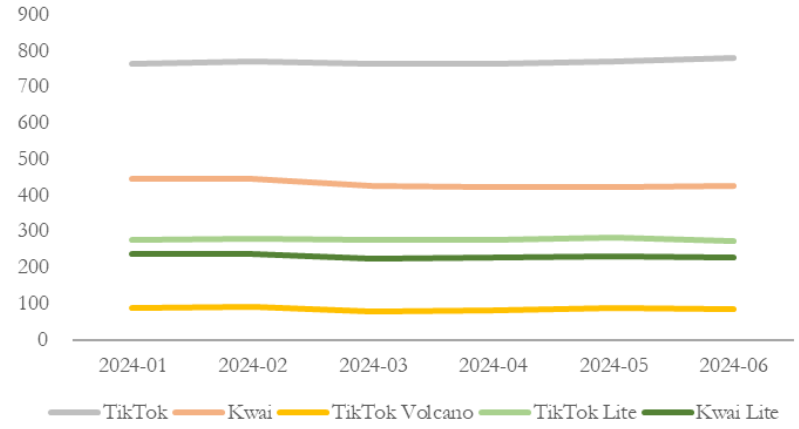

Figure 1: The Monthly Active User Scale of Short Video APP during Jan.-Jun. 2024
Data source: Questmobile
Photo credit: Original

However, from the year-on-year change in MAU scale, TikTok and Kwai have diverged. Specifically, the year-on-year change in the average MAU of TikTok in the first half of 24 was 7.1%, the year-on-year change in the average MAU of TikTok Volcano Edition in the first half of 24 was 18.3%, and the year-on-year change in the average MAU of TikTok Lite Edition in the first half of 24 was 23.6%, while the year-on-year change of Kwai was -6.5%, and the year-on-year change of Kwai Lite Edition was -10.1%.

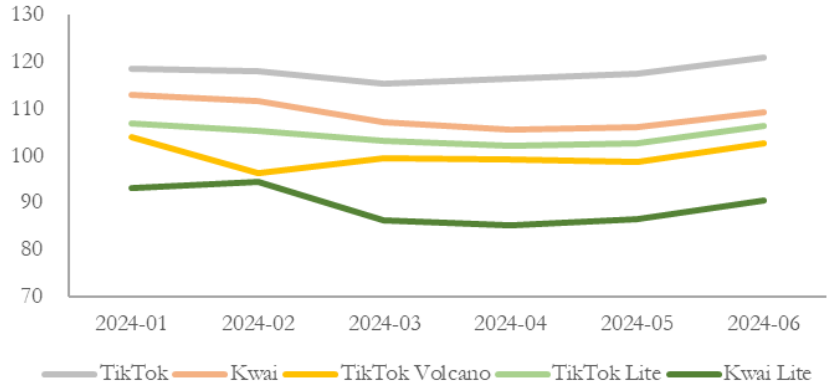

Figure 2: The Average Daily Usage Time per Person of Short Video APP during Jan.-Jun. 2024
Data source: Questmobile
Photo credit: Original

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In terms of the average daily usage time per person, as shown in Fig. 2, in June 2024, the average daily usage time per person for TikTok was 121 minutes, the average daily usage time per person for TikTok Volcano Edition was 103 minutes, the average daily usage time per person for TikTok Speed Edition was 106 minutes, the average daily usage time per person for Kwai was 109 minutes, and the average daily usage time per person for Kwai Speed Edition was 90 minutes, indicating strong user stickiness overall.

2.2. Long Video Apps

As short video platforms compete for the attention resources of Internet users, long video platforms have faced great challenges in recent years. However, the demand for watching movies and TV series is relatively stable, and the development of the platform needs to return to content being king. Long video is essentially a high-threshold entertainment content supply platform, which can form a sufficiently dislocated competitive relationship with other entertainment forms. From the perspective of the industry competition landscape, the natural dispersion of content supply makes it difficult for the winner to take all. For example, the dispersion of streaming media channels in the United States is stronger than that in China. In addition, under the challenges of the external environment, including supervision, epidemics, economy and other factors, cost reduction and efficiency improvement have become the industry theme of long videos in the past [9].

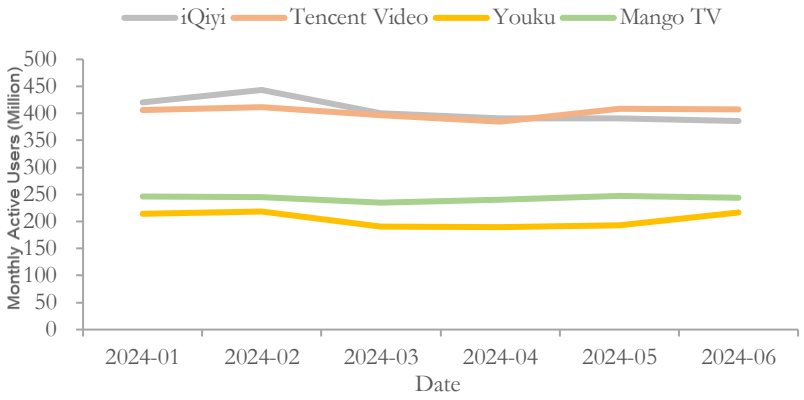

Figure 3: The Monthly Active User Scale of Long Video APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

From the perspective of monthly active user scale, Figure 3 shows that the monthly active user scale of iQiyi, Tencent Video, Youku Video, and Mango TV fluctuated slightly in the first half of 24, but was generally stable. In June 24, the monthly active user scale of iQiyi was 390 million, the monthly active user scale of Tencent Video was 410 million, the monthly active user scale of Youku Video was 220 million, and the monthly active user scale of Mango TV was 240 million. The year-on-year change of the average MAU in the first half of the year was -19.6% for iQiyi, -0.5% for Tencent Video, -21.0% for Youku Video, and -3.9% for Mango TV, all of which showed a downward trend, but the degree of decline was different for different platforms.

For the average daily usage time per person, according to Fig. 4, iQiyi and Mango TV showed an overall downward trend in the first half of 24. In June, the average daily usage time per person of iQiyi was 68 minutes, while the average daily usage time per person of Mango TV was 71 minutes (75 and 81 minutes in January, respectively), while Youku Video showed an upward trend, 62 minutes in June (57 minutes in January).

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Based on the data, it can be considered that for long video APPs, the supply of high-quality content drives demand satisfaction more obviously, which is reflected in the fact that the fluctuations in users and duration are mainly affected by the current content scheduling. Popular content can bring obvious growth in the number of active users on the platform and increase the duration, while the content gap period has an adverse effect on the number of users and duration.

In the first half of 2024, Tencent Video and Youku Video had many high-profile and exclusive phenomenal dramas, such as Tencent Video's "Celebrating Yu Nian Season 2"(*Qing Yu Nian Di Er Ji*), "The Story of Roses"(*Mei Gui De Gu Shi*), "Hunting Ice"(*Lie Bing*) and other dramas, which contributed to its high popularity, thus facilitating the maintenance of the number of users and duration; Youku's "*Mo Yu Yun Jian*", "*Hua Jian Ling*", and "*Xi Hua Zhi*" broke through in the ancient idol creation circle with large traffic and large IP, showing the change of Youku's layout thinking and advanced content thinking.

In contrast, iQiyi lacks big hit dramas, and costume dramas have failed one after another. The popularity performance of "Fox Spirit Matchmaker: Moon Red" (*Hu Yao Xiao Hong Niang Yue Hong Pian*) and "Flame"(*Lie Yan*) is not as expected. Only the drama "Journey to the West" (*Yu Feng Xing*) co-broadcast with Tencent Video on Mango TV gained high popularity, while the popularity of other dramas was relatively unsatisfactory.

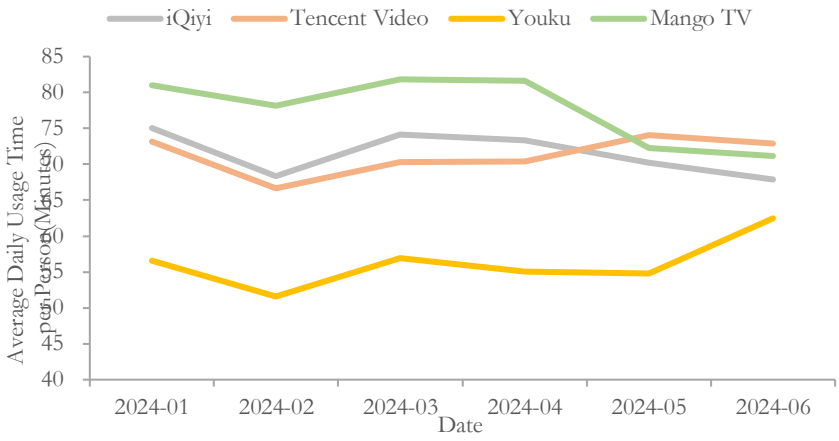

Figure 4: The Average Daily Usage Time per Person of Long Video APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

2.3. Comprehensive video APPs

As social media and content sharing platforms that are popular among young people, Bilibili and Little Red Book have achieved significant influence in the fields of video entertainment and lifestyle, respectively.

Bilibili is based on the community and adopts the "OGV+PUGV" dual drainage strategy, forming a full link of "OGV content drainage-high-quality PUGV content to increase retention". In addition, the company continues to expand the content vertical category, achieving a breakthrough from two-dimensional users to pan-entertainment and pan-knowledge users, and creating a positive cycle ecology of "UP hosts produce high-quality video content-attract fans and get positive feedback-motivate UP hosts to produce more high-quality content" [10].

Little Red Book is currently one of the fastest growing platform companies in the content industry. Its operating mechanism is based on the daily actual needs of users and relies on a deep reserve of

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UGC content to become an effective life experience platform and tool-type application at the user's fingertips [11].

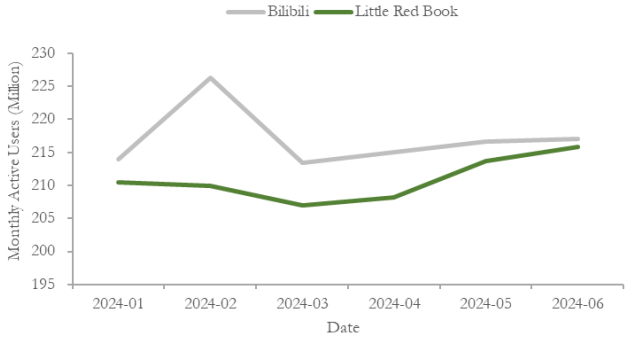

Figure 5: The Monthly Active User Scale of Comprehensive Video APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

Based on Fig. 5, from the perspective of monthly active user scale, the MAU of Bilibili and Little Red Book in June 24 was comparable, both 220 million. In the first half of 2024, the average MAU of the two increased by 7.2% and 15.6% year-on-year, respectively, and the user growth trend was good.

In February 2024, as shown in Fig. 5, Bilibili's monthly active user scale fluctuated greatly. The reason for this is that Bilibili launched a series of special Spring Festival activities in February, including live broadcasts, lucky draws, and New Year's greetings, which attracted a large number of users to participate. For Little Red Book, the proportion of post-95 users among monthly active users is as high as 50%, mainly distributed in first- and second-tier cities. The platform is mainly based on user-generated content (UGC), with an average daily user search penetration rate of 70%, and has become a new generation of search engines and lifestyle encyclopedias.

For the average daily usage time per person, according to Fig. 6, Bilibili was 104 minutes in June 2024 and Little Red Book was 80 minutes, with little change year-on-year.

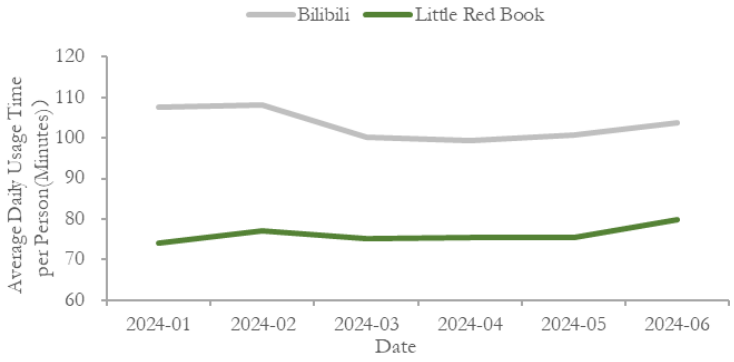

Figure 6: The Average Daily Usage Time per Person of Comprehensive Video APP during Jan.-Jun. 2024

Data Source: Questmobile
Photo credit: Original

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2.4. Movie and Performance APPs

Among the movie and performance apps, movie apps provide online ticket purchase services, as well as movie trailers, box office inquiries, movie rankings, film and television information and other information. Performance apps cover multiple fields such as concerts, dramas, musicals, sports events, music and entertainment, parent-offspring, exhibitions and leisure, and have a full-link layout for content, venues, ticketing, etc.

From the perspective of commercial realization, ticketing APPs mainly earn income by selling tickets to consumers and charging a certain percentage of service fees, which usually range from 3 yuan to 5 yuan. In addition, extending to the upstream and downstream of the industry chain has become another development trend of online ticketing platforms. For example, in addition to ticket sales, film reviews, related information, and real-time box office records, online movie ticketing platforms are also involved in film promotion and production.

At the upstream level of the industry chain, some ticketing platforms such as Damai.com participate in the investment, production and promotion of performances by developing self-operated performance brands and content, such as Mailive, to obtain box office revenue and other related income. Maoyan Entertainment also shares upstream production income by investing in films. At the downstream level of the industry chain, since ticketing platforms have a large amount of user traffic and viewing habits data, they can use user data for precision marketing. Therefore, ticketing platforms can provide user portraits and market analysis for film investors, optimize performance arrangements and marketing strategies, and participate in the distribution and marketing of films and performances. In general, the ticketing platform builds a full industry chain service system by integrating upstream and downstream industry chain resources, such as content production, publicity and distribution, to improve overall service efficiency and market competitiveness. The movie and performance apps in this article will take Maoyan and Damai as examples [12].

As well-known ticketing platforms, Damai and Maoyan occupy important market positions in the performance and film fields respectively. Driven by the development of the national economy and the upgrading of cultural consumption, people's demand for entertainment activities has also increased [13].

From the perspective of MAU (monthly active user scale), Fig. 7 shows that Damai's scale reached 36.35 million in June 24, and Maoyan's scale reached 12.5 million. In the first half of 24, Damai's MAU showed an overall upward trend, with an increase of 40% from January to June; Maoyan's MAU was stable and rising, with an increase of 94% from January to June, showing rapid growth driven by cultural consumption. From the perspective of average daily usage time per person, as shown in Fig. 8, Damai and Maoyan showed an overall upward trend in June 24, with year-on-year growth of 12.4% (reaching 4 minutes) and 8.8% (reaching 5 minutes) respectively.

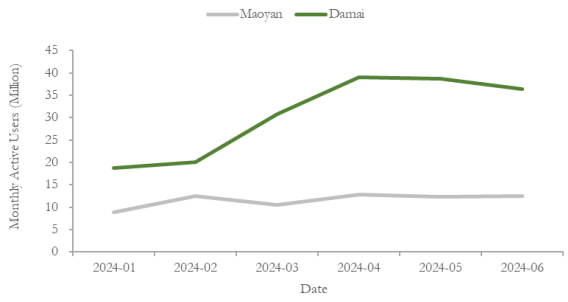

Figure 7: The Monthly Active User Scale of Movie and Performance APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

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The user growth and time increase trend of the ticketing platform are mainly attributed to the gradual recovery of offline performing arts activities after the epidemic. The performance market has ushered in a strong outbreak, driving the high monthly activity growth and retention of the ticketing platform. According to data monitoring and research estimates from the ticketing information collection platform of the China Performing Arts Industry Association, there were 251,700 commercial performances (excluding performances in entertainment venues) nationwide in the first half of 2024, a year-on-year increase of 30.19%; box office revenue was 19.016 billion yuan, a year-on-year increase of 13.24%; the number of spectators was 79.1013 million, a year-on-year increase of 27.10%.

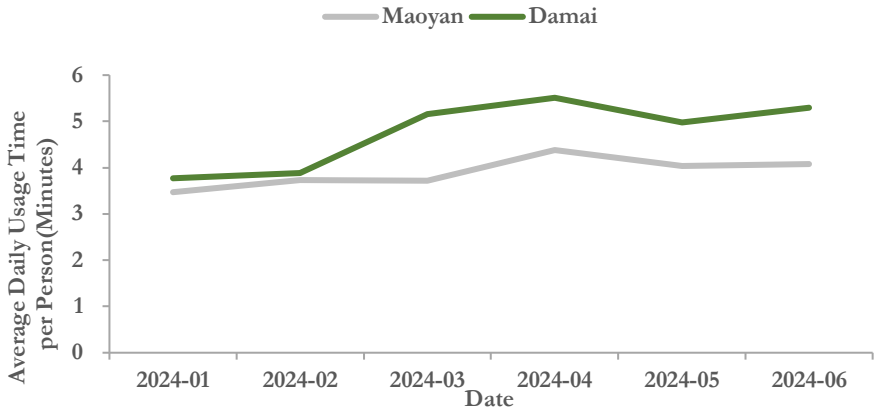

Figure 8: The Average Daily Usage Time per Person of Movie and Performance APP during Jan.-Jun. 2024

Data Source: Questmobile
Photo credit: Original

2.5. Game and animation apps

In the field of games, after years of development, the mobile game industry has basically formed a model of integrated research and development and operation, that is, large companies develop their own products and publish them by themselves, and research and development capabilities and channel traffic capabilities are more important. As a creative industry, the game industry is product-driven as the mainstream way of monetization in the industry. In particular, for research and development companies, the turnover often shows short-term pulse-like fluctuations, and the long-term turnover is driven by new products and the long-term operation of old products. Therefore, the diversified product matrix of research and development companies is more conducive to maintaining the stability of their performance [14]. From the perspective of the industrial chain, after a game is developed by an upstream developer, it is downloaded by players through a distribution operator and an app store, so the distribution capability is also relatively important. TapTap breaks the limitations of traditional game channels and gives benefits to game developers with a business model of "no joint operation, no profit sharing". The game apps in this article will take TapTap and Pixiv as examples.

According to Fig. 9, in June 2024, the monthly active user scale of TapTap was 16.69 million, and the monthly active user scale of Pixiv was 4.07 million, with year-on-year growth of 9.2% and 6.2% respectively. Fig. 10 shows that in June 2024, the average daily usage time of TapTap was 17.5 minutes, and the average daily usage time of Pixiv was 17.9 minutes, with year-on-year changes of -5.5% and +2.1% respectively.

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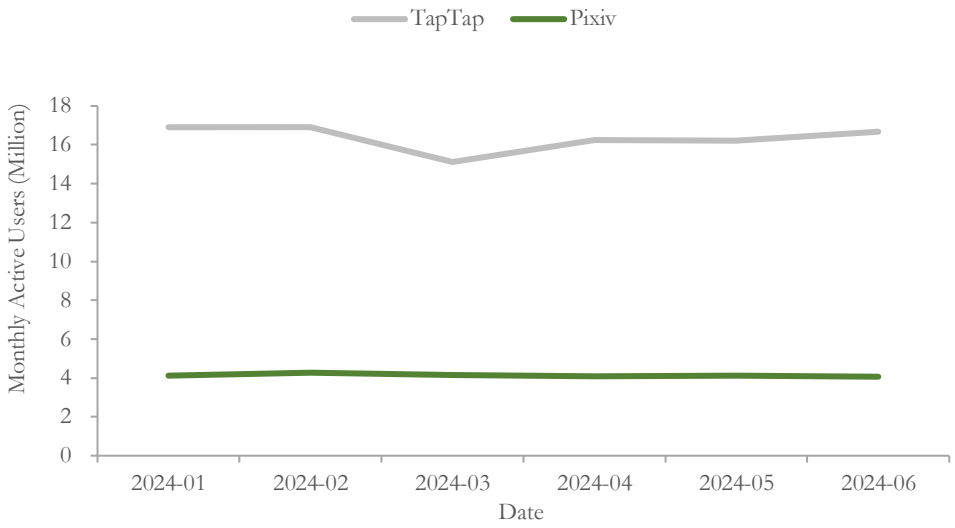

Figure 9: The Monthly Active User Scale of Game APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

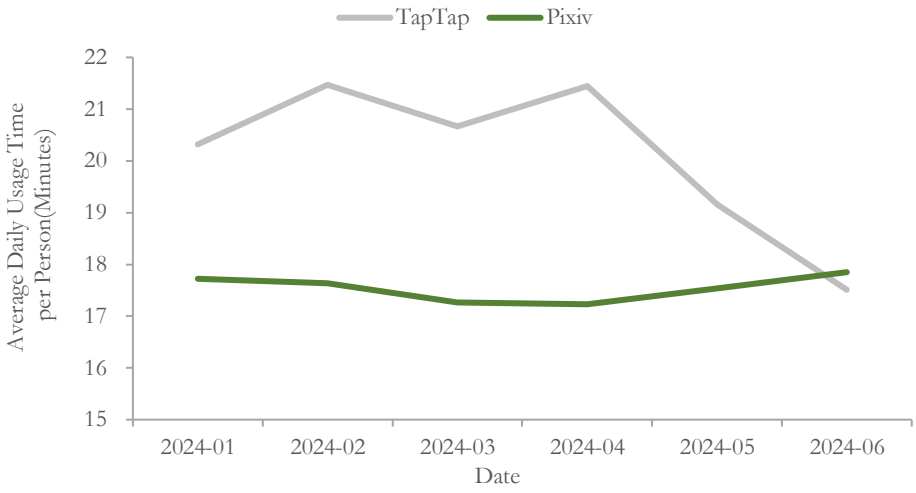

Figure 10: The Average Daily Usage Time per Person of Game APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

2.6. Online Music APPs

In the first half of 2024, the monthly active user scale and average usage time of online music APPs remained basically stable. In June 24, as shown in Fig. 11, the monthly active user scale of Kugou Music was 230 million, the monthly active user scale of QQ Music was 200 million, and the monthly active user scale of NetEase Cloud Music was 150 million, with year-on-year changes of -3.7%, +1.5%, and -0.3%, respectively. Based on Fig. 12, in June 24, the average daily usage time of Kugou Music was 16 minutes, the average daily usage time of QQ Music was 13 minutes, and the average

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daily usage time of NetEase Cloud Music was 8 minutes, down 8.6%, 7.9%, and 5.9% year-on-year, respectively.

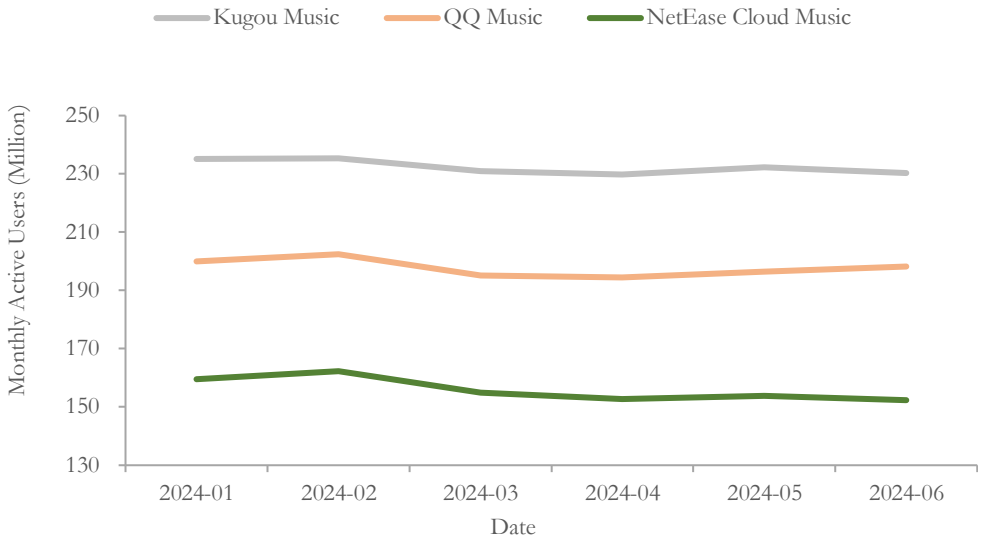

Figure 11: The Monthly Active User Scale of Music APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

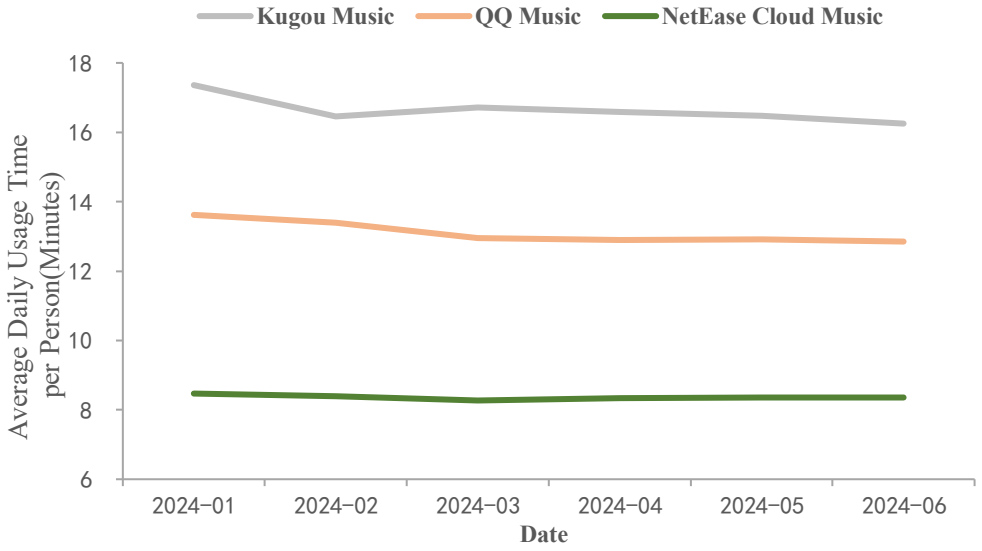

Figure 12: The Average Daily Usage Time per Person of Music APP during Jan.-Jun. 2024
Data Source: Questmobile
Photo credit: Original

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3. Analysis of entertainment APP segmentation data

3.1. Group analysis/user portrait of industry segmentation

3.1.1. Video APP

Long and short videos are two complementary content forms with huge differences in consumption scenarios and forms.[4] The video industry is currently in a period of transformation. The competition for traffic and user attention among Internet platforms has intensified. The rise of short video platforms has indeed impacted the original traffic pool of long videos. However, the competition for traffic between long and short video platforms is not either-or. It does not mean that once the public is used to watching short videos on TikTok, they will not watch long videos on Youku, iQiyi and Tencent Video.

When long video APPs first started, they focused on the young people market. In recent years, the genre structure of online dramas has undergone a transformation. iQiyi, Tencent Video and Youku have begun to re-examine the public's content needs and began to embrace national-level themes and mature content. They have achieved audience coverage of all ages and have moved towards middle-aged people and even the elderly in addition to young people. Whether in the TV era or the Internet era, themes that are close to reality and aimed at all-age audiences are the most recognized, influential and resonant with the audience. Video websites are beginning to focus on more scarce content, which is also good news for the long-term development of long videos. Exploring narrative scarcity, genre scarcity and core scarcity makes it possible to create long video content with scarce value and leading trends.

More than 60% of long video APPs are female, among which Mango TV has a high proportion of females, and Tencent Video and Youku Video users are relatively evenly divided in gender. In the past one or two years, some people outside believe that long videos will decline under the impact of short videos, but in fact, although short videos are efficient and convenient, people can only accept scattered and fragmented information in short videos, while in long videos, people's emotional experience is complete, immersive and profound, and this advantage is irreplaceable.

Short videos have the characteristics of "short", "show" and "chat". "Short" makes users see the essence and can make better use of their fragmented time; "show" allows users to have a stage to show themselves, show their value and significance; "chat" greatly improves users' social vision and ability. These characteristics have made the user scale of short video platforms increasingly large, and have also attracted capital from various fields of media and information to intervene.

Nowadays, people's pace of life is getting faster and faster, and the pressure they face is getting greater and greater. The pressure from work, life, study and other aspects needs to be released, and short videos just provide an outlet for emotional pressure. By browsing short videos, users can temporarily put down the pressure and achieve the effect of relaxation.

In 2023, there are more males than females among short video APP users, and nearly 70% are between the ages of 19 and 35; nearly half of users watch short videos multiple times a day; social positive energy and funny content are the content that short video users prefer to watch. Short video users have high acceptance, and creators have strong growth needs.

3.1.2. Movie and Performance APP

The proportion of female users in movie and performance ticketing apps has increased. As of July this year, female users accounted for 53% of movie and performance ticketing apps, and male users accounted for 47%.

The user age distribution results show that the user composition of movie and performance ticketing apps is relatively young. As of July, this year, users aged 25 and below accounted for 40%,

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an increase of 2.4% over the same period last year. At the same time, users aged 26-35 accounted for 46.6%, and users aged 36 and above accounted for 13.4%.

According to data from iiMedia Research, more than 90% of Chinese netizens have used online movie ticket purchases, and only 1.6% of netizens said they have not purchased and do not plan to purchase. 61.7% of Chinese netizens choose to buy movie tickets online because they save time. Online movie ticketing platforms should focus on creating convenient services and optimizing user experience [15].

3.1.3. Game APP

As time goes by, the age of game market users is undergoing structural changes. As of March 2022, users aged 31 and above accounted for 51%, exceeding users under 30 years old. Among them, users aged 36 and above accounted for 36.6%, also exceeding users under 24 years old. In contrast, in March 2019, users aged 30 and below accounted for 55.5%, and users aged 36 and above accounted for only 30.2%.

In February 2024, the number of active users in the mobile game APP industry reached 659 million, with a year-on-year growth rate of more than 12%. The scale of mobile industry panoramic traffic reached 940 million, and the industry showed a clear upward trend. On the one hand, thanks to the continuous issuance of version numbers, the speed and quality of new mobile games are stable; on the other hand, the small game market is growing rapidly. For example, the number of active users of WeChat mini-program games reached 750 million, accounting for 80.3% of the panoramic traffic.

3.1.4. Music APP

The stickiness of young users' music APP usage has increased significantly, and the increase in usage frequency is higher than the increase in usage time, mainly because: According to the Cloud Music user report and iResearch Consulting, the TGI of special categories such as ambient sound and long audio has increased among the post-90s and post-00s groups, and young users are good at exploring richer usage scenarios; With the popularization of functions such as audio live broadcast and karaoke, the functions of software have also developed from a single player to entertainment and social interaction around music, reshaping the usage habits of young users.

3.2. Case Analysis

Take Xiaohongshu as an example. According to relevant Nielsen survey data, more than 80% of users said that they have been successfully planted on Xiaohongshu.[16] The deep-seated reasons for this are: high-quality notes, direct response to pain points, and a strong community atmosphere. In addition, the information it presents is multi-dimensional, which facilitates rational decision-making in information comparison. Furthermore, Xiaohongshu users are more inclined to become opinion leaders in their own value attitudes, which means that content is easier to form a closed-loop dissemination, through users influencing users, and promoting further interaction and sharing.

As a result, Xiaohongshu has 200 million active users per month and 43 million+ sharers (creators). Judging from the user portrait data of Xiaohongshu in the past two years, young people and strong consumption power are still important characteristics of platform users. Its core users are 72% of post-90s users, and the more detailed age levels are: 16-24 years old: 46.39%; 25-34 years old: 36.08%.

In terms of gender distribution, female users account for 70%. Male users account for 30%. Among them, neutral content such as food and travel, as well as digital, sports events, etc., have developed rapidly, bringing about the growth of male users.

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In terms of user stickiness, according to QuestMobile, Kuaishou's DAU/MAU reached about 45% in February 2024, significantly higher than long video platforms and lower than short video platforms.

In addition to improving the infrastructure of the content platform, Xiaohongshu has also accelerated its commercialization layout, mainly relying on advertising and e-commerce as two growth engines. According to New Retail Business Review, Xiaohongshu's revenue will be approximately 30 billion yuan in 2022, of which advertising revenue will account for 80%, and the remaining 20% will be e-commerce revenue; in 2023, Xiaohongshu's advertising revenue will decline year-on-year, with a slight decline in proportion, but still accounted for 70-80% of the total revenue, but the profit performance exceeded expectations. In terms of e-commerce, content cultivation drives e-commerce consumption, and a differentiated community e-commerce business model is formed with buyers as the core to promote the formation of a closed loop [16].

3.3. Analysis of preferences and personality of active people in Chinese entertainment apps

Based on the above data and case analysis, it can be seen that from entering the pit, seeding, experience to deep investment, in every interest field, young people are vying to be the "number one player". The preferences of active people in Chinese entertainment apps are diversified, driving a multi-category segmentation trend.

As the main force of active people in entertainment apps, young people's interests are highly integrated, their consumption behavior is both rational and emotional, they pay attention to products that are both classic and trendy, and they like and identify with rebellious, distinctive but talented idol representatives; they advocate multi-dimensional social interaction, care for themselves, and show their personality to the fullest. At the same time, they also care about the world, are willing to contribute their own opinions, and have a sense of justice.

As entertainment and related industries, dividing people based on basic portraits or consumption characteristics and conducting precision marketing based on the "interest circles" built by people with similar interests are necessary means for the refined operation of the entertainment consumption economy. Interest circles such as music, games, technology, and tourism already have a large user scale. People in the tourism, food, and sports circles have higher online activity and purchasing power. The scale of circles such as games and technology is still expanding, and the value potential is being released. Sports experts have a high degree of fit with music and professional sports brands. The technology crowd actively embraces various smart devices, including smart cars and smart home appliances. The game crowd is also highly active in other entertainment scenarios such as long and short videos and is the main group of e-sports viewers.

3.4. Current situation and prospects of China's entertainment consumption economy

According to data from the US consulting agency Grand View Research, from 2023 to 2030, the size of the social application market will grow from 60.8 billion to 310 billion US dollars. In other words, social pan-entertainment will still have considerable room for growth, with an optimistic annual compound growth rate of 26.2%. Of course, the overall positive projection to different markets and tracks will be different.

While some professional entertainment apps are developing towards the "small and beautiful" vertical track, comprehensive platform apps are undergoing an ambitious expansion of power. They are well aware that the multi-dimensional social interaction of active Chinese entertainment people has highlighted people's spiritual needs, and the development of the industry will undoubtedly show the integration of entertainment and technology, entertainment and food/sports, and entertainment and tourism.

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Taking Alibaba Pictures as an example, its profitability in the film sector has steadily increased and entered a high-quality growth track. In fiscal year 2024, the film investment, production and publicity revenue was approximately RMB 2.072 billion, a year-on-year increase of 69%; the film ticketing and technology platform revenue was approximately RMB 920 million, a year-on-year increase of 76%; the IP derivatives and innovation business revenue was approximately RMB 1.053 billion, a year-on-year increase of 9%.

In the field of technology business, Alibaba Pictures has laid out its future and continued to enhance its advantages in the technology sector. Taomai VIP membership construction is being fully promoted, and the membership scale and loyalty continue to increase. During the fiscal year, there were more than 2 million high-frequency black diamond members, and the frequency of ticket purchases by members was 2.5 times that of non-members. Various rights and interests such as ticket purchase discounts, fast channels, and celebrity meet-and-greets have brought VIP users a "super value, super expectation" consumer experience; Yunzhi has steadily maintained the industry's first place in ticket-issuing theaters and ticket-issuing attendances, while actively expanding overseas business. During the fiscal year, it has signed cooperation agreements with theaters in Macau, China, Southeast Asia and other regions to accelerate its overseas expansion.

At the same time, AI business has been efficiently implemented to help the development of the film and television industry. The Lighthouse AI version of the intelligent publicity and promotion data product for the entertainment industry will be launched in 2023. It relies on four digital and intelligent functions: box office prediction, publicity and promotion intelligent query, public opinion analysis, and AI publicity and promotion materials, to help the industry's operational efficiency improve significantly. In addition, Alibaba Pictures has also laid out virtual shooting to explore the promotion and application of AI and new technologies in the film and television industry.

In the field of IP derivatives business, Ali Fish, an IP trading and innovation platform under Alibaba Pictures, has built a huge and rich IP matrix, with strong business growth. During the fiscal year, the revenue of Ali Fish's sub-licensing business increased by 77% year-on-year, and the five-year compound growth rate was nearly 60%; the trendy toy brand KOITAKE combined independent trendy toy IP with multiple film and television dramas to create trendy toy products with different styles. As of now, KOITAKE has accumulated more than 10 original trendy toy IPs and combined them with more than 40 film and television content.

Therefore, Alibaba Pictures implemented the "content + technology" dual-wheel drive strategy, continued to increase investment in high-quality content, comprehensively deployed film and television AI, completed the major acquisition of Damai, and steadily built a multi-scenario, full industrial chain, and group-style development pattern, and multi-sector business developed steadily.

4. Conclusion

Based on the above content, it can be seen that among the booming entertainment APPs, Bilibili, as a comprehensive video community, provides a wide range of video content consumption scenarios, centered on professional user-generated videos (PUGV), and supplemented by professional agency-generated videos. Video (OGV), etc., constitute a complete content ecosystem. Xiaohongshu, on the other hand, has gone a long way from “finding good things from all over the world” to “marking my life”, from single beauty to general life; both in terms of the growth of users and content, Xiaohongshu is accelerating to break out of the circle. While the movie and performance APPs have a full-link layout, the game APPs have formed a model integrating research and operation after years of development.

For China's entertainment economy to develop rapidly, it is undoubtedly necessary to carry out precise marketing based on the "interest circle" built by people with similar interests to achieve refined operations of the entertainment consumption economy, and also based on the spiritual needs

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and multi-dimensional social interaction of China's active entertainment population. It is important to focus on the integration of entertainment and technology, the integration of entertainment and food/sports, and the integration of entertainment and tourism, and seize the growth space of social pan-entertainment.

In the future, in economic activities, more attention should be paid to consider consumption formats, industrial structures and regional policies from the comprehensive needs of people, and even more attention should be paid to promote economic development with the freedom and comprehensive development of people. Especially under the current development trend, for China's cultural and entertainment industry, the layout of the entire industrial chain based on multi-dimensional needs, and the precise output supplemented by scientific and technological means, will inevitably lead China's cultural and entertainment consumption economy to a new stage of development.

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The Analysis of the Abnormal Return Rate of Platform Enterprises

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Abstract: It is a definite trend that AI technology has become a new important factor of production. This study will be mainly through the event research method, the use of Shanghai, Shenzhen and Hong Kong listed companies panel data, combined with the relevant platform enterprise financial performance data, establish a mathematical model, study the latest introduction of the new technology of artificial intelligence (LLM, etc.) on the company stock yield, according to different enterprises set up multiple events window, fitting for stock abnormal yield, and use fundamental analysis and other financial means to estimate the future stock yield trend. As is revealed in the mathematical model, the capital market responses positively to the introduction of the artificial intelligence technology. Moreover, the informational announcements have a high degree of impact on regardless of number. The result suggests platform enterprises. The results encourage enterprises to introduce artificial intelligence technology and government to set up regulations accelerating development and productive practice. It has clarified the impact of the application of cutting-edge hot technologies such as new artificial intelligence technologies and large models that attract global attention on abnormal stock returns, which provides a reference basis for the national government to introduce relevant policies to encourage, support and guide the digital transformation of China's listed enterprises and promote the healthy development of artificial intelligence.

Keywords: Artificial intelligence, Event research method, Stock abnormal yield.

1. Introduction

Enterprises' introduction of new artificial intelligence technologies to achieve digital transformation has become an inevitable path to promote economic development, enhance international economic competitiveness, and achieve high-quality development of microeconomic entities. The introduction of new technologies provides new development impetus for companies in all walks of life. But will this bring better capital market performance for listed companies, especially platform enterprises with extensive influence? Moreover, platform enterprises are "an organizational form that can construct flexible combinations of resources, routines, and structures in new business opportunities and challenges". The research makes up for the macro perspective of previous event studies and measures the impact of the introduction of ai technology on platform-oriented enterprises on a micro level [1, 2].

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1.1. Research background

Artificial intelligence technology is booming, especially the LLM large model is on the rise, the Chinese government attaches great importance to the development of artificial intelligence technology and is accelerating the deep integration of artificial intelligence and the real economy [3]. In recent years, platform companies have introduced a large number of new digital technologies, and this may have some difficulty to assess the impact on corporate capital market performance.

1.2. Literature Review

At present, the academic circle pays close attention to the economic effect of digital transformation. Some research focused on the production market performance, revealing the positive impact on enterprises' total factor productivity [4]. When it comes to some research focused on capital markets, it is proved that digital transformation effects investors' concentration, sentiment and enterprises' innovation, thus promoting the rate of stock returns [5], improving stock liquidity and exhibiting certain structural heterogeneity characteristics [6].

When it comes to more specific technology like big data and artificial intelligence, the probability of applying big data in China varies. Large scale, low proportion of tangible assets, strong profitability, and location in the market. Companies with higher levels of digitalization are more likely to apply big data. And big data applications can significantly increase the market value of companies [7]. Moreover, some research perspectives of relevant literature are mainly focused on the macro level such as the country and industry, including the impact of artificial intelligence technology on social and economic growth, industrial structure transformation, labor employment and income distribution.

However, most of the research conclusions are derived from the mathematical model at the macro level, and there is still an obvious gap in the research on the economic consequences of AI technology innovation at the micro level. In the existing about the introduction of new technology, digital transformation of the capital market performance research mainly focused on stock liquidity, synchronicity and share price crash risk direction, there is no literature exact platform enterprise artificial intelligence technology introduction, especially the big model technology introduction and abnormal returns of listed companies. Therefore, the related studies are relatively new.

2. Methodology

2.1. Study sample screening, event window period. The estimation period is determined

Refer to the platform definition and characteristics proposed by Zhu in 2016 [8], this paper have formulated four principles for the screening of this announcement:

(1) this research involved a comprehensive search for all listed company's annual report and half report in the CSRC designated the information disclosure of listed companies media a "tide of information online" ,and according to the criteria of the following screening samples as the definition platform type enterprise: if the enterprise in the annual report, half report mentioned "the company is mainly engaged in business", "core competitiveness analysis", "operating situation discussion analysis" several chapters clearly put forward "the company is an industry platform enterprise", then determine the company as the platform type enterprise.

(2) if the enterprise business covers more than two industry, the company annual report, half annual report of one or a few industry business conditions mentioned in the introduction of "the main mode of operation is to establish / operating platform" or "company is the platform in the field of business enterprise", and this or this business in the past year the operating income accounted for more than 70% of the total revenue, or explicitly this or this business is the core business of the enterprise, determine the company as the platform type enterprise.

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(3) for retail, hypermarkets, commercial real estate, leasing intermediary itself has the nature of platform of traditional industry, only the annual report, half report shows that the company has formed or initially formed a complete online management system, pay attention to the operation mode of the "Internet +", to pay attention to online operations, can determine the company as a platform enterprise.

(4) in the electric business enterprise, only the enterprise has proprietary online platform, not only relying on ali, jingdong, WeChat third party platform for their own online marketing, and has a large number of suppliers, not limited to a single or a few suppliers, which really open in the face of society, rather than only open a link of their supply chain, such electricity enterprise can be defined as a platform enterprise.

In accordance with the above screening rules, there are more than 200 platform enterprises can be identified. follow, this study thoroughly investigate the technology introduction announcements of the select enterprises since (LLM large model technology, etc.), Further select Meituan, Alibaba, Tencent, Baidu and other influential platform enterprises for research, And respectively selected after the corresponding technical announcement and input as the event date, Select the event of 15 trading days before and after the event, Event window period, T= (-15, 15), Select 21 trading days before the event to 121 trading days before the event as the estimated window period, To conduct an empirical study on the impact of technological innovation reports on the value of the company.

2.2. Model establishment and event day selection

According to Mahmood's research in 2010, the stock markets in Shanghai and Shenzhen have entered the effective period of weak levels, so this paper chooses the market model for analysis [9]. This topic selects a general market model to calculate abnormal stock returns under the event occurrence window. It reflects the linear function between the rate of return of the sample stocks in the event window and the market rate of return. The expression of this single exponential model is as follows:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} R_{it} \quad (1)$$

In the model, the return of the stock i on day t is taken as the dependent variable. R_{mt} represents the yield of the market securities portfolio, used as an independent variable. The i is the intercept of the stock i, and the β_i is the slope, the error term of the stock on day t. The $\beta_i R_{mt}$ shows the part of the change in stock yields that can be explained by market volatility, while it shows the part of special corporate events that cannot be explained by market volatility.

This paper converts the calendar time of each sample event into event time according to certain rules: setting the day of the announcement , the trading day as the first day, the trading day after the event as the first day, and so on. If the day when the platform enterprise releases the announcement of the introduction of AI technology is not the normal trading day of the stock market (weekends, legal holidays, etc.), the normal trading day after the event will be set as the 0 day.

If a platform enterprise issues an announcement of the introduction of artificial intelligence technology on the normal trading day of the stock market and the announcement is later than the closing time of the stock market (this study is 15:00 of each stock trading day, this section set the trading day after the actual release date of the announcement as the 0 day.

Because this paper's study is a platform enterprise CSR announcement short-term market reaction rather than long-term market reaction (long-term market reaction affected by various factors comprehensive and difficult to accurately assess, so this topic is not considered), after the stock market after announcement made the corresponding processing, the day after the release as the event day, so in order to better research platform enterprise artificial intelligence technology introduced the announcement of the stock market short-term response to the event, the topic also choose event day on the same day as the window period of research market reaction.

Thus, the event study of 214 announcements on the introduction of new technologies such as artificial intelligence from 176 platform-type enterprises was conducted

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2.3. Calculation of abnormal stock returns

In order to facilitate the analysis of the abnormal yield rate of the samples, in this paper, the 200 trading days before the announcement is selected as an estimation period to calculate the variance of i, i and ε_{it}. In order to increase the accurate and effective results of the estimation, the estimation period and event date need to be separated by two weeks, that is, the estimation period starts on day-220 and ends on day-11. In addition, this paper eliminated the samples with less than 40 valid stock data in the estimated period of 200 trading days to ensure the reliability of parameter estimation. This section used the least squares method to produce the estimates β_i, i, and $\hat{S}_\varepsilon^2$. The expression for the abnormal yield of the stock i on day t is:

$$A_{it} = R_{it} - (\alpha_i + \beta\hat{}iR_{mt}) \tag{2}$$

The average abnormal yield of the samples on day t is:

$$\overline{A}_t = \sum_{i=1}^{N} \frac{A_{it}}{N} \tag{3}$$

The result of the sum of the average anomaly returns over several days is the cumulative anomaly yield of the sample:

$$\overline{CAR}[t_1, t_2] = \sum_{t=t_1}^{t_2} \overline{A}_t \tag{4}$$

2.4. Model significance test

This study selected 214 technical introduction announcements from 176 Chinese platform listed companies in China from 2020 to 2024 as research samples for the event study. Assuming that the anomalous yields of the samples are independent of each other and have mean 0 and variance S. According to the central limit theorem, the result of the significance test of the average abnormal yield for a certain day is :

$$T\overline{A} = \sum_{i=1}^{N} \frac{\frac{A_{it}}{\hat{S}_\varepsilon^2}}{\sqrt{N}} \sim N(0,1) \tag{5}$$

The significance test expression for the cumulative abnormal gain in the window period is as follows:

$$T\overline{A} = \sum_{i=1}^{N} \frac{A_{it}}{\hat{S}_\varepsilon^2} \sim N(0,1) \tag{6}$$

3. Empirical Results

3.1. Base Line

Under the general assumption of the abnormal returns of the stock market, the four supposed adjustment variables H1-H4 in this paper are H1: type of platform enterprise (trading platform or information platform), H2: degree of information disclosure of technology announcement, H3: technology introduction for ToB / ToC, H4: technology introduction into the operation state of enterprises. They are now hypothesis-tested separately.

To test the overall hypothesis, an examination of the average anomalous gain was conducted. Since the anomalous returns under the null hypothesis, and according to the central limit theorem, to test the effect of anomalous gain values, this section refer to Xia'research in 2016 [10], two non-parametric tests were applied to exclude the influence of outliers on the test results. On the one hand, the Wilkerson signed rank test was selected to test whether the median value of abnormal gains is significantly non-zero. On the other hand, the binomial sign test was employed to assess whether the

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probability of abnormal returns is significantly higher than 50%. For the technology introduction announcement of platform enterprises, it is speculated that it can produce a positive market response, prompting the selection of a one-sided T-test to evaluate the abnormal returns in this research.

For regulatory effects, to test H 1 to H 4, this paper tested by cross-sectional regression model. The dependent variable in the model is the cumulative abnormal rate of return on the day of announcement (Day0), and the independent variables are the four variables and control variables related to hypothesis H1~H4. Among these, the four variables corresponding to those from H 1 to H 4 are shown below.

Types of platform enterprise (X1):

This is an indicator variable. If the trading platform enterprise, the value is 0, if the information platform enterprise, the value is 1, so as to control the potential impact of the platform enterprise type on abnormal earnings.

Information disclosure degree of technical announcements of platform enterprises (X2):

This is an indicator variable. Past studies have shown that the level of detail of information disclosure has an impact on stock returns [11].

The company's sustainable operations disclosure is measured by using whether the company issues regular technology introduction announcements. This variable is used to control the impact of different company disclosure conditions. If the company has regularly issued regular technology introduction announcements for the past three years, to assign a value of 1, otherwise 0.

Application type of technology introduction described in the announcement (X3):

This is an indicator variable. If the calculated value is 1, it means that the technology introduces a platform enterprise suitable for ToB, and 0 means that it is suitable for ToC. It is expected that the coefficient of this variable to be positive.

Announcement of the enterprise operation status introduced by the technology (X4):

The return on assets in the accounting quarter before the event shows the company's operating performance before the announcement of technology introduction. If ROA is 0, the coefficient is 0. The computational analysis was performed using the following cross sectional regression.

The computational analysis is performed with the use of the following cross-sectional regression model:

$$CAR_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i \quad (7)$$

This section used the market model to get the CAR of LLM and others after the release of other AI technical announcements and conducted statistical tests to verify the overall hypothesis.

The abnormal revenue results of the technology introduction announcements on event days are shown below.

Table 1: Statistical Data of Abnormal Returns on Day 0

Indicator	Value
Mean	0.010693427450980392
Median	0.0022821
Positive Rate	0.5555555555555556
t-Statistic	3.478846315006499
Wilcoxon Signed-Rank Test	2.56

As shown in Table 1, the t-statistic at day 0 was 3.4788, which indicates that the abnormal gain for that day was statistically significant and significantly different from zero. This could mean that the introduction of new AI technologies has a significant impact on stock prices. At day 0, more than

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half the time abnormal gains was positive. This suggests that the market in Shanghai and Shenzhen had a significant positive reaction on the day of the event.

Later, some independent variables and control variables are added to test whether the several factors mentioned in the hypothesis H1-H4 will affect the market response of the announcement of technology introduction by platform enterprises. First, the study by Jacobs and Singhal in 2014 is referenced to employ cross-sectional regression models for testing the impact of the variables mentioned in H1 to H4 on the response of stock markets in Shanghai and Shenzhen of technology introduction events [12]. The dependent variable is the average abnormal return of the sample on the day of the announcement, and the independent variable includes the variable one-to-one corresponding to the hypothesis and the control variable.

Table 2: Coefficient estimate

	variable	Symbol expectation	Parameter estimate	saliency
Type of Platform Enterprise Technology Announcement	X1	+	0.556	0.011989
Information Disclosure Degree	X2	+	0.428	0.122110
Introduction of technology	X3	+	-0.887	0.000795
Analysis of Operation Status of Enterprises Introducing Technology	X4	+	0.611	0.059789

According to Table 2, the type coefficient of platform enterprises is positive, which indicates that the technology introduction announcements issued by different types of platform enterprises will significantly adjust the market response, and the market responds more positively to the events issued by information platform enterprises. So the H1 was established.

The coefficient of the degree of information disclosure is positive, which indicates that the degree of sustainable operation information disclosure of the company will significantly adjust the market response, and the market is more actively to the technology introduction announcement issued by companies with high degree of information disclosure, so H2 was established.

The coefficient of the technology introduction is negative, which indicates that the different introduction of technology will significantly adjust the market response, and the market is more positively to the application of T o C-end AI technology. Therefore, H3 is rejected, but its coefficient has a certain degree of significance, which shows that the coefficient of the technology introduction purpose of the announcement is opposite to the expectations.

The announcement of the introduction of enterprises, and at the level of 10% significant, which shows that the announcement for good operation of enterprises will significantly adjust the market response. Show that the H4 assumption holds.

Through the above calculation, the research has preliminarily drawn the conclusion of the overall hypothesis of the model and the four hypotheses of H1, H2, H3 and H4, which provide the basis for further research.

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3.2. Robustness test

In addition, to determine that the market model chosen in this paper is not limited, an alternative model is employed for validation (see Table 3). The common models adjust the market models to conduct sensitivity analysis. The comparison of the computational results of the two methods can exclude the influence of the computational method and test the robustness of the results.

Table 3: Robustness test

Indicator	Value
Mean	0.008655648554566
Median	0.0032449
Positive Rate	0.6123657854548
t-Statistic	4.238473846295
Wilcoxon Signed-Rank Test	4.29

4. Conclusion

The research examines the reaction of China's capital markets to the announcement of the introduction of new AI technologies for platform-based enterprises. This paper selected 214 technology introduction announcements from 176 Chinese platform-based listed companies from 2020 to 2024. Combined with the market efficiency hypothesis, this paper revealed that on the day of the introduction of new ai technologies, the market would produce a significant positive response, with an average abnormal return of 0.011 and a positive rate of 56%. The research results are relatively significant. In addition, this paper also found that the market responds more positively to announcements made by companies that are informational, have a high degree of information disclosure, use of AI technology at the ToC end, and are in good operating condition.

Finally, there are some limitations to our study. First, our sample is limited to China's Shenzhen and Shanghai stock markets and lacks data on Chinese platform companies listed in Hong Kong and the United States. Our announcement samples are mainly from the information of the Shanghai Stock Exchange and the Shenzhen Stock Exchange, and the number of announcement samples is insufficient.

In addition, some studies suggest that the market may overreact to the release of technical announcements, and stakeholders may produce large feedback in a short period of time, which will directly affect the market value of enterprises. In addition, this study is to conduct market research on platform enterprises introduced by new artificial intelligence technologies in the past five years. For example, a more detailed division of time nodes and exploration of the influence mechanism may be another good research direction.

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Forecasting Market Activity and Aggregate Demand in China Using Time Series Models

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Abstract: The purpose of this study was to forecast market activity and aggregate demand in China using time series models. Forecasts of market activity (MA) and aggregate demand (AD) provide insights into consumer behavior and economic trends, which are crucial for policymakers and businesses alike. In order to forecast the MA and AD in China, this study uses the time series model, especially the exponential smoothing model. Based on the increase rates of M1 and M2 money supply, respectively, and the difference in increase rates between them. These indicators are necessary to assess MA and AD and reflect changes in money liquidity and people's spending behavior. The results suggest that people will be less willing to spend and more inclined to save in the coming years. This finding suggests that MA may decline as consumers become more cautious and prioritize saving over spending. This trend could be attributed to a variety of factors, including economic uncertainty or changes in monetary policy. The implications of this research are significant because it provides a forecasting framework that can help policymakers and businesses anticipate changes in consumer demand and adjust their strategies accordingly. Understanding these trends can lead to more informed decisions in economic planning and financial forecasting.

Keywords: Market Activity, Aggregate Demand, Forecast, Time Series, Money Supply.

1. Introduction

1.1. Research Background and Motivation

The background of the study is based on the impact of the increase rate of money supply on China's MA and AD. China's monetary policy has become increasingly frequent since the 2008 financial crisis [1]. Therefore, understanding the money supply will be extremely important. There are two important concepts. One is M1, the narrow money supply, which includes money in circulation, demand deposits of enterprises, and so on. The other is M2, the broad money supply, which has added time deposits, foreign currency deposits, trust deposits and so on to the original part of M1. M1 only contains the most liquid currency, while M2 covers more less liquid funds, such as time deposits and corporate deposits, etc. Therefore, M1 is often used to observe the current purchasing power of the public, and M2 is more used as an observation indicator of future inflation expectations. The difference between the growth rate of M1 and M2 is called the money growth scissors difference. When the difference is greater than 0, it indicates that the liquidity of funds is good, and individuals

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and enterprises are more optimistic about the economy and more inclined to consume and invest, which can enhance the economic vitality. When the difference is less than 0, it indicates that the liquidity of funds is poor, individuals and enterprises are more pessimistic about the economy and tend to save, which is not conducive to economic growth and may cause the stock market to fall. Therefore, when the money growth scissors difference between M1 and M2 is calculated, it can be a good analysis of China's MA and AD.

1.2. Literature Review

Money supply is an important intermediate variable of monetary policy instruments [2]. In the post-financial crisis era, China's economic downturn is the fundamental reason for the formation of the scissors gap of currency increase rate. The decrease in the opportunity cost of residents and enterprises to hold demand deposits and the decrease in the return rate of time deposits are the direct reasons for the formation of the scissors gap of monetary growth [3]. Ren Biyun's analysis of the reverse expansion of the scissors gap of M2 and M1 increase rate in China after the reform and opening up puts forward five suggestions based on the basic characteristics of China's economic operation [4]. The increase rate of money supply M1 continues to rise under the overall low economic condition, so as to obtain the impact brought by the increase rate of M1 [5]. There is a long-term positive correlation between the money growth scissors, and the impact on the macro economy is mainly achieved by changing money liquidity, bank liquidity, market liquidity, entrepreneurs' expectations for the future and the capital market [6]. The M1 and M2 scissors spread index can be used as a leading indicator to forecast the change trend of the inflation rate. By paying close attention to and detecting the change trend of the M1 and M2 scissors spread, the future price trend can be forecast in advance, so as to timely adjust the direction and intensity of monetary policy and improve the countercyclical macro-control behavior of the central bank [7].

1.3. Research Contents

The main research content of this paper is to use time series model to forecast the MA and AD of China. The value of the scissors difference between M1 and M2 can be used as a leading indicator of MA and AD in China. Therefore, the research idea is to predict the value of the scissors difference between M1 and M2 by using the time series model, so as to obtain its change, and then judge the performance of MA and AD.

2. Methodology

2.1. Data Selection and Source

In order to forecast the activity and total demand of the Chinese market, the increase rate of M1 and M2 as well as their growth scissors difference are extremely important data in the research. Monthly data of M1 and M2 from 2008 to 2022 were selected as the training set. The data is selected from the People's Bank of China, which calculates the monthly data of money supply M1 and M2 from 2008 to 2022. The increase rate of M1 and M2 can be calculated through calculation, and the increase rate of their difference can be calculated by subtraction. In any data analysis task, the first step is to map the data. Because charts can visualize many features of data, including patterns, abnormal observations, time changes, and relationships between variables. R Studio is used to draw the increase rate of M1 and M2 as well as their growth scissors difference, and the results are shown in Figures 1-3.

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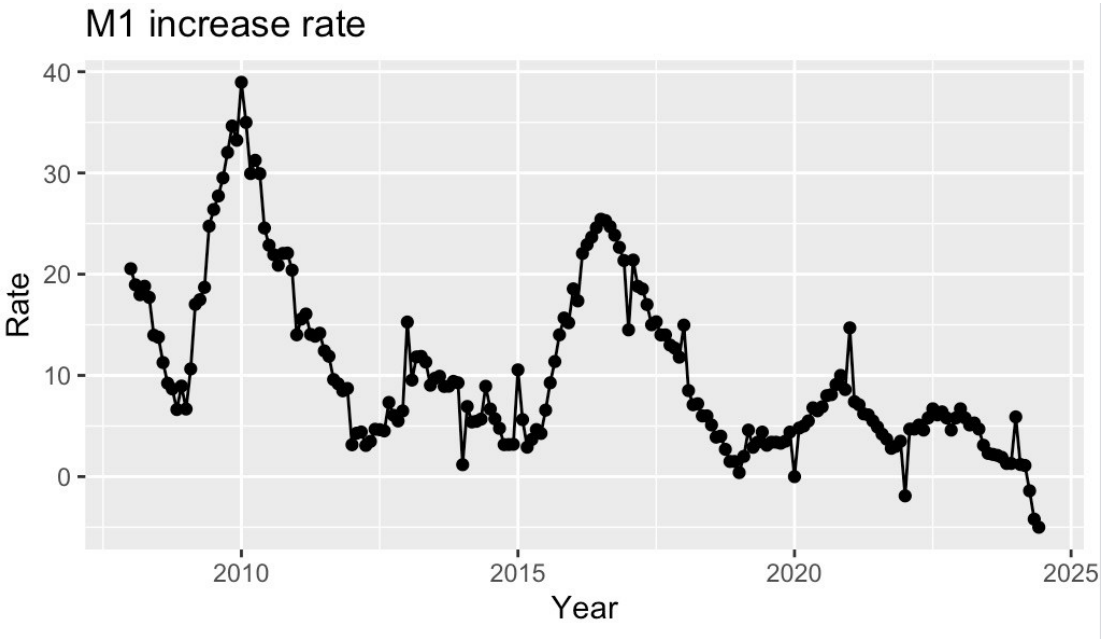

Figure 1: M1 increase rate.

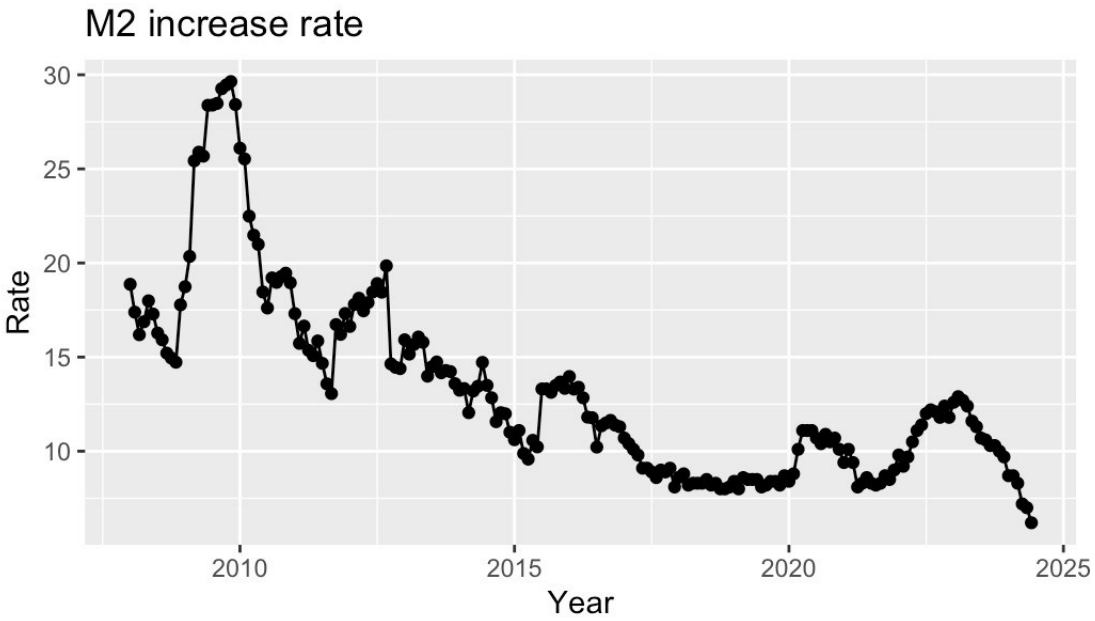

Figure 2: M2 increase rate.

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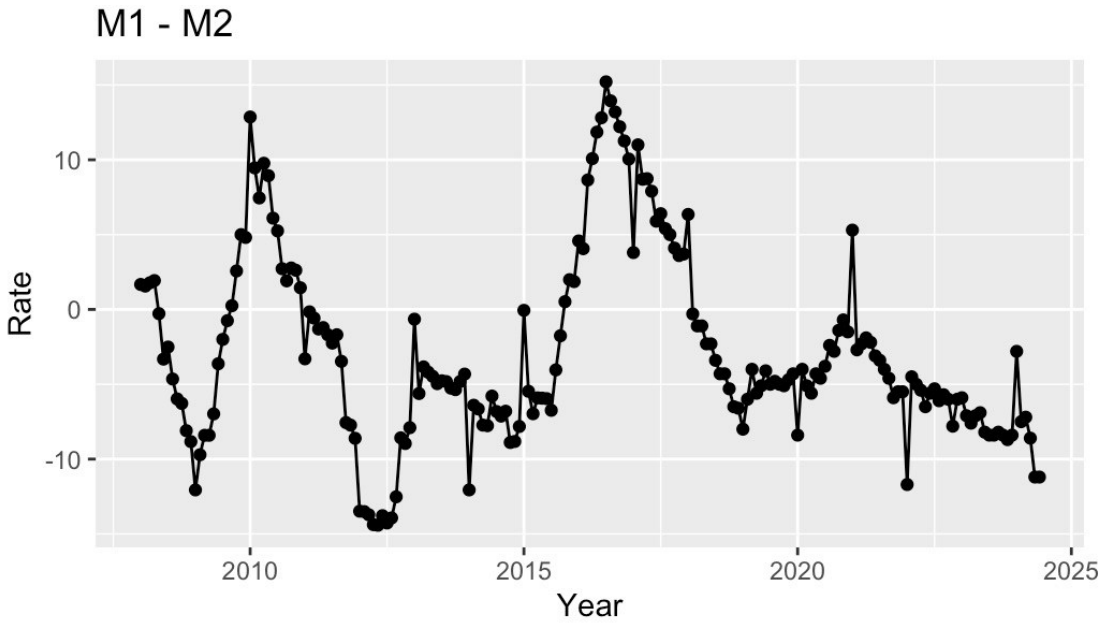

Figure 3: M1-M2 increase rate.

2.2. Stationary Test and White Noise Test

When the graph is finished, it is necessary to incorporate as many data features as possible into the forecast method that needs to be used. It can be seen from the diagram of M1-M2 increase rate that this picture is not stable enough, so what needs to be done is to make a non-stationary time series stationary and calculate the difference between the continuous observation data, which is to make the difference of the data. The result after difference is shown in Figure 4.

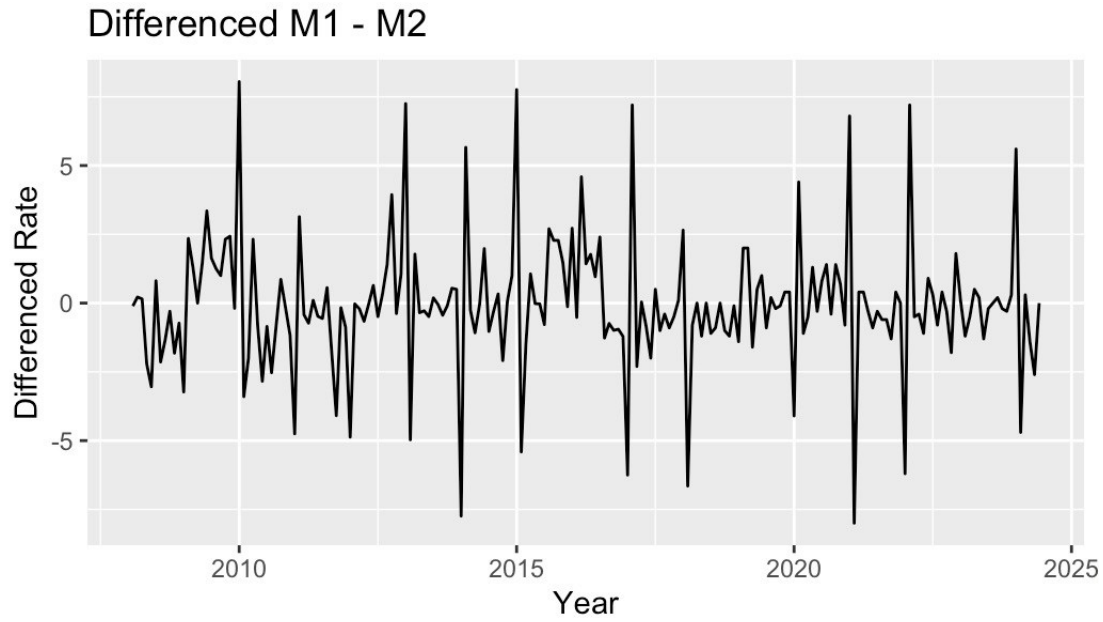

Figure 4: Differenced M1-M2.

After completing the difference, what needs to be done is to check the stationary of the result after the difference. Next, adf.test() is used to test whether the data is stationary, and the result is that the P-value is 0.009, which is much less than 0.05. So now the data is very stationary, although the data

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in the chart looks very volatile. Another test that needs to be performed is the white noise test. A time series without autocorrelation is called white noise. Therefore, when the time series is white noise, it means that the time series cannot be forecast, so the white noise test is particularly critical. Ljung-Box test is used to test the white noise of the time series, and the result obtained is also that the P-value is much less than 0.05, so it can be seen that M1-M2 after difference is not white noise and can be forecast.

2.3. Exponential Smoothing Model

Exponential smoothing models are used to describe trends and seasonality in data and are one of the most widely used methods in time series. Exponential smoothing was developed in the late 1950s and underpins some of the most successful forecasting methods. The calculation using the applied exponential smoothing method is a weighted average of past observations. In other words, the closer the observation time, the higher its weight. In industrial applications, creating reliable forecasts quickly and using complex time series is a huge advantage. In this study, the exponential smoothing method can well forecast a trend of future MA and AD. The next step is to apply Error Trend Seasonality (ETS) equation to select a suitable model, and then choose Damped Holt's method after comparing with Akaike's Information Criterion (AIC). Most estimates based on Holt's linear method have some development. Empirical evidence suggests that these methods are often too predictable, especially when they are most widely used [8]. To sum up, Damped Holt's method is the most suitable method for forecasting MA and total demand. The final forecast results are shown in Figure 5.

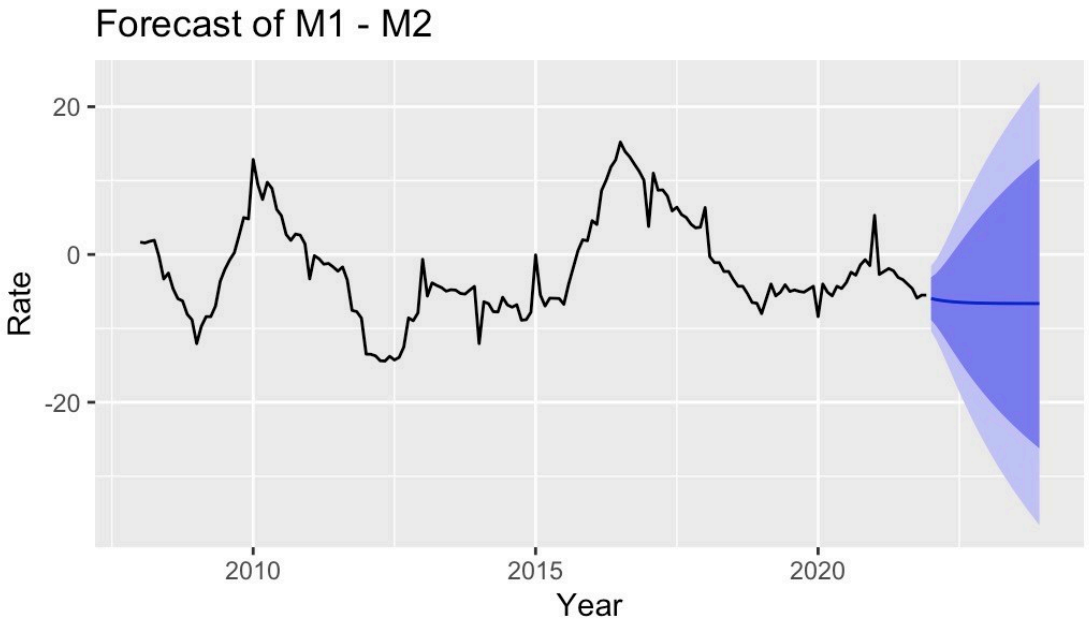

Figure 5: Forecast of M1-M2.

To sum up, it can be seen from the forecast chart that in the next two years, the increase rate of M1-M2 will be less than 0, which indicates that in the following period of time, consumers' willingness to consume will decline, enterprises and consumers will be more inclined to save, and MA and AD will also be reduced to a certain extent.

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3. Discussion

M1-M2 growth rate scissors difference is less than 0, indicating that the money supply is lower than the money demand. Comprehensive industry analysis, affected by multiple factors such as deposit "moving" and weak financing demand dragging down deposits, the increase rate of M1M2 slowed down [9]. This may reflect some structural problem in the economy or a misfit in monetary policy. First, economic growth is weak and the demand for money exceeds the actual supply. This situation may be due to slow economic growth and low confidence among businesses and consumers, resulting in insufficient demand for money. Second, the inflexibility of monetary policy. The central bank may not adjust the money supply in time to respond to changes in the economy, resulting in a shortage of money in the market. Third, insufficient money supply can lead to deflation, or a decline in the price level. This phenomenon increases the real debt burden, discourages consumption and investment, and further exacerbates economic weakness. Fourth, insufficient money supply can also lead to instability in financial markets. Due to the lack of liquidity, the market may break the capital chain, thus exacerbating financial risks. For the future development, there are also the following suggestions: First, the central bank should adjust monetary policy flexibly according to economic conditions. Second, the government should introduce proactive fiscal policies, such as increasing infrastructure investment, cutting taxes or issuing consumer vouchers, to stimulate economic growth. Third, in order to deal with the financial risks caused by insufficient money supply, financial supervision should be strengthened to ensure the stability of financial institutions. At the same time, central banks can provide temporary liquidity support to prevent sharp market fluctuations [10].

4. Conclusion

This study presents the forecast of MA and AD in China through a time series model. The results show that China's MA and AD will most likely decline in the next two years. This paper is innovative in data selection. The data given by the People's Bank of China is only the monthly total data of M1 and M2, and further calculations are needed to obtain the data needed for the research. At the same time, this paper also has some shortcomings. On the one hand, the analysis of the relationship between M1 and M2 growth scissors difference and macro-economy is not comprehensive enough. On the other hand, exponential smoothing is poor when dealing with time series data with obvious trends or seasonality, and it is usually only suitable for stable time series data without obvious trends and seasonal fluctuations. When there are long-term trends or periodic fluctuations in the time series, simple exponential smoothing methods may not accurately capture these patterns, thus affecting the accuracy of the forecast results. In addition, future policy changes are highly likely to affect the trend of data, so the uncontrollability of policy changes will lead to inaccurate forecast results. There are the following ways to improve the above shortcomings: Firstly, learn more macro-economy-related content and have a deeper understanding of the relationship between M1 and M2 growth scissors difference and macro-economy. Secondly, in terms of forecast, learning and trying to use more methods may find a method that is more suitable for this study.

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Investment Suggestions for Individual Investors: A Case Study of Bill Hwang

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Abstract: On March 26, 2021, Archegos, the family fund office managed by hedge fund manager Bill Hwang, exploded, and the heavily held stocks under his management were sold, with a total amount of $20 billion, and the market value of the related stocks was wiped out by about $33 billion. This huge event has aroused widespread attention in the financial world, but also sounded the alarm for individual investors. This paper analyzes the process of Archegos' implosion, and analyzes the reasons for the implosion: the extensive use of financial derivatives, the concentration of investment strategies and the abuse of leverage. Then it provides relevant suggestions for individual investors to better participate in the financial market: establishing effective investment portfolio, be cautious to leverage, robust risk management and continuous monitoring. Based on the analysis of Bill Hwang event, this article provides reference for individual investors to identify investment risks, choose better investment strategies and more effective risk management.

Keywords: Bill Hwang, Individual Investor, Leverage, Risk Management.

1. Introduction

Many individual investors have actively participated in the financial markets, aspiring to emulate Warren Buffett, who boasts exceptional ability in forecasting financial markets and generating substantial profits with their capital. Nevertheless, within the expansive financial sector, only a narrow fraction of investors achieve success. Most investors failed because they indulge in the zealous desire of profits, which consequently causes them to overlook the evaluation and management of risk. Indeed, there is a typical correlation between risk and return, and any logical investor must not overlook the evaluation and control of risk while predicting future anticipated gains.

However, history always seems to repeat itself. Those who forget history repeat it, and too much greed may lead to a loss of capital. 1998 was a wake-up call for investors when Long-Term Capital Management (LTCM) suffered a major loss. LTCM used sophisticated computerized calculations to identify abnormal market price differentials, leveraged funds to magnify them, and entered the market to make a profit. “The investment strategy. From 1994 to 1997, LTCM had been maintaining a good momentum of net asset appreciation, but due to the occurrence of small probability events in the market, Russian debt defaults caused LTCM to start losing money. As losses from the fixed investment model continued to mount, LTCM had become increasingly difficult to meet margin requirements and needed more collateral to ensure that it would be able to service all of its debt, but lacked high-value assets to use as collateral. Not only that, LTCM was in the difficult position of

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having difficulty liquidating its assets. Most of its assets are still illiquid and difficult to sell in normal market times. This shows that high risk in the capital market may not necessarily come with high profit. High leverage is a double-edged sword. When the market moves in an unfavorable direction, highly leveraged transactions require LTCM to have sufficient cash to support margin requirements. Ultimately, the LTCM crisis not only led to significant losses for this fund company, but also affected the global financial market[1].

The impact of LTCM was felt throughout the financial world, but similar incidents still occur. In 2008, as one of the once Big Four investment banks in the United States, Lehman Brothers went from being a leading and respected major investment bank to a company struggling to find external financing and ultimately a company on the verge of bankruptcy in a matter of months. This was due precisely to Lehman Brothers' concentrated investment in high-risk and illiquid subprime loans on real estate at 30 times leverage [2].

The above case did not seem to make investors pay enough attention to risk management, and a similar event occurred again in 2021, when the collapse of the family management office founded by Bill Hwang hit the financial markets again. This article will analyze this event and provide advice on risk management for individual investors.

2. Literature Review

In the context of risk management for individual investors, many studies have examined how to effectively identify, assess and respond to potential investment risks. Risk management for investors involves not only forecasting market developments, but is also closely related to the behavioral characteristics and decision-making processes of individual investors. Klement suggests that risk profiling for investors is necessary because knowing the risk profile of investors contributes to suitability of the investment decisions [3]. By examining the metrics that have an impact on individual investor decision-making, it is noted that market returns are usually an important metric of interest to investors. In this context, risk management in the pursuit of high returns is also more important [4]. Miller identifies the benefits of leverage in improving the efficiency of the company[5]. However, Ge and Qiu point out that leverage have negative relationship with investment level, and limit the firms with weak growth opportunities [6]. Markowitz imply that modern portfolio theory emphasizes the importance of asset diversification, which can reduce the overall risk of a portfolio [7]. Individual investors should adopt an asset allocation strategy to diversify their funds among different assets, such as stocks, bonds and real estate, in order to reduce the impact of fluctuations in individual assets on the overall investment. Besides, Lekovic suggests that Portfolios should consider the optimal number of securities to reduce management costs [8]. Nikolaou points out that the liquidity is important for investors which help investors restore balances when they encounter crisis [9]. Hon expresses that financial derivatives is a good tool to hedge risks. But financial derivatives amplify the risk to some extent for the investors and if not utilized properly, it can have a huge impact [10].

Based on the above research, this essay analyzes how individual investors can effectively manage risks, through the explosion of Bill Hwang and Archegos Capital. Through this research, it can theoretically integrate and expand the risk of individual investors in the investment process, and at the same time can give specific investment advice and reminders for individual investment in practice.

3. Overview of the Implosion Event

3.1. Background of Bill Hwang and Archegos

Bill Hwang is the founder of Archegos Capital Management. After working at various financial institutions, including Deutsche Bank and Goldman Sachs, Hwang is known for his quantitative investment strategies and large-scale leveraged investments. He has been investigated by the U.S.

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Securities and Exchange Commission (SEC) for insider trading and has been banned by the Hong Kong Securities and Futures Commission (SFC) from participating in trading activities in Hong Kong. It can be inferred that Bill Hwang is a relatively aggressive investor with a low reputation.

Archegos Capital Management was a private investment firm founded in 2013 and operated as a family office, managing wealth accumulated by Hwang from his previous ventures. Under the management of Bill Hwang, Archegos employed high leverage to amplify returns, heavily investing in technology and media stocks [11]. Table 1 shows Archegos's concentrated equity strategy, which is Bill Hwang's top seven holdings.

Table 1: Bill Hwang's Top Seven Holdings.

Rank	Stock	Ticker	Archegos Ownership Stake
1	GSX Techedu	GSX	70%
2	Discovery Class A	DISCA	Over 60%
3	IQIYI	IQ	Over 50%
4	Paramount (formerly ViacomCBS)	PARA	Over 50%
5	Tencent Music Entertainment	TME	Over 45%
6	Vipshop Holdings	VIPS	25%
7	Shopify	SHOP	1.3%

3.2. The Whole Process of the Event

The crisis commenced on March 22, 2021, when the American media company ViacomCBS declared a $3 billion stock offering, a decision that instigated a sell-off resulting in a persistent and significant decrease in ViacomCBS's shares [12]. It prompted an emergency margin call from banks that had borrowed from Archegos to cover his significant exposure to ViacomCBS. Nevertheless, Bill Hwang lacked the liquidity to satisfy the demand.

Credit Suisse indicated that on March 24, as the ViacomCBS stock price persisted in its slide, another significant long position of Archegos, Tencent Music Entertainment Group, diminished by 20% [13].

On March 26, the extensive compulsory liquidation began. Goldman and Morgan initially liquidated Archegos-related equities to generate liquidity and mitigate exposures. By the time Nomura and Credit Suisse choose to start selling, their share prices had declined to such an extent that substantial losses were inevitable.

Consequently, Bill Hwang incurred losses of more than ten billion dollars in one day, creating the greatest single-day loss in history. On March 31, the formerly illustrious corporation filed for bankruptcy, and Bill Hwang faced legal repercussions. Besides, statistics reveal that Credit Suisse incurred losses amounting to 4.7 billion dollars, while Nomura Securities experienced losses of approximately 2.9 billion dollars. Across Wall Street, losses reached $10 billion.

4. Reasons Analysis

4.1. The Use of Financial Derivatives

The evolution of the financial market has compelled investors to seek more than mere investing in fundamental financial assets like equities and bonds. To mitigate risk and achieve superior returns, an increasing number of individuals are investing in financial derivatives.

As an aggressive investor, Bill Hwang used Total Return Swaps (TRS) and Contracts for Difference. This lets him trade securities and generate income without owning them. TRS refers to the total return of the reference asset from the payer to the recipient throughout the contract. Principal,

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interest, prepaid expenses, and capital gains from asset price movements comprise the overall return. The TRS recipient agrees to compensate the other party with a preset share of the asset's appreciation, typically LIBOR plus any deviations, and the capital loss from unfavorable price movements. Baidu and other stocks underpin Archegos' total return swap (TRS) with numerous investment banks.

A contract for difference is a financial derivative that involves investors and traders agreeing on the pricing of stocks, commodities, foreign exchange, and other financial instruments. It combines several TRS contracts and standardized financial derivatives. Archegos predicts Baidu and other equity changes, while Nomura Securities associates use leverage to trade CFDs. To profit from the asset differential, they liquidate the position when the stock price rises or falls to the expected objective.

In essence, both total income swaps and CFDs do not involve Archegos owning the apparent shares; rather, they are held by the investment banks with which he collaborates. Both of Archegos' instruments are traded over-the-counter, making it difficult for investment banks to estimate its holdings in other equities without transaction data and comparative research. As the price fell, the investment bank was uninformed of Archegos' trading at other institutions until several investment banks issued simultaneous margin calls. After Archegos defaulted, major investment banks liquidated contract assets progressively, liquidating stakes.

4.2. Concentrated Investment Without Diversification of Risk

Another important reason for Archegos's collapse is Bill Hwang’s concentrated holdings in several stocks, which maximizes the leverage of the trades, thereby increasing the total amount of the Archegos positions.

Bill Hwang Mainly investing in several large technology stocks and other growth companies, this stone portfolio is relatively concentrated, and it is difficult to diversify the risks. On March 22, ViacomCBS declared a public offering of 20 million shares at a price of $85 each. This announcement precipitated a substantial decrease in its stock price, which plummeted to 48.23 yuan per share by the market close on March 26, representing a total reduction of 50.6% over the course of a week. A study by Earl indicates that Bill Hwang and Archegos clandestinely amassed more than 50% of the common stock of ViacomCBS. The precipitous drop of ViacomCBS stock resulted in substantial losses for Archegos [14]. On March 26, GSX Techedu, an online education firm significantly backed by Archegos, saw a 41.6% decrease in its stock price due to speculations of the Chinese Ministry of Education's crackdown on extracurricular education, culminating in an overall fall. On the same day, China's Ministry of Industry and Information Technology unveiled the draft of the "New Regulations on the Implementation of the Tobacco Monopoly Law," which aims to regulate new tobacco products, including electronic cigarettes, in accordance with existing cigarette provisions. Concurrently, the shares of Wucore Technology, an electronic cigarette manufacturer owned by Archegos, experienced a continuous decline, totaling 53% over the course of a week.

Meanwhile, Archegos's major holdings declined, resulting in a decrease in the price of the contracts for difference. Nomura Securities and more investors jointly issued a margin recovery notification. Archegos, propelled by significant leverage, is exposed to between $60 billion and $100 billion, complicating short-term margin recovery. The investment strategy aimed at minimizing losses initiated the liquidation of contracts for difference, concurrently leading to the sale of a substantial quantity of underlying equities, which precipitated the collapse of Archegos.

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4.3. Highly leveraged Investment Strategy

The key characteristics of Bill Hwang's investment strategy is high leverage, which means that it get margin financing from major brokers to increase their returns, or reduce their losses. Usually, the greater the leverage, the higher the cost to provide a fund manager.

Bill Hwang is an experienced user of leverage. He possesses an extensive quantity of shares in enterprises like Baidu, which is a Chinese multinational corporation specializing in artificial intelligence and internet-related products, with its stock price escalating from $97.20 a year ago to $339.91 in February of this year. Additionally, ViacomCBS is an American mass media conglomerate whose stock price has increased by approximately 700% over the past year. Bill Hwang employed substantial leverage to greatly enhance these returns, enabling him to gain considerable wealth in a short period [15].

High leverage is usually favorable when the underlying asset moves in a favorable direction, but when things are unfavorable, high leverage means extremely high losses. Based on the analysis of the above two points, Bill Hwang not only uses financial derivatives to expand leverage in his portfolio, but also increases returns through concentrated investment. Such an investment strategy expands leverage multiple from multiple angles, allowing him to accumulate huge wealth in a very short period of time. As reported by hedgeweek, Archegos's total assets were only $10 billion, while the stock exposure was nearly $50 billion. That was almost five times its total assets, and they essentially lost $30 billion on eight stocks.

5. Thinking and Enlightment

The collapse of Bill Hwang's Archegos Capital Management has sounded the alarm for individual investors regarding risk management when investing in derivatives.

5.1. Establishing Effective Portfolio

Individual investors need to establish efficient portfolios to reduce their investment risk. Hwang's investments are mainly in technology equities and both domestic and international media companies, which typically experience similar external influences, resulting in comparable fluctuations. This is often disadvantageous when facing risks, as it causes the risks to accumulate rather than to be dispersed and offset. Hwang's concentrated portfolio underscored the dangers of concentrating on a limited number of investments. Therefore, individual investors ought to strive for diversification of their portfolios across various sectors and asset classes to reduce risk. The failure of a single investment should not undermine an entire portfolio.

5.2. Be Cautious to Leverage

While pursuing high returns, individual investors should recognize that this typically means high risk. The utilization of leverage can magnify both gains and losses. Archegos heavily depends on leverage and engages in billions of dollars in margin trading, resulting in considerable portfolio volatility, where minor market fluctuations can precipitate substantial losses. Hwang's excessive leverage ratio serves as a cautionary tale for personal investors regarding margin trading or leveraged products. Therefore, it is imperative for individual investors to comprehend the associated risks, as significant downturns can result in considerable financial losses.

5.3. Robust Risk Management

When Hwang's portfolio went wrong and related stocks fell sharply, liquidity quickly dried up, making it unable to effectively reduce its asset holdings to reduce its losses. Archegos’s lack of

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adequate risk management practices, such as stop-loss orders or limits on position sizes, contributed to its downfall. Personal investors should implement stricter risk management strategies, such as setting clear limits on how much of their total capital they are willing to risk on a single investment, which could control the total amount of losses and ensure the losses is within the affordability of investors.

5.4. Continuous Monitor

The necessity of ongoing monitoring of investments became evident during this crisis. If Bill Hwang and Archegos effectively monitor their portfolios, they can timely adjust their positions to make relatively small losses, rather than passively accepting all losses. Investors should stay informed about market conditions and actively manage their portfolios, adjusting positions as needed in response to market changes.

6. Conclusion

The fall of Bill Hwang's Archegos Capital Management highlights the significance of risk management for individual investors. Hwang's strategy of excessive leverage, concentrated investments, and inadequate risk management may result in devastating losses, which is similar to the history events the LTCM crisis and the collapse of Lehman Brothers.

The case of Bill Hwang suggests that individual investors should establishing well-diversified portfolios across multiple industries and asset classes, which can reduce market volatility. Besides, a prudent strategy for leveraging is crucial, because it may poses a risk of considerable losses. Moreover, effective risk management strategies, such as establishing explicit investment thresholds and employing stop-loss orders, can substantially alleviate the impact of unfavorable market fluctuations. Finally, continuous monitoring of investments actions could facilitate modifications in reaction to market fluctuations, empowering investors to manage risks proactively rather than passively. The lessons learned from the Archegos catastrophe highlight the imperative of intelligent investment strategies, based on risk awareness, for effectively traversing the complex financial terrain. By complying to these regulations, individual investors can improve their chances of success while safeguarding their capital from unforeseen market volatility.

However, this article has specific limitations. Although it analyses some objective reasons that leading to the collapse of Archegos, it may ignore the psychological variables affecting investors' judgments, including behavioral biases and the influence of market mood.

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Analysis of Changes in the Sensitivity of US Housing Prices and Construction Sector GDP to Each Other's Activity under VAR Model

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Abstract: This paper examines the evolving degree of mutual influence and sensitivity to fluctuations between FHFA house prices and GDP-Construction across different periods, thereby clarifying the relationship between these two variables. Utilizing a linear autoregressive model, this paper employs the VAR framework to analyze the data, followed by impulse response analysis and error variance decomposition post-prediction. The temporal responses of the data are presented. Upon summarizing our findings, the article observes a positive correlation between FHFA house prices and GDP-Construction that predicts an upward trajectory for FHFA house prices alongside a slight decline in GDP-Construction growth. Both tests indicate that sensitivity to each other's fluctuations has gradually intensified by Q3; While FHFA's influence on GDP-Construction diminished under economic policy regulation, it rebounded once economic conditions stabilized; On the contrary, during periods of economic stability, the impact of GDP construction on FHFA housing prices has increased. To some extent, policy-driven support for housing prices and GDP-Construction activities outweighs macroeconomic influences; Furthermore, economic policies appear to diminish GDP's responsiveness to changes in FHFA house prices. This study enriches the existing analysis on the interaction between housing prices and GDP, provides a foundation for future research, and helps stakeholders in the real estate and construction industries better cope with potential short-term adverse effects of economic policies.

Keywords: Real Estate and Construction Industry, GDP, Inflation, Economic Policy.

1. Introduction

1.1. Research Background and Significance

As an important component of GDP, the real estate and construction industry constantly influences the macroeconomy's expansion and contraction. For the construction industry, slower labor value-added compared to other industries leads to a slow fluctuation frequency in its production factors [1]. However, property prices have a significant degree of stickiness and randomness. GDP-Construction is theoretically influenced by economic conditions and policy regulation, but property prices, as part

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of the construction industry, directly drive the implementation of contractionary policies [2]. Das, Gupta and Kabundi also mentioned in his research that housing price fluctuations can serve as an indicator of GDP and inflation rate fluctuations [3]. In the latest economic data released on the official website of the US government, it can be seen that the GDP growth rate for the second quarter of 2024 in the United States is 2.9%. Although it ranks among the top in developed countries, its long-term economic trend is not stable, showing significant fluctuations up and down, reflecting the continuous volatility of the overall economic environment in America. As one of the five major pillar industries in America, real estate and construction industry are important components of its economy and are currently in an initial stage of recovery within the economic cycle.

Output and prices are gradually increasing, making them a crucial part of US GDP and one of the driving forces behind economic growth. The significance of the impact of the financial crisis on the construction industry makes the housing market particularly important in terms of GDP forecasts. Real estate as an important indicator for output and prices influences trends in construction industry GDP, both being affected by cycles, interest rates, economic conditions, consumer preferences etc. The significant increase in housing price index drives market profits and boosts activity within the construction industry; investment stimulation directly impacts numerical values for construction industry GDP. The significance of the impact of the financial crisis on the construction industry makes it particularly essential to housing market in terms of GDP forecasts. From a political perspective, housing price indicators play a dominant role in real estate markets which is closely linked to sensitivity towards economic policies; housing prices are always used as a major benchmark. The two theoretically have some unidirectional correlation together reflecting trends in American economy and activity within construction industry while also influencing policy decision-makers' market interventions. However, there needs to be an understanding from a bidirectional perspective regarding issues faced by construction industry within real estate sector (such as excessive inflationary impact on enthusiasm for building under rising conditions or bubble risks) when analyzing housing price indices alongside construction industry GDP.

The article explores the possible linear relationship between FHFA house prices and GDP-Construction, and examines the sensitivity and bidirectional impact of both variables to shocks in different periods. Based on this condition, better fitting predictions can be made for their respective trends. By determining the weight values of variable stimuli affecting fluctuations in the dependent variable during different time periods, can the proportion of influence between variables be intuitively understood. This study infers the reasons for changes in trends and bidirectional impact levels of FHFA house prices and GDP-Construction by combining economic environments, policies, and data from different periods. It provides a deeper analysis of the immediate relationship between FHFA house prices and GDP-Construction, predicts trend changes after removing exogenous variables, helps adjust oneself better to cope with changes in investor consumption preferences and economic policy shifts. Conversely, macroeconomic policies can use this as partial basis for decision-making when effectively regulating inflation's control over the Construction Industry, thus formulating more suitable policies for the real estate industry.

1.2. Literature Review

The price of real estate plays a crucial role in the measurement of GDP-Construction that cannot be overlooked. The 'wealth effect' indicates that the consumption share within the real estate sector directly influences GDP growth, while economic expansion positively impacts housing prices [4]. Plakandaras and Gupta noted that housing prices typically adjust sales volume in response to fluctuations in their own values, suggesting that housing prices exhibit sticky characteristics [5]. According to the characteristics of housing price stickiness, its degree of activity can be analyzed to understand the different impacts it has on the economy. Canarella, Miller and Pollard substantiated

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through an analysis of unit sales that the long-term fluctuations in housing prices exhibit a 'ripple effect', shaped by various factors within the real estate sector and overarching macroeconomic trends [6]. Nevertheless, Asadov, Brahim and Yildirim's research indicates that house prices exhibit asymmetric returns in relation to economic growth [7]. The research further demonstrated that residential investments exhibit a lagged payback in their response to fluctuations in the economic cycle [8]. Although the economy theoretically propels consumption within the real estate sector, subsequently stimulating GDP output and influencing the broader economic environment, this straightforward positive correlation fails to adequately account for the concurrent fluctuations observed in both GDP and housing prices during the same period. The interplay between real estate bubbles and economic dynamics is intricate, with housing prices being shaped by a multitude of specific factors, rather than exhibiting a straightforward linear correlation with economic growth [9]. Previous research has substantiated the potential for further investigation into the relationship between housing prices and GDP. While the datasets pertaining to housing prices and GDP exhibit varying degrees of complexity and randomness, the analysis of GDP data offers a broader array of analytical options compared to that of housing prices. In evaluating future trends in housing prices, the Case-Shiller index is extensively utilized. Beyond index analysis, Balcilar, Gupta and Miller opt to employ both linear and nonlinear autoregressive models under macroeconomic conditions to forecast housing prices [10]. Building upon the foundational AR time series model, Gupta and Kabundi employed dynamic factors and Bayesian shrinkage models to forecast overall housing prices in the United States, akin to the BVAR approach utilized by Gupta and Das for effectively predicting housing prices across 20 states [11, 12]. Additionally, Plakandaras, Gupta, Gogas and Papadimitriou opted for BVAR and BAR models due to prior research clearly demonstrating the superior fitting capabilities of vector autoregressive models in housing price prediction. Previous studies have clearly demonstrated the high degree of fitting of vector autoregressive models for house price forecasting, and explored the causes and potential impacts of changes in GDP on house prices under the regulation of vector autoregressive models [5].

Nevertheless, there exists a paucity of research examining the bivariate correlation between housing prices and GDP within the same timeframe. This study intends to employ the VAR model to validate their correlation, perform impulse response analysis, and conduct error variance decomposition predictions. Furthermore, it aims to analyze potential factors contributing to fluctuations in the relationship between GDP and housing prices by assessing the impact of shocks over varying time intervals. Building upon existing literature, this paper investigates these two variables from diverse perspectives to elucidate activity level fluctuations more effectively and provide constructive guidance for economic policy through an examination of external variables.

1.3. Research Contents

Based on the active exploration and analysis of the sensitivity between FHFA house prices and GDP-Construction presented in this article, the research process can be categorized into the following steps according to the study's direction. (1) Utilize a two-variable time series to construct a two-dimensional Vector Autoregression (VAR) model, and forecast the future actual changes in FHFA house prices and GDP-Construction based on this model. (2) Perform impulse response analysis and predict error variance decomposition using the model, systematically examining the effects of short-term fluctuations and variance weighting values. (3) Investigate the underlying causes of varying trend fluctuations within the VAR framework, providing a coherent explanation for alterations in the bidirectional feedback relationship. Following this analysis, relevant recommendations are proposed for macroeconomic considerations.

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2. Method

2.1. VAR

This paper cites the housing price index provided by the Federal Housing Finance Agency (FHFA) and the total value of US construction industry GDP from the official website of the US Department of the Treasury. The sample period from September 2008 to March 2024 is selected to construct two quarterly time series. The study aims to explore the dynamics of the US real estate price index and its predictive ability and impact on construction industry GDP.

In the realm of data analysis, a fundamental vector autoregression (VAR) model was employed to conduct a cross-analysis of two time series. The VAR model effectively mitigated the influence of exogenous variables, treating all variables as endogenous. The linear correlation among the endogenous variables was examined based on their interrelationships.

In the VAR model, all variables are represented by y. $y_{1,t}$ is the observed value of variable y_1(FHFA housing price) at time t, $y_{2,t}$ is the observed value of variable y_2 (GDP-Construction) at time t, and $y_{1,t}$ and$y_{2,t}$ jointly act on $y_{1,t+1}$and$y_{2,t+1}$ respectively. A (2*2) identity matrix was used to show the bidirectional feedback relationship between variables (see figure 1).

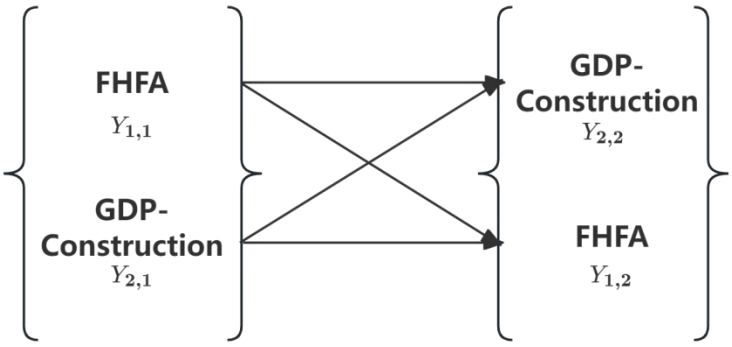

Figure 1: Two-way feedback relationship of VAR model.

After considering the impact of white noise process(e) and the self-lag term (ϕ_{ii}) on the variable $y_{i,t}$ in L-period lag, a two-dimensional VAR(1) model is assumed with the lag term set to 1 before specific variables are inputted.

$$y_{1,t+1} = c_1 + \phi_{11,1}y_{1,t} + \phi_{12,1}y_{2,} + e_{1,t+1} \quad (1)$$

$$y_{2,t+1} = c_2 + \phi_{21,1}y_{1,t} + \phi_{22,1}y_{2,} + e_{2,t+1} \quad (2)$$

By satisfying accurate prediction requirements under conditions with a small number of variables and few categories, VAR models provide flexibility for analysis. Under this premise, impulse response analysis and variance impact testing are performed to identify immediate relationships between FHFA house price index and US GDP-construction in different intervals, as well as comparing relative effectiveness at sample turning points between these two types of time series models. Specific correlation data analysis results are obtained based on VAR models, revealing reasons behind trend synchronization fluctuations, along with recommendations for both predictions.

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2.2. Pretreatment

Use the ts function to define the FHFA House Price Index and US GDP-construction as time series data from 2008 to 2024, divided by quarters, and perform preliminary processing. The stationarity of the FHFA House Price Index after first-order differencing is verified through Ljung-Box test. From the initial observation plot (see Figure 2), it can be seen that after experiencing irregular fluctuations around 2010, the FHFA House Price Index tends to remain stable within a certain range but shows significant volatility trends after 2020.

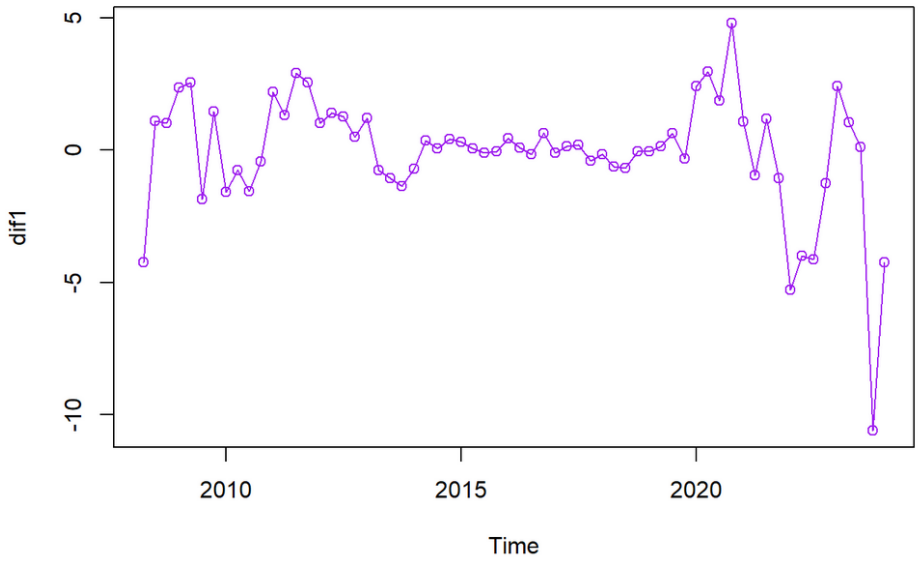

Figure 2: FHFA house price index first difference.

ADF testing confirms that US GDP-construction is a non-white noise sequence, it is observed that it stabilizes and rises after a local minimum point in 2010 but sharply declines after 2020 (see Figure 3).

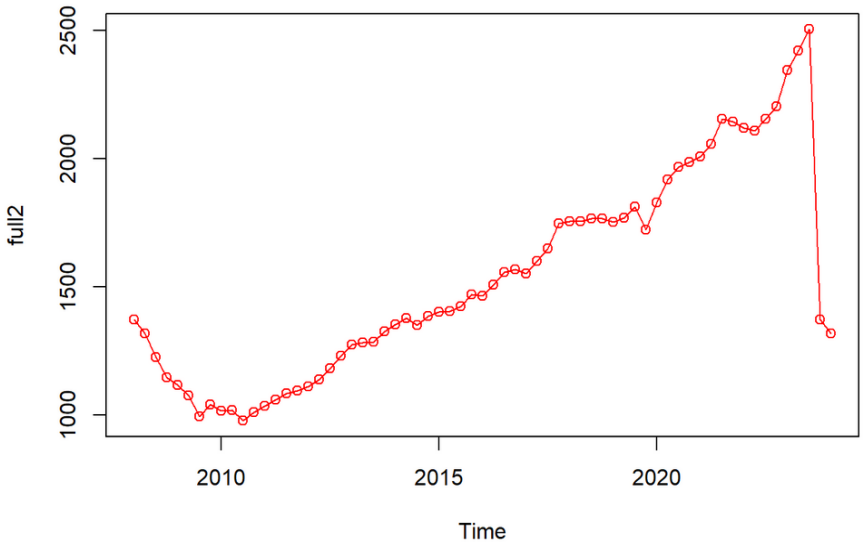

Figure 3: US GDP-construction.

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2.3. Model Assumption

After constructing the VAR model, using ADF test with respect to the overall sample size of the model, the study determines the relationship between polynomial roots and unit circle positions. The results show that all polynomial roots are approximately located inside the unit circle, ensuring the stationarity of VAR model and further validating its reliability. After preliminary evaluation of the model, VAR select function is used to select optimal lag order according to Bayesian criteria with appropriately fitting p-value set at 5 (see Table 1).

Table 1: optimal lag order.

AIC(n)	HQ(n)	SC(n)	FPE(n)
6	6	5	6

When applying VAR model to these two matrices, it is found that standard errors are small and coefficient estimates are relatively accurate. Both FHFA House Price Index and US GDP-construction have p-values less than 0.05 in both first quarter and fifth quarter periods which indicates statistically significant correlations between these variables during different time periods aligning with varying frequency fluctuations of FHFA House Price Index (see Table 2). The multivariate R-squared values for FHFA House Price Index and US GDP-construction are 0.9167 and 0.919 respectively. The difference between F value and P value is very large, and the model fitting effect is remarkable.

Table 2: The results of VAR model.

	Std. Error	Pr(>|t|)		Std. Error	Pr(>|t|)
(1) FHFA_ts FHFA			(2) GDP_ts GDP		
FHFA_ts 11	0.215764	1.91e-10 ***	FHFA_ts 11	15.0100	0.018604*
GDP_ts 11	0.003151	0.01580 *	GDP_ts 11	0.2192	\
FHFA_ts 15	0.209121	0.01458 *	FHFA_ts 15	1.890	0.064733 .
GDP_ts 15	0.006854	\	GDP_ts 15	0.396	\
const	\	0.00725 *	const	\	0.000227 *

Note: $p < 0.05$, * $p < 0.01$, ** $p < 0.001$, *** $p \rightarrow 0$

After organizing the VAR model, the Table 3 shows that there are outliers in the data. Through correlation analysis, it is found that there is a strong positive correlation coefficient of 0.78 between FHFA house price index and US GDP-construction. Based on their synchronous growth phenomenon, it can be initially hypothesized that there are common driving factors between FHFA house price index and US GDP-construction in the short term, which mutually influence and drive each other.

Table 3: The covariance and correlation.

Covariance matrix of residuals:		
	FHFA_ts.FHFA	GDP_ts.GDP
FHFA_ts.FHFA	3.402	184.6
GDP_ts.GDP	184.603	16465.5
Correlation matrix of residuals:		
	FHFA_ts.FHFA	GDP_ts.GDP
FHFA_ts.FHFA	1.00	0.78
GDP_ts.GDP	0.78	1.00

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Using the VAR model to predict FHFA house price index and US GDP-construction (see Figure 4), the results show that the former shows a gradual upward trend while the latter first rises and then falls.

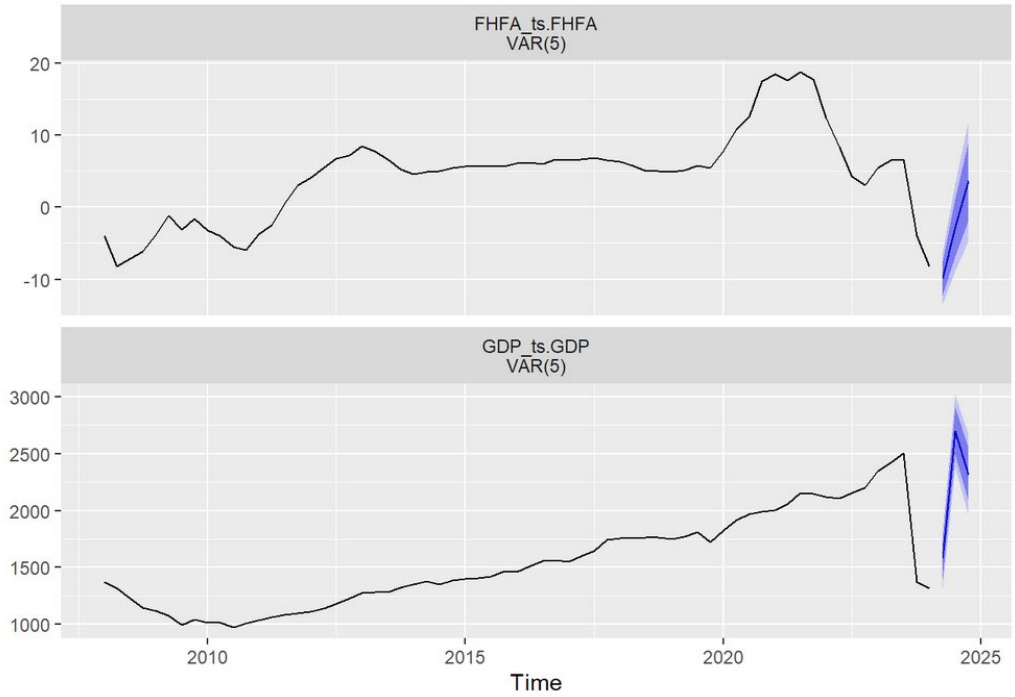
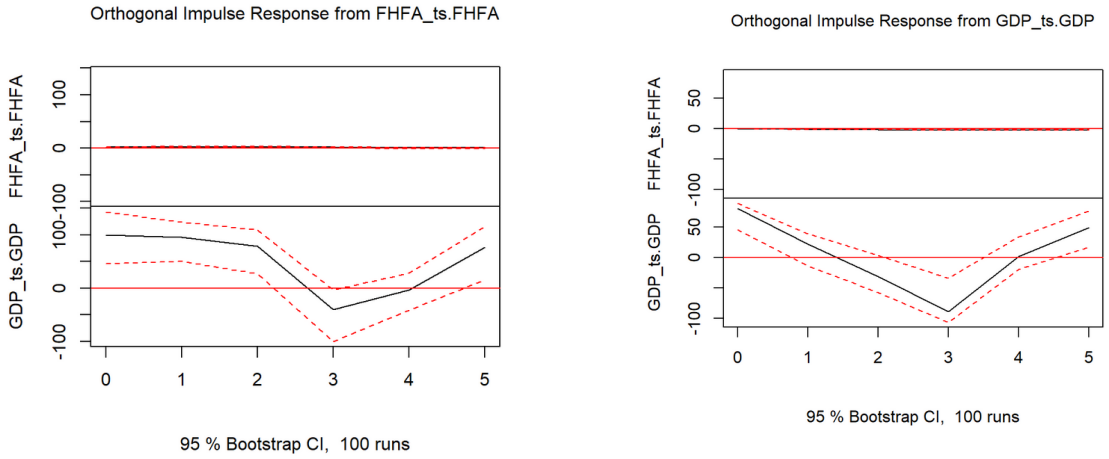


Figure 4: the prediction of FHFA house price index and US GDP-construction.

3. Hypothesis Test

3.1. Pulse Wave Response

Impulse response analysis was conducted on the two variables using the VAR model. From Figure 5, it can be observed that the predicted values fit significantly well within a 95% bootstrap CI, with both variables showing a gradual upward trend after the third period.



(1) (2)

Figure 5: Pulse Wave Response.

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3.2. Homogeneity of Variance Test

The variance decomposition test was performed on the two variables (see Figure 6). It revealed that FHFA house price index contributes relatively more to the variance of US GDP-construction, indicating a significant impact of external shocks from FHFA house price index on US GDP-construction. The proportion charts of these two variables suggest that the influence of construction industry GDP on FHFA house price index gradually increases over quarters, while the impact of FHFA house price index on construction industry GDP shows a monotonic decreasing trend followed by an increasing trend within each quarter and reaches its minimum peak in the third time period.

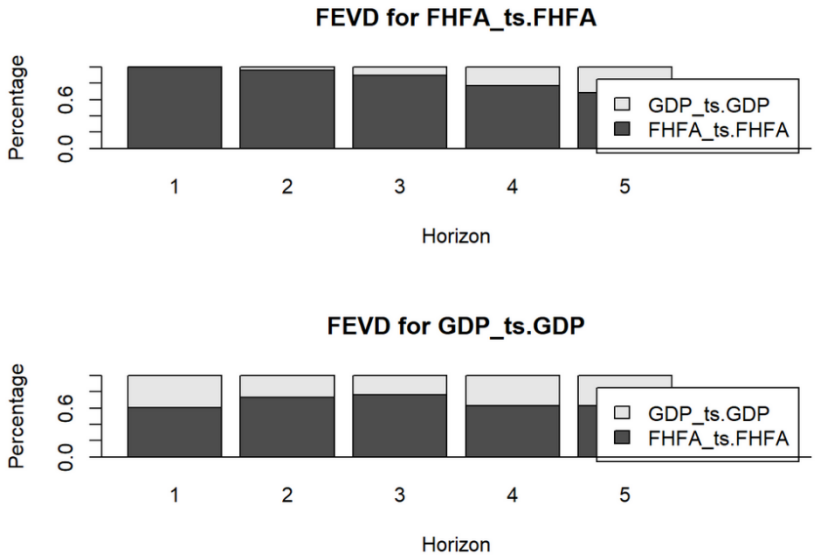

Figure 6: Homogeneity of Variance Test.

4. Discussion

There are several changes that the real estate and construction industry can make from within itself. Firstly, accelerate the transformation of the existing manufacturing and sales forms to adapt to the adjustment of economic policies. Change the cost of goods in the manufacturing process and start from the way goods are exchanged with consumers. Reasonably avoid losses and information errors to a certain extent and avoid the negative impact of inflation and interest rate policies. Not only that, the output of real estate construction and the national investment demand for real estate as the fundamental cause affecting market balance should be given greater focus on research, focusing on the supply and demand relationship in the market and making positive adjustments to it. Accelerate the upgrading and transformation of the real estate and construction industry. In addition, the consumer's preference for real estate selection is reflected directly in the fluctuation of GDP-Construction.

In terms of national policies, firstly, the comprehensive coverage of infrastructure bill funding is one of the important prerequisites for its effective implementation. Regular inspections of the disbursement of funds can help verify the effective implementation of the bill and better utilize government regulation to encourage the active participation of the construction industry. Secondly, the government should make appropriate adjustments to inflation and change the intensity at any time to give the industry time to respond, so that it can better adapt to different periods with greater conformity. Finally, real estate investment, as a high-cost consumption, has fostered a lending chain

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in the real estate industry, and due to the influence of monetary policy on the cost and quantity of credit, fluctuations in interest rates on loans have a fundamental determining effect on the fluctuations of the housing market. Related authorities should reasonably set the standards for borrowers based on changes in purchasing power and economic environment. Reasonably setting borrowers' expectations can help enhance their rationality and minimize their "zeitgeist" to the greatest extent possible, which Commit to maintaining a balanced credit market [13].

5. Conclusion

According to the VAR model results, it can be analyzed that the FHFA house price index exhibits an unstable trend at both ends, especially the terminal change greatly affects US GDP-construction. In the original time series graph of US GDP-construction, it can be observed that during the economic recovery period after entering the economic crisis around 2010, the growth of US GDP-construction was more constrained by macroeconomic factors. Market instability is a common factor causing fluctuations in both variables. During the transition from decline to recovery, government intervention through monetary policies and other economic measures regulates the market. The government's intervention somewhat suppresses the volatility of house price index, and during this period, there is less impact of FHFA house price index on US GDP-construction.

Both FHFA house price index and US GDP-construction experienced sudden declines in their original data during 2020; however, their correlation steadily increased during this period. Based on this correlation analysis, it can be inferred that exogenous variables influenced both variables in the same direction at this time. Firstly, due to continuously rising inflation rates, Federal Reserve chose to increase loan interest rates as a response policy; multiple increases in mortgage rates impacted consumer demand. Secondly, after a stable boom in its initial stage, real estate industry entered an adjustment phase; meanwhile 2020 marked a period of economic recovery post-pandemic where uncertainty about overall economic environment affected investors' decisions regarding real estate assets - setting up a contraction for FHFA house price index and US GDP-construction.

According to the analysis of FHFA house price index and GDP-Construction, the following correlation suggestions are proposed from both the real estate and construction industry itself and government macro-control perspectives: The construction industry should undergo transformation and upgrading in various aspects, effectively grasp consumer psychology and consumption expectations to intuitively promote positive economic development. At the same time, in different periods, appropriate changes should be made to monetary policies and other economic policies based on existing conditions to more effectively intervene in market regulation and support the long-term development of the construction industry. This will stabilize the economic environment and further drive the gross domestic product of the construction and real estate industries.

However, although the VAR model used in this paper avoids the intervention of exogenous variables, for the variable with large randomness such as housing price, although parameterization can unilaterally analyze the relationship between housing price and GDP-Construction in a short period of time, it is certainly not enough to make the most reasonable analysis of its complex correlation. Several significant issues remain on the agenda for further researches: (1) The randomness of time series weakens the explanatory power of the model, and the prediction credibility of future changes is reduced compared with stable data. (2) The lag class used in this paper is relatively large, which can only predict the short-term trend and is not suitable for the long-term overall analysis. (3) The macroeconomic environment and policy regulation considered in this paper cannot be the only basis for changing the complex relationship between housing price and GDP. Us housing price is not only regulated by economic fluctuations and policies in a certain period of time, but also influenced by a large number of exogenous variables such as household income.

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In this regard, further research in the future can expand and improve the method by adding more restrictive factors to the model. For example, adding an intermediate variable to better cope with changes at different times to ensure the accuracy of the index or constructing a multi-dimensional matrix with other factors as variables. For this study, fiscal policy and macroeconomic changes can be represented by fiscal policy variables (FISPOL) and inflation rate (INFL), and significant fluctuations can be separated as key time periods as sub-time series for discussion. In addition to the VAR model used in this study, other models such as radial basis function (RBF), sigmoid, polynomial, and the most common BVAR model and DSGE model can be used. After building and comparing multiple models, the best model can be selected to ensure the validity of the conclusions with a large number of experiments.

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The Influence of 2020 California Wildfire on ESG Investment in Equilibrium Based on Sustainable Investment Model

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Abstract: With the change of climate and the pursuit for a balanced development between economy and society, green companies in the ESG investment have received much attention in recent years. At the same time, there are some extreme environmental events that may have influence on the market attitude towards ESG investment, thus affecting the benefits of ESG investors. In order to study the impact of 2020 California Wildfire, this research constructs the optimal portfolios considering ESG investors' ESG preference based on the portfolio theory for both the before-fire and after-fire periods. Then the portfolio performance is quantified by using a sustainable investment model in the equilibrium market. It is found that the difference between the return of ESG portfolio and the market portfolio was larger before the fire, representing an insufficient market attention on the ESG investment. However, the gap was narrowed after the fire. Meanwhile, despite lower investor surplus, after-fire ESG investors had larger alphas than before. Therefore, the 2020 California Wildfire raised the market attention on ESG investment, which reduced the actual financial losses of ESG investors.

Keywords: Wildfire, ESG preference, portfolio theory, sustainable investment model, investor surplus.

1. Introduction

On Sep.4th, 2020, a serious wildfire broke out in the National forests of Sierra Leone, California. The fire lasted more than two months, destroying over 2 million acres and robbing 31 people of their lives. Because of its devastating influence, it was recorded as the largest wildfire in the American modern history[1].

In the financial market, ESG investing, which refers to a sustainable investment strategy, is now emerging. It contains three essential elements, environmental, social and governance factors. The environmental factor refers to the business impact on natural environment. Companies should take measures to manage their waste, limit their pollution or preserve biodiversity during their production. The social factor represents the employee situations including inner relationships and social impact. The governance factor describes the firm management, transparency and ethical practices[2]. Though the ESG investment is closely correlated with the environmental events and many studies have proved that wildfire can enhance the pessimism towards environmental risks thus influencing house values

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[3,4] , there are limited studies focusing on the impact of these extreme environmental events such as wildfires on stock market especially with ESG preference from the investors in the current world which can help both government and investors set up accurate policies and investment strategies. As a result, this research is going to find out whether the symbolic 2020 California Wildfire can affect the financial market by arousing the preference towards ESG investment and what impact it will bring to those ESG investors who contribute to the emerging ESG investment in the equilibrium market.

Pástor et al. have set up a sustainable investment model under the equilibrium situation which can help quantify the investors' ESG preference[5]. According to the model, the assets in the market can be divided into green assets and brown assets. Green assets can generate positive social impact while brown firms impose negative externality and may suffer from ESG risks. The alpha of green assets is usually negative because ESG investors can obtain non-pecuniary utilities from investing in those green assets which can compensate part of the financial losses. At the same time, investors in the market can be divided into two groups, ESG investors and non-ESG investors[5]. For those ESG investors, they have positive ESG tastes and above-average ESG preference, so besides the market portfolio, their optimal portfolio will also include the ESG portfolio which is based on the greenness of firms. The optimal portfolio of ESG investors has the structure of long green and short brown. Besides, greener firms will have larger weights[5]. This research will construct the ESG investors' optimal portfolio based on these constraints by using essential indicators in the portfolio theory to define the best performer.

In an equilibrium market, all the investors will hold the market portfolio which may not be the optimal portfolio for those ESG investors because they can get extra return from their optimal portfolio. It means that the ESG investors have to sacrifice for their optimal portfolio when the market is in equilibrium. The maximum sacrifice is defined as Δ. Besides, α refers to the return an ESG investor actually sacrifices. These two types of returns will be quantified based on the model above and there will be a comparison between the them which will show how the changing market attitude towards ESG investment brought by the wildfire will affect the gain and loss of ESG investors.

This paper is organized as follows. Section 2 presents the data. Section 3 describes the method of portfolio construction and the changing market attitude reflected in the results. Section 4 analyzes the quantifiable results of Δ, α and investor surplus of those ESG investors. Then suggestions on policy making are provided based the impact of the fire. Section 5 concludes.

2. Data

The portfolio construction uses the adjusted close prices (considering the stock split and the dividend payment) of NASDAQ-100 equal-weighted index (NDXE) and the included firms (https://nz.finance.yahoo.com/), ranging from Jan.3rd 2017 to Aug.2nd 2024. Because the benchmark weight distribution of stocks in the ESG portfolio should keep in line with the one of market portfolio so that the weights in ESG portfolio can then reflect the pure impact of the greenness. All the data will be divided into four groups. Jan.3rd 2017 to Dec.31st 2019 is the before-fire group, Sep.4th 2020 to Dec.29th 2023 is the after-fire group while the rest data of 2020 and 2024 are back-testing groups.

The asset classification uses MSCI ESG ratings (https://finance.sina.com.cn/esg/grade.shtml)[6]. The companies are assumed to stay in their ESG rating groups for the whole time period.

Figure 1 shows the classification of firms in NDXE based on MSCI ESG ratings. All the B, BB and BBB firms are classified as brown assets while the leader groups in MSCI ESG ratings (AAA & AA) are considered as green assets in order to balance the number between the two asset types. Since the A level group is the average group according to MSCI ESG ratings, these firms are excluded from both the green and brown assets[5].

The averaged interest rates of 10-year US Treasury of the two periods (before and after the fire) are set as risk-free rates, which are 2.4586% and 2.5946% separately (https://www.federalreserve.

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gov/DataDownload/default.htm). Since a small proportion of the companies have been listed in the market in recent two or three years, their adjusted close prices are limited. Therefore, these companies are dropped from the ESG portfolio construction.

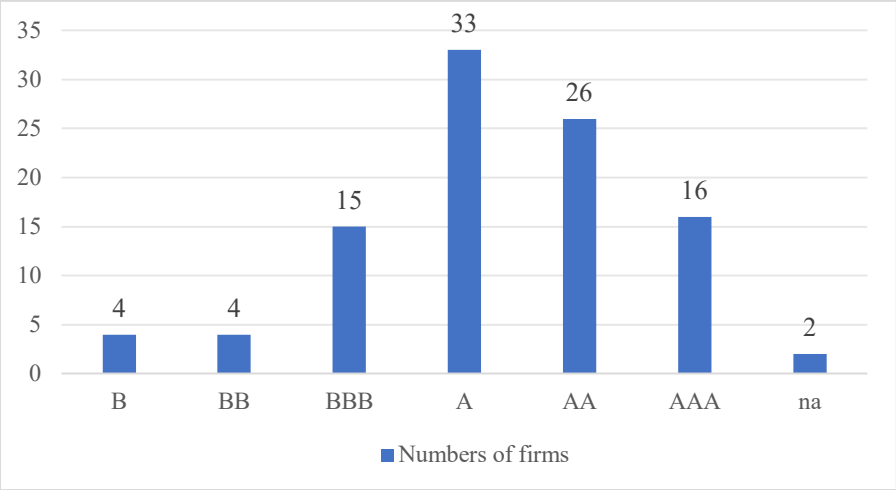

Figure 1: Classification of firms in NDXE

3. Portfolio Construction

This section will show the detailed process of optimal portfolio construction and explain some of the findings on the portfolio return of the two time periods.

3.1. Rating Group Portfolio Construction

Based on the daily close prices, averaged daily return and covariance are calculated and multiplied by 252 to compute the yearly return and covariance because it is assumed that there are 252 trading days in a year. The portfolio construction follows certain constraints including:

$$\sum w_i = 1 \ (w_i \in [0,1]) \tag{1}$$

in which w_i refers to the weight of each ESG rating group portfolio.

In order to construct the optimal portfolio, three types of portfolios are considered. First is the portfolio with the maximum Sharpe ratio. Sharpe ratio refers to a measure of risk-adjusted return and can be calculated by:

$$P = \frac{W^T \mu - R_f}{\sqrt{W^T \Sigma W}} \tag{2}$$

in which W refers to the weight vector, μ is the average return, R_f represents the risk-free rate while Σ is the covariance matrix of the assets. Highest Sharpe ratio represents a largest return relative to the risk taken[7].

Second is the minimum variance portfolio which is considered to have the lowest volatility and outperform especially in the emerging market with the increasing of global economy uncertainties[8]. The variance can be computed by:

$$VaR = W^T \Sigma W \tag{3}$$

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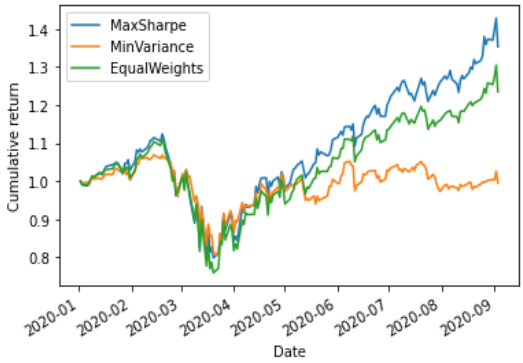
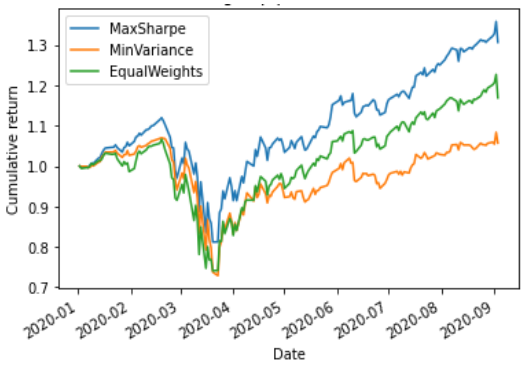
Besides, the equal-weighted portfolio is included because it is an ideal asset allocation that the investors may choose[9].

3.2. Back Test

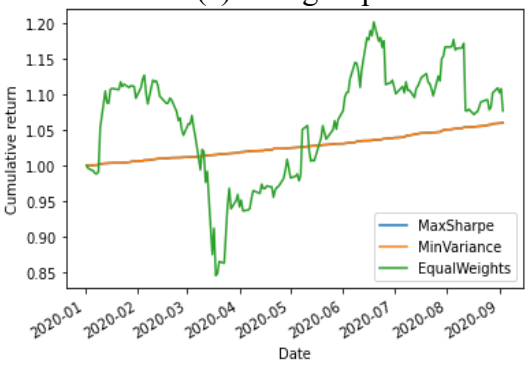
The back test is conducted by calculating the cumulative return of the 2019 and 2024 portfolio with initial capital of $1 in the three portfolios above. Figure 2 shows the back-testing results. For B group before the fire and BBB group after the fire, the best performer can not be distinguished directly, so an additional indicator Calmar ratio is calculated.



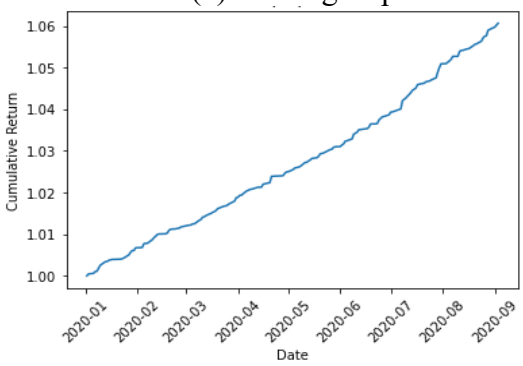
(a): AA group.



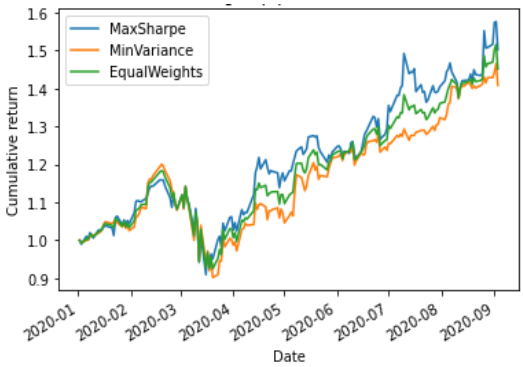
(b): AAA group.



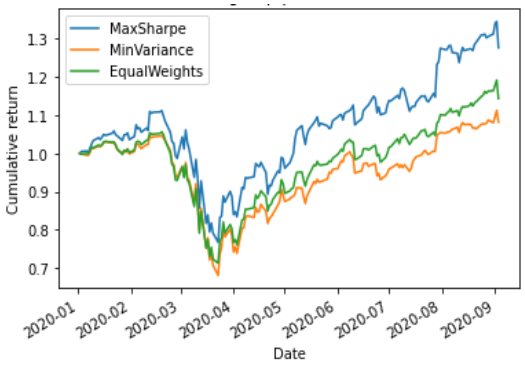
(c): B group.



(d): B group MaxSharpe.



(e): BB group.



(f): BBB group.

Panel A: Before-fire group.

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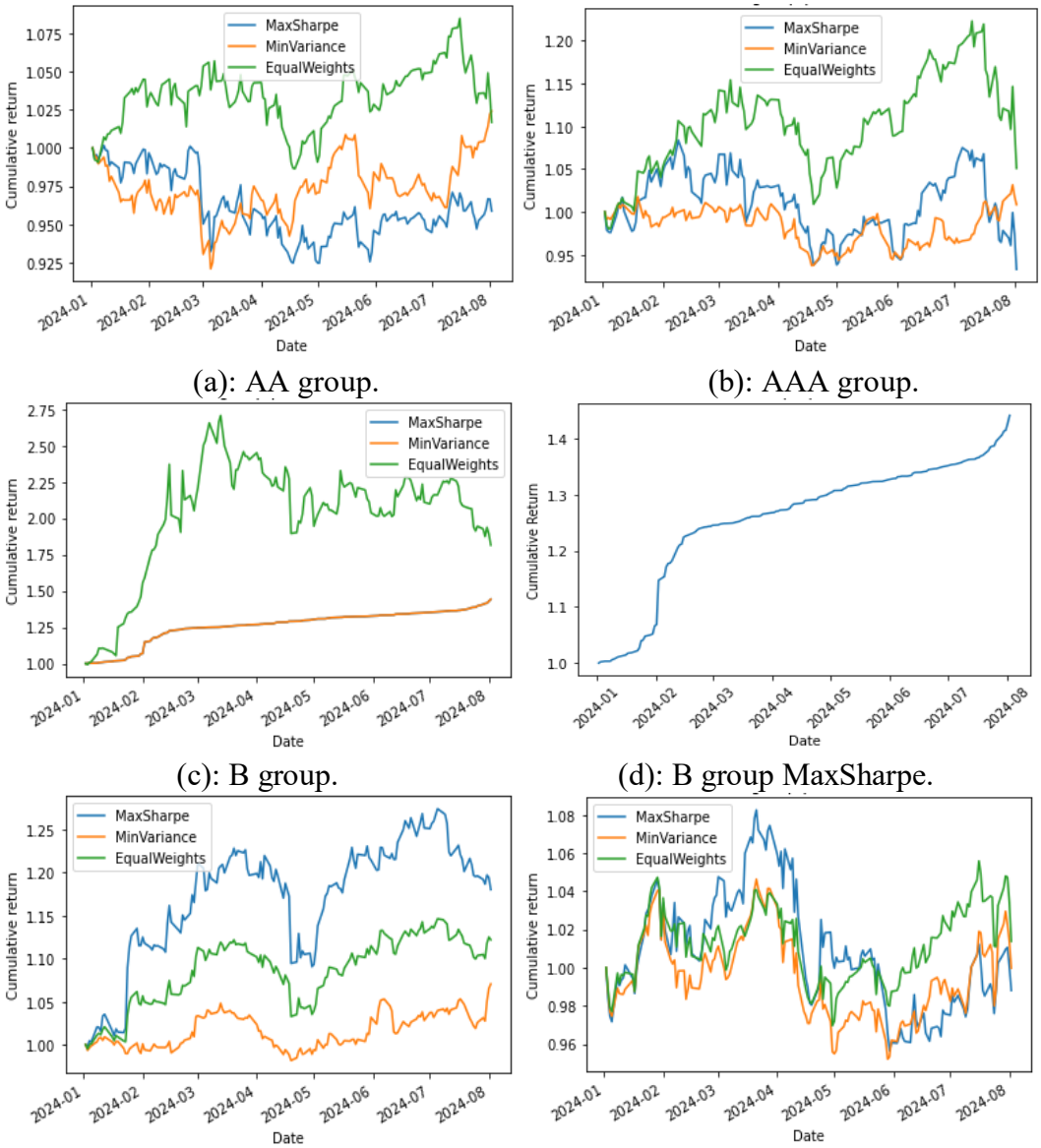

(a): AA group. (b): AAA group.

(c): B group. (d): B group MaxSharpe.

(e): BB group. (f): BBB group.

Panel B: After-fire group.

Figure 2: Back-testing results.

Since Calmar ratio refers to the relationship between the return and the maximum drawndown, investors prefer to choose the portfolio with larger Calmar ratio[10]. As shown in Table 1, for before-fire group B the maximum Sharpe ratio portfolio has the largest Calmar ratio while for after-fire group BBB the equal-weighted portfolio performs the best. Table 2 shows that except B asset, all the other asset return decreases after the fire. It happens when investors have higher demands on the greener assets and show less interests in browner assets.

Table 1: Calmar ratio.

	B (Before-fire)	BBB (After-fire)
MaxSharpe	12372.9495	-0.0584
MinVariance	7417.0963	0.1021
EqualWeights	0.6583	0.4446

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Table 2: Returns of each rating group portfolio.

	B	BB	BBB	AA	AAA
Before-fire	0.0508%	0.1178%	0.1450%	0.1202%	0.1514%
After-fire	0.2189%	0.0490%	0.0546%	0.0846%	0.0884%
Difference	0.1681%	-0.0688%	-0.0904%	-0.0356%	-0.0630%

3.3. ESG Portfolio Construction

The same procedure is repeated when constructing the ESG portfolio, but the constraints contain another two rules:

$$w_{AAA} > w_{AA} > 0, w_B < w_{BB} < w_{BBB} < 0 \quad (4)$$

It is based on the long green and short brown structure in the ESG portfolio and the assumption that the greener the firm is, the heavier its weight will be[5]. Since the minimum variance portfolio performs more stable than the maximum Sharpe ratio portfolio, the final after-fire ESG portfolio return (0.0577%) can be computed and is lower than the before-fire one of 0.1655%.

Table 3 shows that the weights in the ESG portfolios in the two time periods are the same, which confirms with the assumption that the company greenness may not be impacted by the fire. Therefore, the difference in the ESG portfolio return only comes from the changes in asset return shown in Table 2.

Table 3: Weights in the ESG portfolios.

	B	BB	BBB	AA	AAA
Before-fire	-0.3	-0.2	-0.1	0.75	0.85
After-fire	-0.3	-0.2	-0.1	0.75	0.85

3.4. Optimal Portfolio Construction

The optimal portfolio for the investors should be:

$$(1-\phi) * \text{market portfolio} + \phi * \text{ESG portfolio} \quad (5)$$

in which ϕ is negatively correlated the subjective variable risk aversion[5]. To cover several possibilities, ϕ is set to change from 0.1 to 1 in 0.1 increments. The return of the optimal portfolio (r^*_{ESG}) is mainly related with the difference between the return of market portfolio and ESG portfolio, which reflects the market attitude towards the ESG investment. Larger difference represents lower market attention on the ESG investment because the ESG preference is not fully reflected in the market prices. As shown in Table 4, after the wildfire broke out, the market starts to pay more attention on the ESG investment, thus leading to smaller difference. Meanwhile, the market return is lower, both of the two factors contribute to lower optimal portfolio return.

The excess return is correlated with both the risk-free rate and the optimal portfolio return. Since the risk-free rate after the fire is larger due to the constant rate increase, the excess return is even lower than before.

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Table 4: Optimal portfolio excess returns.

	ϕ =0.1	ϕ =0.2	ϕ =0.3	ϕ =0.4	ϕ =0.5
Before-fire	-2.3837%	-2.3738%	-2.3638%-	-2.3538%	-2.3439%
After-fire	-2.5467%	-2.5456%	-2.5445%	-2.5434%	-2.5423%
	ϕ =0.6	ϕ =0.7	ϕ =0.8	ϕ =0.9	ϕ =1
Before-fire	-2.3339%	-2.3239%	-2.3140%	-2.3040%	-2.2940%
After-fire	-2.5413%	-2.5402%	-2.5391%	-2.5380%	-2.5369%
The market portfolio returns: (1) Before-fire:0.0659% (2) After-fire:0.0468%					

4. Performance Comparison

This section will show the quantitative results of the ESG investor performance based on the equilibrium situation (the investors all hold the market portfolio) and the optimal portfolios which have already been built. Then a comparison will be made between the performance in the two time periods.

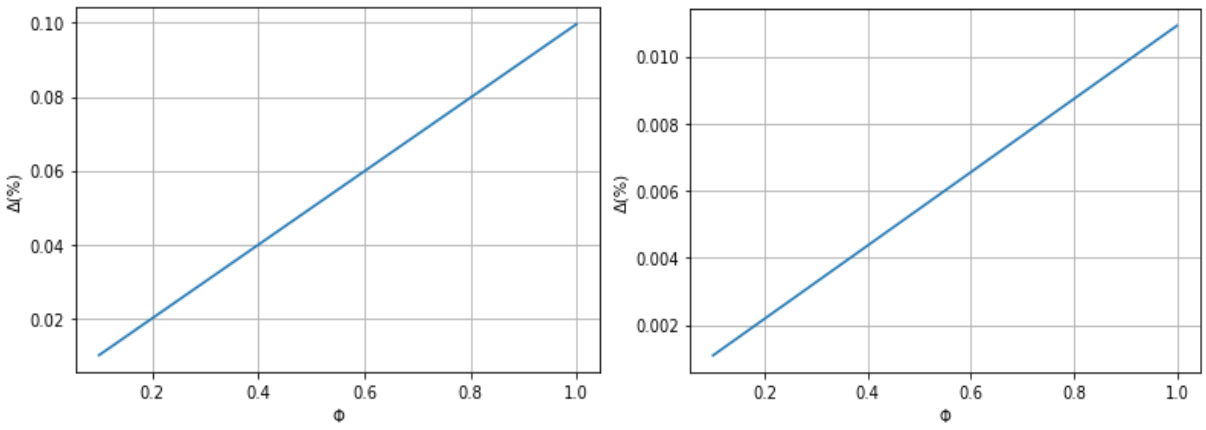
4.1. Parameters

There are two critical parameters that should be defined.

First is Δ which represents the maximum excess return the investor has to sacrifice to hold his/her optimal portfolio. According to the equation:

$$\Delta = r^*_{ESG} - r^*_M \tag{6}$$

in which r^*_{ESG} refers to the excess return when holding the investor's optimal portfolio and r^*_M represents the excess return an ESG investor will obtain when he/she is forced to hold the market portfolio[5]. Δ is only related with the difference between the ESG portfolio return and the market return. Figure 3 shows the Δ with changing ϕs. Before the fire, the ESG portfolio return is much higher than the market portfolio return (0.0996% > 0.0109%), which means that the ESG investor has to sacrifice more under the equilibrium situation. Besides, since ϕ is inversely proportional to risk aversion, an investor with more risk aversion has a smaller ϕ. It can also be observed from Figure 3 that the Δ is positively correlated with ϕ. Therefore, a more risk-aversed ESG investor is willing to sacrifice less.



Panel A: Before-fire group. Panel B: After-fire group

Figure 3: Δ of ESG investors.

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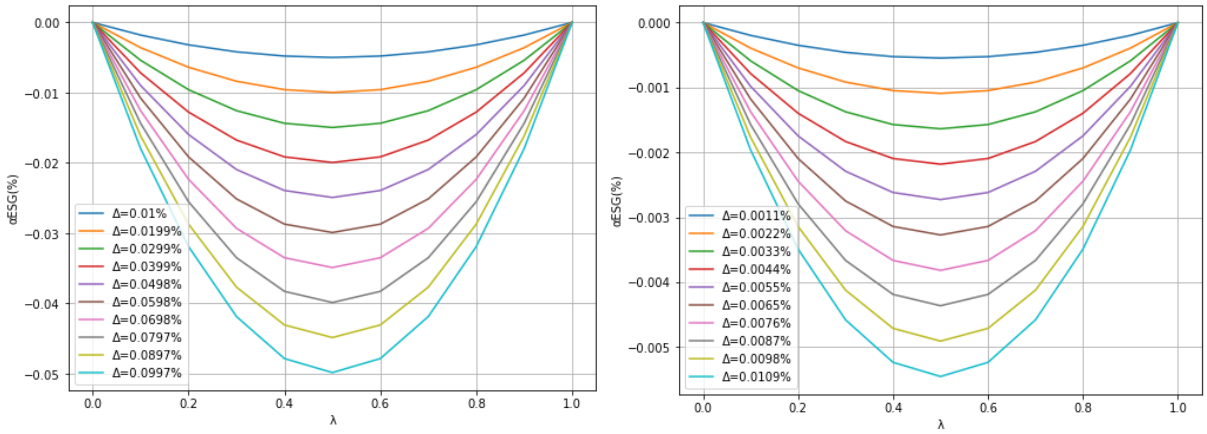
Another parameter λ, representing the proportion of the ESG investors' wealth in the market, is set to change from 0 to 1 in 0.1 increments[5].

4.2. Result Analysis

Alphas of the ESG investors can be calculated based on the equation[5]:

$$\alpha_{ESG} = -2\lambda(1-\lambda)\Delta \tag{7}$$

Figure 4 plots that the α_{ESG} during the whole time period are negative and the alpha lines are in the 'U' shape with the lowest point when λ=0.5. It is because when λ changes from 0 to 0.5, the market is still dominated by the non-ESG investors. When the number of ESG investors becomes larger, their stronger ESG preference will push the optimal portfolio excess return to deviate largely from the market excess returns, which means that they actually sacrifice more. However, when λ changes from 0.5 to 1, ESG investors dominate the market, so the market will start to reflect their preference. The α_{ESG} will return back to 0 at last when the market is full of ESG investors and fully reflects their ESG preference. Comparing the two time period, it can be found that in the time series, λ is not the main factor to affect the α_{ESG}, because the α_{ESG} after the fire are less negative than the before ones, which shows that the ESG investors actually sacrifice less when investing in their optimal portfolio after the fire.



Panel A: Before-fire group. Panel B: After-fire group

Figure 4: α of ESG investors.

However, the absolute values of the minimum α_{ESG} are smaller than Δ, which means that an ESG investor actually sacrifices lower returns than he/she has to. The compensation comes from the reflection of his/her ESG taste in the equilibrium return which is called the investor surplus[5].

The distance between the colorful lines and the benchmark line in Figure 5 can reflect the investor surplus. The benchmark lines with the slope of -1 refer to the situation when the return an ESG investor is willing to sacrifice equals to what he/she actually sacrifices. The colorful lines represents that there is a difference between $|\alpha_{ESG}|$ and Δ. When the ESG investors dominate the market, the reflection of their ESG preference in the market prices will be more evident with the increase in the number of ESG investors.

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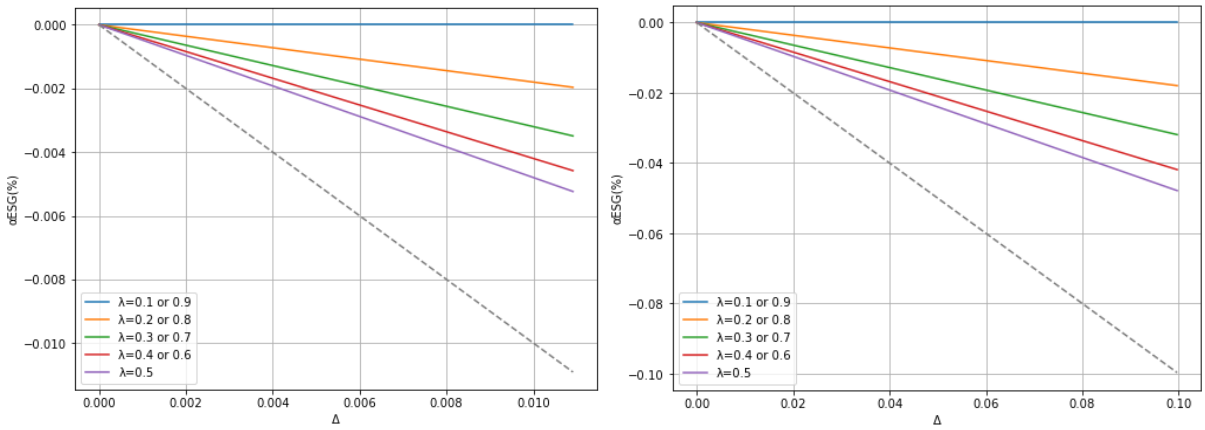


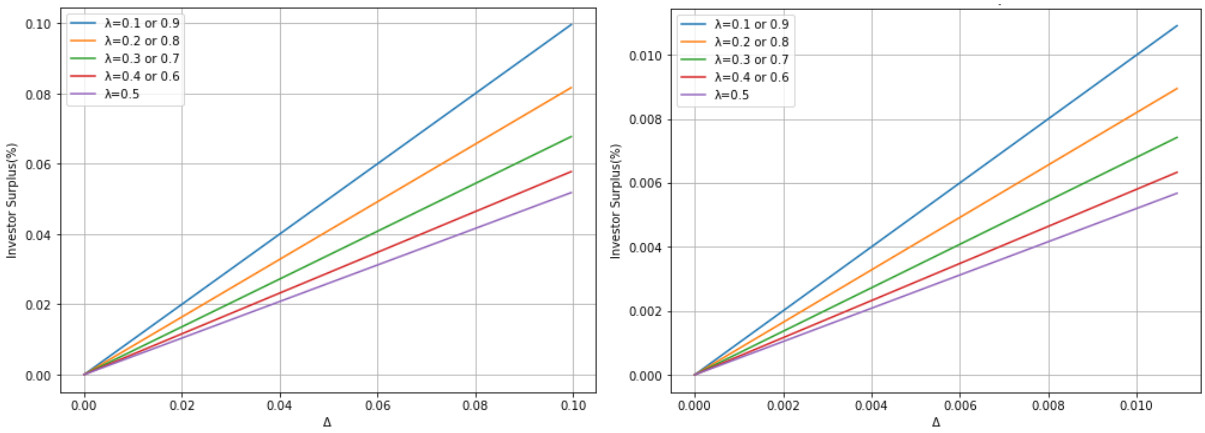
Panel A: Before-fire group. Panel B: After-fire group.

Figure 5: The indirect indication of investor surplus.

The value of the investor surplus can be calculated by[5]:

$$\tau = \Delta\left[1 - 2\lambda(1-\lambda)\right] = \Delta - |\alpha_{ESG}| \tag{8}$$

Figure 6 shows that the before-fire investor surplus is larger than the after-fire one, which represents that though the ESG investors may obtain more compensation from the equilibrium return, they still have to suffer greater financial loss to hold their optimal portfolio. It is because the market attention paid on the ESG investment is still not enough, which again highlights the influence brought by the 2020 California Wildfire.



Panel A: Before-fire group. Panel B: After-fire group.

Figure 6: Investor surplus.

4.3. Influence of the 2020 California Wildfire

The 2020 California Wildfire was the largest recorded wildfire season in the modern history of United States with over a 2 million-acre area consumed, which has aroused the public attention on the health impact and damages brought by the fire[11].

From the aspect of the financial market, the wildfire can be caused by the resource exploitation and pollution in the production activities of those companies relying on oil and gas which may reduce the recovery capability of forests[12]. When the wildfire breaks out, the supply chain of certain companies may be disrupted, leading to negative impacts on their production and revenues. More

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seriously, the wildfire can increase credit risks and market fluctuations. Therefore, investors start to turn to those green firms which are eco-friendly.

As shown in this data research, before the 2020 California Wildfire, insufficient attention on the ESG investment made those ESG investors sacrifice more in the equilibrium market. However, after the fire lights up the ESG preference in the market, the ESG investors' financial losses are reduced.

As a result, currently in the equilibrium market with ESG preference, the return of the ESG investors is closely correlated with the market attitude. Though the environmental disasters can boost investors' ESG preference, the cost is high. Thus, some initiatives should be taken. If there are policies that can promote the development of those green companies by encouraging renewable resources and offering preferential taxes, the ESG investment will naturally be motivated by higher return. Besides, the publicity channels should be broadened to help more investors know about the ESG investment.

5. Conclusion

ESG investment can be influenced by non-financial factors including environmental disasters. This article focuses on the impact of the serious 2020 California wildfire on the market attitude towards ESG investment and ESG investors. Based on MSCI ESG ratings and portfolio indicators such as Sharpe ratio and variance, ESG investors' optimal portfolio with greenness consideration in NDXE is constructed.

It can be found that before the wildfire the market didn't pay much enough attention on the ESG investment, so the preference of ESG investors could not be fully reflected in the market prices, thus leading to a large difference between the excess return of market portfolio and ESG portfolio. In the equilibrium market, the ESG investors then suffered from a great loss even though they could obtain high investor surplus. However, the wildfire unfortunately broke out, bringing forest deterioration, air pollution and even loss of life. Because of its devastating impact, people began to change their attitudes. In the financial market, investors started to have more ESG preference which pushed the market return move closer to their expected return.

As a result, despite the larger investor surplus, insufficient market attention on the ESG investment leads to larger financial losses of those ESG investors under the equilibrium situation, thus leading to even less willingness for investors to invest in green assets, which is a vicious circle. At the same time, though the influence of the environmental disasters have aroused ESG awareness among investors, it is time for us human beings to do something spontaneously instead of just passively adjusting to negative events.

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The Impact of Artificial Intelligence on Economic Growth

—An Industrial Structure Based Perspective

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Abstract: Artificial intelligence is the leading technology of the new round of scientific and technological revolution and industrial revolution, and its impact on the economic development is profoundly intricate and has garnered significant attention from scholars and professionals across various sectors. The industrial domain, serving as the backbone of economic progress, plays a crucial role in fostering high-quality economic growth. Industry, as the core carrier of economic development, is of great significance for high-quality economic development. AI technology penetrates into various industrial sectors through its techno-economic characteristics, and has an impact on the industrial structure and economic growth mode. Based on combing the current situation and future trends of AI development, this paper analyses in detail the role mechanism of AI affecting the transformation and development of the three major industries, and discusses the impact of AI on economic growth, with a view to providing useful reference for the research and practice of AI, industrial development and economic growth. Through a comprehensive review, this study seeks to provide valuable insights into how AI can be harnessed to propel industrial development and sustain economic growth.

Keywords: Artificial intelligence, economic growth, industrial structure.

1. Introduction

Artificial Intelligence, also known as Machine Intelligence, abbreviated as AI, usually implies the implementation of human intelligence through computer programmes. AI technology is a new technological science that can simulate any process about human consciousness and logical thinking, and can even think like a human being, and can also exceed human intelligence [1]. AI absorbs human's massive knowledge and objective world data through networks such as the Internet of Things and cloud computing platforms, continuously learns and evolves in depth, derives and applies robots, language recognition, image recognition, natural language processing and specialised systems, and so on, to become a universal integrated technology and fusion innovation tool. Under the wave of the new round of scientific and technological revolution, the new scientific and technological convergence and innovation with artificial intelligence, big data and cloud computing, Internet of Things, 3D printing, intelligent robots (hereinafter referred to as the new scientific and technological revolution pioneering technologies) as the spearheads are constantly optimising the tools, modes,

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speeds and processes of innovation, profoundly altering the production and life of human beings and the paradigm of innovation, and exerting unprecedented and tremendous influence on the economy, industry and society.

AI is the core driving force of the new round of industrial change in the 21st century, and the development of AI and its industries will certainly create a new powerful engine. Currently, AI is accelerating its integration with various industries, fuelling the transformation and upgrading of traditional industries and improving quality and efficiency, and having a profound influence on economic growth. Based on the support of national policies and the importance of AI and its industrial development, there is an urgent need to study the relationship between AI and economic growth in order for the AI industry to effectively play a driving role in economic growth and promote the high-quality development of the technology economy. On the other hand, many segments within the secondary and tertiary industries have applied AI technology to enhance their development. However, since the application of AI in many industries is still at an early stage, the impact of its application on economic growth and structural optimisation is not yet clear, a detailed analysis is needed to guide different industries to better cope with the impact of AI technology and further enhance the positive effects of AI on economic growth. The paper also discusses how different industries are responding to the challenges posed by AI and offers suggestions for fostering the development of the AI industry to drive high-quality economic growth. Finally, the article summarizes the overall impacts of AI technologies on industrial development and economic growth and highlights future research directions. The paper also concluded that AI has promoting roles in Agriculture, Manufacturing, and Service Industries. Some strategies and suggestion in this article could give better guidance for production activities.

2. Basic Situation of AI

2.1. Current Situation of AI Development

Accurately understand and grasp the current status of AI technology and industry development is first necessary to study the relationship between AI and economic development. The following summarises the main development status and characteristics of current AI.

2.1.1. AI as a Whole is in a Rapid Growth Trend

The current global AI industry is in a period of rapid development. According to the data from Statista [2], the total global AI investment scale is $128.8 billion in 2022, and the total global AI investment scale is expected to reach $154 billion in 2023, a year-on-year increase of 19.6%. Looking ahead to 2024, the development of the AI industry will become the wind vane of global economic recovery. According to the Sullivan Consulting forecast, the global AI market is expected to reach US $615.8 billion in 2024. The number and amount of investment and financing in the field of AI will reach another record high, and the development trend will continue to be positive (see Figure 1).

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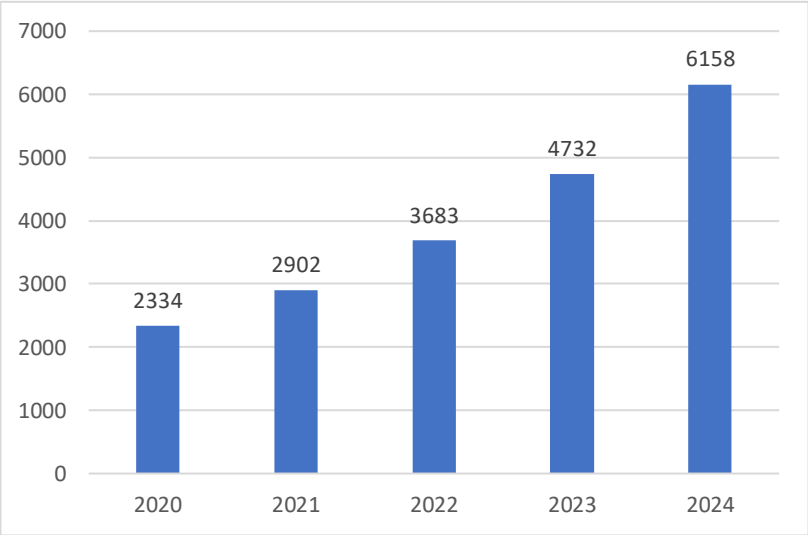

Figure 1: Global AI Market Size, 2020-2024 (USD Billion)

2.1.2. Important Breakthroughs in Specialised AI

From the perspective of applicability, AI could be broadly categorized into specialized AI and generalized AI. Specialized AI systems, designed for specific tasks like playing Go, have achieved significant advancements in their respective fields. This success can be attributed to factors such as focused tasks, well-defined requirements, clear application boundaries, abundant domain knowledge, and relatively straightforward modelling. As a result, specialized AI has been able to surpass human performance in certain narrow domains. Recent AI progress has primarily concentrated on specialized intelligence. For instance, AlphaGo defeated the world champion in Go, AI systems have outperformed humans in tasks like large-scale image and facial recognition, and AI models have achieved expertise comparable to professional doctors in diagnosing skin cancer. While specialized AI has seen considerable progress, the development of generalized AI still faces significant challenges, and overall, AI as a whole remains in an early stage of growth.

2.1.3. AI Innovation and Entrepreneurship

The global industry widely acknowledges the significant role of AI in spearheading a new wave of industrial transformation, and has consequently recalibrated its development strategies. For instance, at its annual developer conference in 2017, Google explicitly shifted its focus from a 'mobile-first' to an 'AI-first' approach. Similarly, Microsoft's fiscal year 2017 annual report marked the first instance where AI was positioned as the cornerstone of the company's strategic vision.AI is at the forefront of innovation and entrepreneurship. McKinsey & Company report pointed out that the global investment in AI research and development exceeded 30 billion U.S. dollars in 2016 and is in a phase of rapid growth; as of June 2023, the scale of China’s core AI industry has reached 500 billion yuan, and the number of AI enterprises is more than 4,400 companies.

2.1.4. The Social Impact of AI is Becoming More and More Prominent

On the one hand, as the driving force behind the latest scientific and technological revolution and industrial transformation, AI is facilitating the modernization of traditional industries, accelerating the swift development of the unmanned economy, and exerting a beneficial influence on various

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aspects of daily life, including intelligent transportation, smart homes, and intelligent healthcare [3,4]. On the other hand, challenges such as the protection of personal information and privacy, as well as the intellectual property rights of AI-generated content. The issues of potential discrimination and bias in AI systems, traffic regulations for unmanned systems, and the technological ethics surrounding brain-computer interfaces and human-computer symbiosis have already surfaced, significantly needing solutions. For example, related literature has studied and analysed AI and economic growth. Hanson used a neoclassical economic growth model to estimate the impact of machine intelligence on the economy, and found that the use of machine intelligence increases the economic growth rate [5]. Aghion provided a comprehensive analysis of how the development of AI would strongly drive economic growth, pointing out that automation brought about by AI promotes economic. Brynjolfsson argues that modern technologies such as the internet and computers have played a key role in increasing productivity and driving economic growth, and that the impact of AI on this is likely to be even greater [6].

2.2. Future Trends of AI

At present, AI has been widely used in all aspects of people's daily life, and the introduction of AI tools has also brought a huge increment to the development of the digital economy, and its development trend is healthy, stable, sustainable and optimistic. At the same time, in the process of industrial intelligent transformation and upgrading, the participation of traditional industries will become more and more in-depth, which will provide massive data and richer application scenarios for AI, and open up new space for the application of AI. In the next few years, AI will continue to develop in the direction of greater intelligence, autonomy and popularisation. With the optimisation of algorithms and the improvement of arithmetic power, AI will be able to handle more complex problems and achieve more accurate decision-making and prediction. Meanwhile, with the development of 5G, IoT and other technologies, AI will be deeply integrated with these technologies to achieve a wider range of applications. In addition, with the support of policies and the influx of capital, the AI industry will continue to grow and become an important force in promoting economic and social development.

3. Contribution of AI to Economic Growth

3.1. The Promoting Role of AI on Agriculture Industry

The supportive role of AI in the process of agricultural production and management is reflected in the fact that, in order to achieve the development goals of precision agriculture, safe agriculture and ecological agriculture, through the application of the Internet of Things, big data, cloud computing and intelligent terminal equipment, it builds an intelligent agricultural system of perception, identification, analysis and decision-making, and pushes the transformation and upgrading of agriculture from traditional agriculture to intelligent agriculture. Firstly, precision agriculture is mainly an intelligent agriculture that uses AI to achieve the perception, control and input decision-making process. In the production process of precision agriculture, the investment in the Internet of Things, big data computing and intelligent terminals and equipment forms capital deepening, and at the same time brings innovation and upgrading of production technology to achieve the decision-making goal of precise discovery and control of agriculture. In this way, it can save the time of determining and dealing with crop growth problems, improve the efficiency of agricultural production, and consolidate the technical foundation for the improvement of production quality. Secondly, safe agriculture is mainly based on precision agriculture, crop safety and labour safety intelligent agriculture. Through the precision agriculture production program, production tools can be upgraded, both through labour substitution, reducing labour costs, improving production efficiency and

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protecting labour safety; and through technological progress, adopting advanced production equipment, reducing crop disaster losses, lowering production costs, and improving production efficiency and product quality. Eventually, intelligent agriculture with crop safety and labour safety will be achieved. Thirdly, ecological agriculture is mainly based on precision agriculture and safe agriculture, and realises efficient land and environmental utilisation, resulting in smart agriculture in harmony with nature. Ecological agriculture programmes can reduce the maintenance and restoration time of arable land, which in the long term is conducive to the maintenance of the quality of land resources and improves the quality of arable land production and the efficiency of agricultural production operations. At the same time, through the analysis of land use data, land use can be effectively assessed and effective land use programmes can be provided. Therefore, AI technology can help traditional agriculture transform and upgrade to eco-agriculture and achieve the harmonious development of land, environment and nature. In short,via the joint efforts of the Internet of Things, big data and intelligent terminals, AI achieves the improvement of agricultural production efficiency, the reduction of production costs and the improvement of the quality of production at the first level through the upgrading of production technology, production tools and production management, and promotes the transformation and upgrading of agriculture from traditional agriculture to intelligent agriculture.

3.2. The Promoting Role of AI on Manufacturing Industry

The mechanism of the impact of AI on the manufacturing industry, that is, the impact of AI on the production and management within the production enterprise, mainly includes the operation integration system that connects the production enterprise's machines and equipment, business processes, and application systems (vertical integration), as well as the whole chain integration system within the production enterprise that includes the workflow of design, production, logistics, sales, and service across departments and workshops (horizontal integration). Firstly, production intelligence is mainly a transformation of the production mode, i.e., to achieve information-based, integrated and autonomous production through artificial intelligence analysis and decision-making. Taking the production target as the starting point, AI analyses and plans the allocation of production resources through machine learning, deep learning, etc., including the whole process of production operation such as the amount of raw materials, the amount of accessories, the logistics transmission of production factors, the use of equipment, the preparation and planning of work processes, the control of risk points of product testing and safety management, and so on. Intelligence in the whole production process will circumvent the problems of time lag in decision-making, accurate operation, idle equipment and low operational efficiency in the production process, and therefore will promote the continuous optimisation and reduction of energy consumption. Secondly, management intelligence is the process of networked manufacturing to converged manufacturing, i.e., information - manufacturing convergence mode (IoT), so that the digital and physical to establish a mapping relationship, to achieve the digital twin manufacturing function. Through the digital system to command the physical system production, the physical system production feedback to the digital system information as the next implementation of the experience input - artificial intelligence deep learning to achieve the creation of knowledge, to achieve the overall production efficiency, the production of trial and error to reduce the target. In short, 'AI + manufacturing' transformation and upgrading is through the intelligent equipment to support the production of intelligent, intelligent management functions to achieve, and then the implementation of accurate quality control and processing, labour force substitution, and energy, raw materials, production equipment and other factors of production and efficient allocation, in order to achieve product quality enhancement, production cost reduction and production efficiency. For China, the upgrade of 'AI + manufacturing' will increase China's GDP growth rate by 1.4% [7], and it is expected that by 2035, the growth rate

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of manufacturing value-added can be ranked first among all industrial sectors, increasing by about 2% [8].

3.3. The Promoting Role of AI on Service Industry

The large number of industries within the service industry makes it difficult to identify uniform standards for measuring service quality. As a result, the inconsistency of the claims or development goals of the industry segments within the service industry has led to inconsistencies in the ways in which new-generation information technologies, such as AI, can empower the service industry. However, it is still possible to sort out a mechanism with relative commonality of the impact of AI on the service industry based on the current AI product and service system by examining the situation of the medical, education, financial and other service industries that have a generally high degree of integration with AI. The overall logic of AI-enabled service industry is 'technology + traditional service industry scene'. AI technology is integrated into AI products, and the technology-enabling capability is released through the application of AI products in various scenarios of the traditional service industry, so as to play a rapid response to meet the needs of customers for improving service quality and lowering service prices. Assuming that customers prefer cost-effective products and services, i.e., the price and service quality are in line with the customer's psychological expectations, the application of AI technology products will improve the overall user satisfaction and drive the increase in consumer demand. Therefore, AI can not only improve the quality level of the development of the service industry to improve user satisfaction as a criterion, but also increase the output value of the service industry, and promote the service industry into an efficient and high-quality development track.

4. Suggestions for Artificial intelligence in promoting economic growth

4.1. Agriculture Industry

Under the backdrop of artificial intelligence, agricultural management is advancing towards a new era characterized by big data intelligence, collective intelligence, cross-media intelligence, and 'hybrid-enhanced' intelligence. This evolution also encompasses the development of autonomous intelligent agriculture, leading to innovative models such as precision agriculture, facility-based agriculture, precision farming, and marketing agriculture [9]. There are three pathways for the advancement of smart agriculture: first, leveraging intelligent alternatives to reduce labor requirements; second, increasing capital investment to upgrade traditional production tools into smart technologies; and third, enhancing the application of intelligent technology to facilitate advancements in agricultural techniques and management practices—ultimately improving the quality of agricultural products [10]. It is evident that achieving high-quality development in smart agriculture necessitates harnessing AI technology to replace traditional production factors like labor and tools, thereby enhancing agricultural productivity. Concurrently, employing big data analytic, Internet of Things (IoT) applications, and AI technologies will elevate the standards of agricultural management. Through this dual enhancement approach—improving both efficiency and management—the quality of agricultural products will be elevated; total factor productivity within agriculture will increase; supply-side reforms will be advanced; and ultimately, agriculture will progress towards high-quality development.

4.2. Manufacturing Industry

In terms of development model, AI should be leveraged to transform the manufacturing industry across six dimensions: product intelligence, equipment intelligence, production intelligence,

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management intelligence, business application intelligence, and industrial ecological intelligence. This approach aims to foster the healthy operation of intelligent production management, intelligent production operations, intelligent organizational management, intelligent business models, and intelligent enterprise competition models. It effectively promotes the deep integration of AI with the manufacturing industry [11]. From a technical operations perspective, it is imperative to harness the capabilities of a new generation of AI to construct a multifaceted, cross-media, heterogeneous database. Additionally, a big data-driven mining system designed to meet specific requirements, a virtual experience system, a virtual manufacturing system, and a fully automated information collection, production control, and collaborative optimization system are key technologies that need to be developed. Moreover, data mining technology, sensor technology, embedded monitoring systems, fault prediction algorithms, machine vision technology, machine learning, and other supporting technologies should be advanced to elevate the development of intelligent manufacturing to a higher level [12].

4.3. Service Industry

Since the characteristics of the application scenarios of 'AI+Service Industry' vary greatly, it is difficult to consider the development of the service industry from the perspective of a unified framework. For example, some studies have taken the lead in summarising the application of AI in the financial sector in advanced developed countries and put forward China's countermeasures. However, China's financial services intelligence still needs to continue to improve the rules of the financial transaction market, strengthen information security and cybersecurity, and enhance the role of AI in financial regulation if it is to realise its application. In addition, a study focuses on China's aging population and the unreasonable layout of regional pension services and other contradictory problems, by analysing the characteristics of China's aging and the requirements of high-quality development of the pension industry, it is believed that AI technology can improve the scale of the pension industry, the industrial system, the industrial layout, and the industrial ecology, and promote the high-quality development of the pension industry [13]. From the perspective of 'AI+service industry' products, it is found that intelligent service robots, unmanned vehicles, AIoT (intelligent Internet of Things), entertainment and assistants, and other public and private service AI products, as well as medical, financial, legal, education, logistics and other industry AI products are subtly changing the production and life of human beings, and are also silently affecting the service industry. silently transforming and upgrading the service industry [14]. From the perspective of the development path of the intelligent service industry, it is necessary to innovate the intelligent service industry model, meet the demand for consumption upgrading, consolidate the foundation of the intelligent service industry infrastructure and public service system, and improve the intelligent service industry system, regulatory laws and ethical restrictions and other related measures, so as to promote the high-quality development of the intelligent service industry [15].

5. Conclusion

This paper analyses the impact of artificial intelligence on economic growth by analysing the impact mechanism of AI on different industries. From the aspect of the impact on the three industries, smart agriculture mainly relies on AI to play a role in the transformation of production tools and the implementation of agricultural production technology under the level of agricultural management to achieve. The realisation of smart manufacturing has the shortcomings of the lack of key components, operating systems, and core technologies, but it is argued both theoretically and empirically that AI can improve manufacturing productivity, product quality, and total factor productivity. However, we still need to face up to the difficulties, increase technological innovation and combination of

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applications, transform the traditional manufacturing production management and operation mode, through improving the efficiency of the use and allocation of factors of production, organisational and management efficiency and operational efficiency, to create an intelligent manufacturing system with intelligent decision-making and intelligent production as the goal. The main mode of AI-enabled service industry development is 'AI products + traditional service industry scenarios'. From the aspect of production mode, AI can improve labour productivity and achieve industrial upgrading and transformation through knowledge restructuring and tool transformation, thus changing the mode of production; and promote the intensive level of economic growth through technical efficiency and technological progress.

At present, research on the impact of AI on industrial development has yielded numerous results; however, a comprehensive review of existing literature still reveals several future research directions and trends. Firstly, a general theoretical analysis framework regarding the influence of AI on industrial development has yet to be established. Second, the quantitative characterization of AI requires further enhancement. In conclusion, given the uncertainties surrounding future economic growth and the opportunities and challenges posed by emerging technologies—particularly in light of the industrial revolution driven by AI—the study of AI impact on industrial development holds significant implications for promoting high-quality economic advancement through AI.

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Analysis of the Impact of Educational Attainment on Nominal Wages and Wage Growth Rates

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Abstract: This study explores the impact of educational attainment on nominal wages and wage growth rates, focusing on whether education reduces or exacerbates wage inequality. As globalization and technological advancements reshape the labor market, understanding these dynamics is crucial for identifying and supporting disadvantaged groups to mitigate economic instability. Utilizing data from the U.S. Department of Labor, this research employs box plots and log-difference analysis to examine wage distribution and convergence among different educational groups. This research indicates that wage disparities are more significant among individuals with higher levels of education, whereas wages tend to be more consistent within groups of those with less education. Additionally, wage growth shows greater volatility and disparities are more pronounced among those with less education, whereas those with higher education generally experience more stable, incremental salary increases. In addition, the wage gap between highly educated and less educated individuals is also becoming increasingly pronounced. These results suggest that targeted policies are needed to address wage disparities and support disadvantaged groups, particularly those with lower educational levels who may be more vulnerable to the economic shifts brought about by globalization and technological advancements.

Keywords: Educational Attainment, Wage Inequality, Nominal Wages, Wage Growth Rates, Labor Economics.

1. Introduction

1.1. Research Background and Motivation

Education plays a crucial role in the contemporary labor market. Studies from various countries and different time periods consistently show that individuals with higher education levels tend to earn more than those with lower levels of education. Despite the substantial evidence supporting the positive correlation between education and labor market status, social scientists remain cautious when asserting a causal relationship between education and income. For instance, Cheah, Carnevale and Wenzinger stated in their research that not all workers with more education earn more than those with less education, due to the heterogeneity in educational levels and fields of study [1]. Furthermore, with the development of automation and information technology, the demand for skills in the modern labor market is constantly evolving, leading to significant differences in the opportunities available to workers with varying levels of education. According to a study by Autor and Dorn, although the

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overall skill level of society today is much higher than it was fifty years ago, the opportunities for low-educated individuals to engage in technical work have significantly diminished [2]. Against this backdrop, this study aims to explore wage inequality from the perspective of the impact of educational attainment on nominal wages and wage growth rates. Additionally, by comparing wage trends among workers with different educational backgrounds, this study seeks to assess whether educational attainment helps to alleviate or exacerbate the wage gap between highly educated and less educated workers.

1.2. Literature Review

Regarding the issue of wage inequality, much of the literature tends to examine wage disparities among different labor groups from the perspective of external factors. For example, Acemoglu and Restrepo in 2022 studied how automation and technological advancements lead to wage inequality by influencing the allocation of tasks, using both simulation and empirical methods [3]. Similarly, Valletta emphasized that as technological advancements in the workplace progress, particularly with the increasing reliance on computers, this development has reinforced wage disparities [4]. However, the mechanisms through which external factors and workers' own factors, such as education, affect wages are different. External factors influence wage levels by altering the demand structure of the labor market, replacing low-skill jobs, thereby impacting wage levels. In contrast, education affects wages mainly by enhancing an individual's productivity, knowledge, and skills, enabling them to secure higher-paying jobs. Moreover, the influence of education is usually long-term; as educational attainment increases, an individual's income and job stability may continue to improve, while external or social influences may be more immediate, potentially causing sudden job losses and significant wage fluctuations in the short term. Therefore, analyzing wage levels based solely on external factors cannot fully explain the issue of wage inequality.

Some studies on the indirect relationship between education and wages, which may result in discrepancies when compared to direct research. For instance, Daly, Jackson, and Valletta used the Phillips Curve model to investigate the correlation between educational attainment and unemployment rates, and to ascertain the connection between educational levels and wages, with respect to the relationship between unemployment rates and wage levels [5]. Such studies usually focus on a macroeconomic perspective and often infer the impact of education on wages indirectly through unemployment rates, which may introduce some errors.

This study aims to build upon previous research, further expanding the understanding of wage inequality by analyzing the issue from the perspective of internal factors. Additionally, this study will focus on micro-level analysis to avoid interference from macroeconomic factors, directly examining the impact of educational attainment on wages. Given that most existing literature focuses on short-term effects, this study intends to delve deeper into the differences and trends among various educational levels over time, thereby revealing the long-term impact of education on wages.

1.3. Research Contents

The focus of this study is to investigate the impact of educational attainment on nominal wages and wage growth rates. The central research question is how educational levels influence individual wage levels and whether the wage gaps between groups with different educational levels are narrowing or widening. The study primarily employs box plots and log-difference analysis to illustrate the wage distribution and wage growth rates across different educational groups. Box plots are used to visually represent the characteristics of wage distribution, such as the median, dispersion, and outliers. Log-difference analysis is primarily utilized to quantify the wage gaps between groups with varying educational levels and to observe how these gaps change over time. Through this research approach,

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the study aims to provide new insights into how educational attainment influences wage inequality and to offer robust data support for policymakers.

2. Methodology

2.1. Education Level and Nominal Wage

This study uses different levels of education as a categorization criterion to examine the median weekly nominal wage and the wage growth rate. Nominal wages reflect the current income disparity among different groups, while the wage growth rate reveals the potential for future income disparity. For example, while the current nominal wage may be higher for those with higher levels of education, a higher wage growth rate for those with lower levels of education suggests that the wage gap between these groups may narrow over time.

The categorization criteria in this study cover different levels of educational attainment, including those with a bachelor's degree or higher, those with some college education, high school graduates who did not continue their education, and those who did not complete high school.

2.2. Data Sources

This paper utilizes the data published by the Federal Reserve Bank of St. Louis [6]. Murray states, "Quarterly earnings can vary due to fluctuations in overtime pay, bonuses, payday weeks, average weekly hours paid, or base wages."[7]. This explains why using weekly nominal earnings data can more accurately capture short-term income fluctuations, thereby enhancing the precision and reliability of the analysis. The dataset records changes in median weekly nominal earnings across different education levels over time, covering 98 quarters from Q1 2000 to Q2 2024, provided by the U.S. Department of Labor.

2.3. Box Plot

During the data pre-processing for the box plots, the study first cleansed the data by removing outliers and missing values, then categorized it according to educational attainment. The processing differs for nominal wages and wage growth rates. Nominal wages are handled directly, while wage growth rates require additional steps like smoothing and trend adjustment for stability.

In this study, box plots are used to illustrate the distribution of nominal wages and wage growth rates across educational levels, emphasizing comparisons between groups and visualizing data skewness. Analyzing central tendencies, such as the median or mean, allows for an assessment of typical wage levels within each educational group, helping confirm whether higher educational attainment correlates with higher wages.

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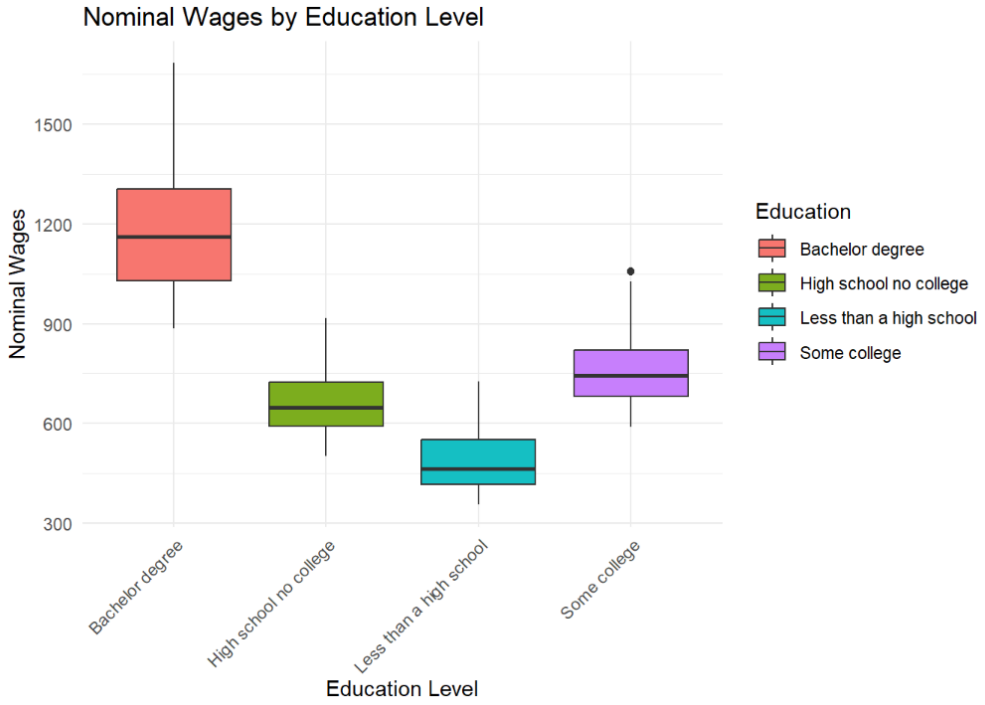

Figure 1: Nominal Wages by Education Level.

Figure 1 is a box plot illustrating the distribution of nominal wages across different educational attainment groups. It displays that the group with a bachelor's degree has the highest median nominal wage, approximately $1,200, follow by the individuals with some college education and those with a high school diploma but no further education, while individuals who did not complete high school have the lowest median wage, approximately $500. In other words, higher educational attainment is often positively correlated with higher wages.

Moreover, dispersion, such as variance or standard deviation, reveals the volatility within each educational group's wages. Larger dispersion may indicate significant wage inequality within the same educational group. Additionally, box plots allow for assessing data symmetry and skewness. If the box is skewed in one direction, the data may have positive or negative skewness, indicating wage distribution inequality. For example, if a group shows positive skewness in wage distribution, it means most individuals in that group earn below the average wage, with only a few earning significantly more.

As shown in Figure 1, there are significant differences in wage distribution ranges among different educational groups. The wage distribution range for individuals with a bachelor's degree is wide, with some earning as much as $1,500, while the lowest wage is around $900. On the other hand, the wage distribution for those who did not complete high school is relatively concentrated and low, with the highest wage under $700 and the lowest around $400. The length of the box indicates that groups with a high school diploma or lower have less internal wage disparity, while individuals with a bachelor's degree have greater internal wage disparity. This suggests that wage inequality may be more pronounced in higher educational groups.

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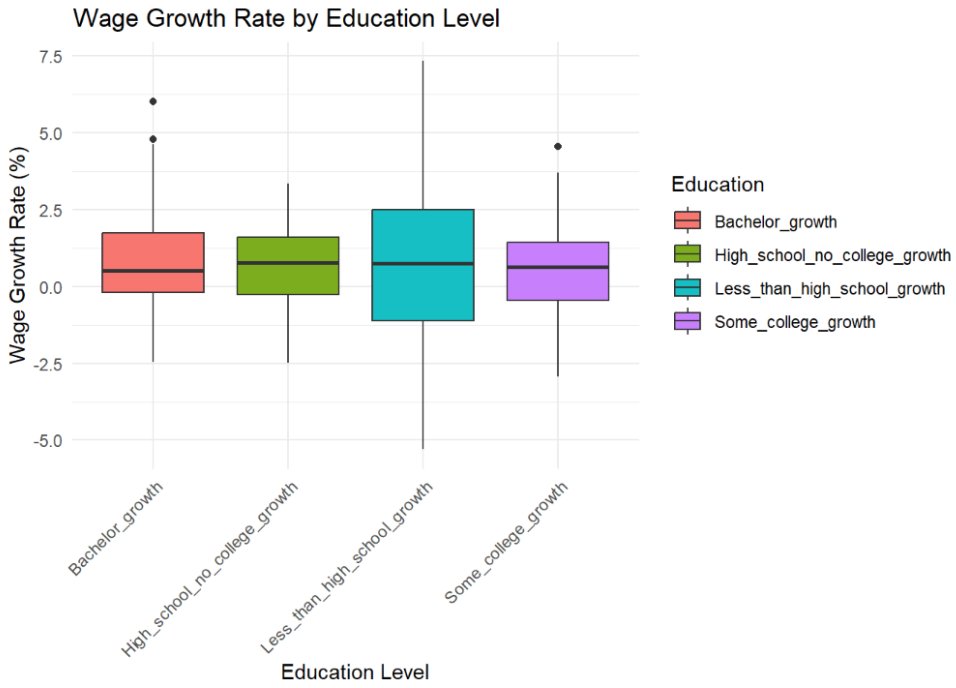

Figure 2: Wage Growth Rate Distribution.

Figure 2 illustrates the wage growth rate performance of groups with different educational attainment. Overall, individuals who did not complete high school show the greatest volatility in wage growth rates, ranging from -5% to 7.5%, indicating that some individuals in this group experienced significant wage increases, while others saw wage decreases. This result also indicates greater inequality in wage growth within the group of individuals who did not complete high school. In contrast, the median wage growth rate for those with a bachelor's degree is close to 0%, with a relatively narrow distribution range. This suggests that although the group with a bachelor's degree has higher nominal wages, their wage growth rate is not significant, possibly indicating that wage growth flattens at higher wage levels. Furthermore, the wage growth rates for high school graduates with no college education and those with some college education are relatively close, with median growth rates around 1% and relatively close distribution ranges. This suggests that wage growth rates remain comparatively stable within these two educational categories, also demonstrating that greater educational achievement does not inherently equate to more rapid wage growth.

2.4. Log-Difference Analysis

In the data pre-processing process for log-difference, after ensuring no missing or outlier data, the differences of the two nominal wage data for each educational level is log-transformed. Once the log transformation is complete, the next step is to calculate the log differences relative to the baseline educational level, which is the bachelor's degree or higher. After calculation, the log difference data is visualized and decomposed to better observe the data trends.

This study employs a log-difference analysis method by calculating the log differences between each group and the baseline group, which is individuals with a bachelor's degree or higher, to quantify the differences between groups. Log differences capture relative changes or growth rates of variables, providing a standardized growth rate that facilitates comparisons across different scales or magnitudes. This study focuses on the convergence of nominal wage gaps between groups. By examining the convergence of trend components among groups, it is possible to assess whether relative differences between groups are gradually narrowing.

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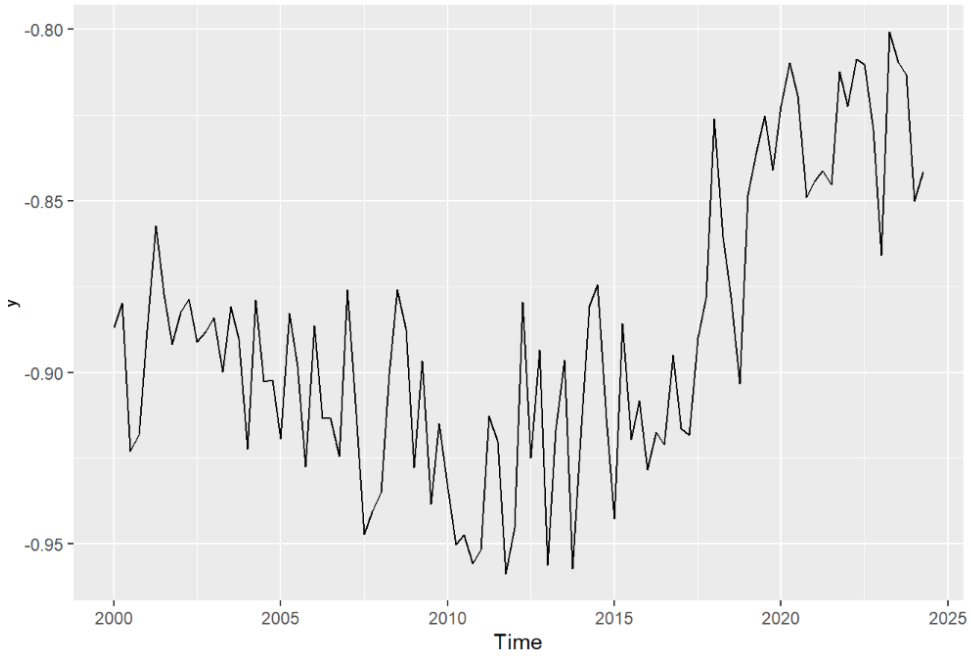

Figure 3: Log Difference Between Individuals with a Bachelor's Degree and Individuals with Less Than a High School Degree.

Log-difference analysis further reveals the convergence trends of wage gaps between different educational attainment groups. In Figure 3, the log difference between individuals with a bachelor's degree and those who did not complete high school shows an upward trend over time. This trend suggests that the wage gap between the group that did not complete high school and the group with a bachelor's degree is widening, indicating that the lower-educated group is losing wage competitiveness.

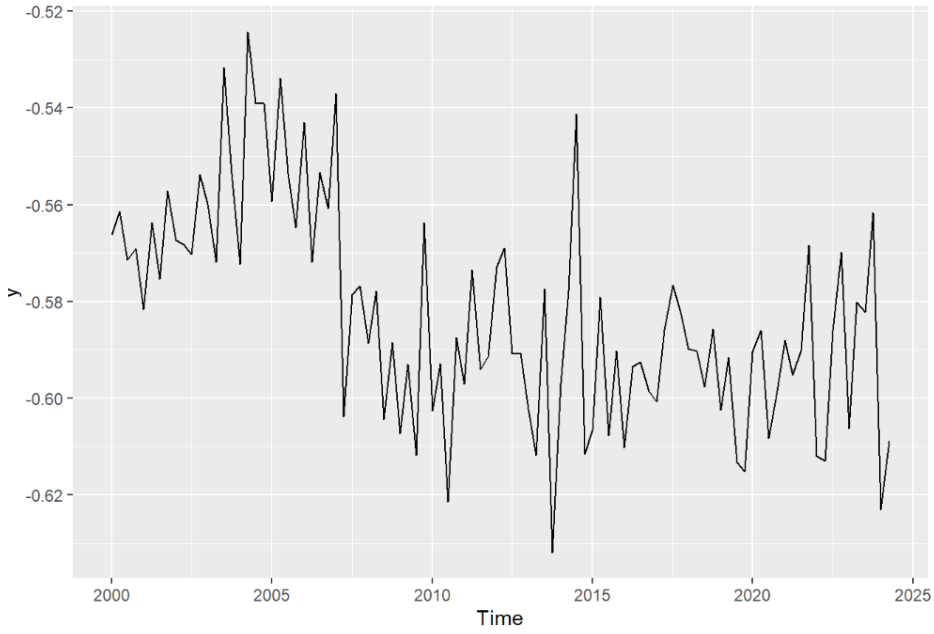

Figure 4: Log Difference Between Individuals with a Bachelor's Degree and Individuals with Less Than a College Degree

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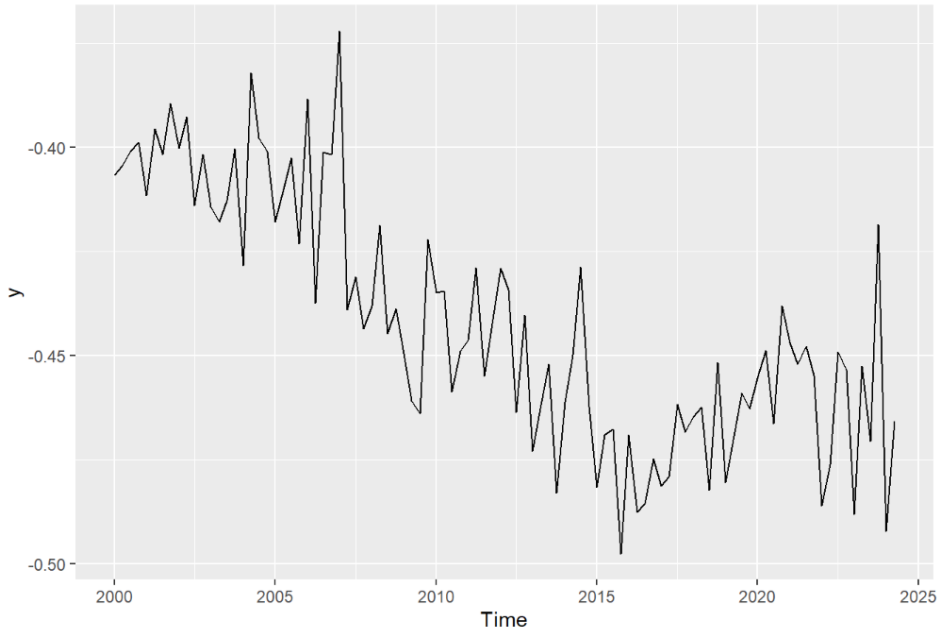

Figure 5: Log Difference Between Individuals with a Bachelor's Degree and Individuals with Some College

On the other hand, Figure 4 and 5 describe the trend of decreasing volatility between the log differences between high school graduates with no college education and those with some college education compared to individuals with a bachelor's degree, indicating that the wage gaps between these two groups and the group with a bachelor's degree are narrowing. This analysis underscores the importance of educational attainment in shaping wage gaps, with higher education clearly leading to a higher starting point, but the relative position of lower-educated groups depends on their opportunities for further education and training on the job.

3. Discussion

Regarding Conclusion 1, "Wage disparity is greater within higher-educated groups, while wages are more concentrated within lower-educated groups," the primary reason is that higher-educated groups tend to choose industries with a high wage ceiling, where wage disparities are significant. Top positions in these industries, such as executives or senior technical staff, command very high wages, while entry-level or non-core positions within the same industry may have wages well below the industry average, leading to substantial wage differences among individuals with the same educational background. According to Mishel and Bivens, the widening wage gap between the vast majority of workers and top-tier workers is one of the causes of growing inequality [8]. At the same time, higher education is not homogeneous. Graduates from top universities usually secure higher starting salaries and broader career development opportunities, while graduates from ordinary or lower-ranked schools, although holding the same bachelor's degree, often face lower employment opportunities and wages. This disparity caused by school reputation and educational quality further exacerbates wage inequality within higher-educated groups. In contrast, lower-educated groups have limited employment choices, with relatively similar skill demands, leading to more uniform wages. Additionally, lower-educated groups typically face career advancement bottlenecks, making it challenging for them to achieve significant salary increases over their careers. Thus, wages are more concentrated within lower-educated groups.

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Regarding Conclusion 2, which states that "Wage growth exhibits greater volatility and inequality is more pronounced among individuals with lower levels of education, while those with higher education tend to experience more stable and gradual wage increases," the 2008 financial crisis emerges as a pivotal influence, disproportionately impacting workers with lesser educational attainment. Following the financial crisis, the U.S. economy plunged into a severe recession, leading to business closures and soaring unemployment rates. During economic downturns, companies frequently resort to layoffs, often starting with those who possess fewer skills and lower levels of education, in an effort to sustain operations and cut costs. This practice leads to a significant increase in unemployment rates among less-educated demographics, subsequently causing downward pressure on wages. In contrast, higher-educated groups usually work in relatively stable, high-skill jobs, such as in finance, law, and healthcare industries. At the same time, Shibata mentioned in his article that the although global financial crisis had a significant negative distributional impact on employment prospects, workers with higher education were less affected during any economic recession [9]. Employees in these industries were able to maintain high wage levels even during the crisis and quickly recover after the economic recovery. Moreover, high-skilled industries are more likely to attract capital investment and technological advancements during recovery, helping them quickly restore wage levels and further increase them, which corresponds to the relatively stable wage growth rates observed in the box plots for higher-educated groups. However, the recovery of low-skilled industries is slower, and many low-educated workers continue to face low wages and job instability, contributing to the significant volatility in wage growth rates among lower-educated groups.

Regarding Conclusion 3, 'The wage gap between individuals with higher education and those with lower education is widening.' the primary reason is that higher-educated groups tend to choose industries with a high wage ceiling, where wage disparities are significant. The rise of information technology and automation in the early 21st century has increased the demand for highly educated workers, leading to higher wages for them. Conversely, lower-educated workers face wage stagnation or decline due to the risk of being replaced by automation and outsourcing. Additionally, globalization has worsened the situation for low-skilled workers, as manufacturing jobs have moved to low-cost countries, reducing employment opportunities and wages for those without a high school diploma, while higher-educated workers benefit from opportunities in industries like finance and technology.

4. Suggestions

Mellacher and Scheuer suggest that policies and institutions should not focus solely on raising the relative wages of low-skilled workers [10]. Therefore, the government can provide more vocational training programs and continuing education opportunities, especially for lower-educated groups. These programs should focus on developing relevant skills in high-demand industries, thereby enhancing the competitiveness of lower-educated groups and expanding their career development and employment opportunities. At the same time, the government should ensure that the promotion of automation and digitization creates new employment opportunities for low-skilled workers while creating positions for high-skilled employees. For example, when automated logistics replace sorters, the maintenance and cleaning of automated equipment could provide jobs for low-skilled workers. Additionally, to address job instability among lower-educated groups, the government can expand social security and employment support for lower-educated individuals, such as unemployment benefits or job opportunity information, especially during economic downturns. By combining the above policies with skill upgrading and job opportunity expansion, the income gap between high-educated and low-educated groups can be narrowed to some extent.

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5. Conclusion

This study explores the relationship between educational attainment and wage dynamics, revealing a positive correlation between higher levels of education and both higher wages and more significant wage disparities within groups. Specifically, individuals with a bachelor's degree exhibit the highest median wages but also show considerable wage disparity within the group, whereas those without a high school diploma earn lower wages, which are more concentrated. The study also indicates that the wage gap between bachelor's degree holders and those without a high school diploma is further widening, underscoring the critical role of higher education in wage disparity.

However, the research has some limitations. For instance, the study only considers education as an influencing factor, neglecting other factors such as external economic conditions or individual worker differences, which might also impact wage dynamics. Additionally, the research might have employed certain simplifying assumptions during the data analysis process, such as the stability of wage growth rates and the homogeneity of returns to education. While these assumptions help streamline the analysis, they may overlook the complexity of real-world scenarios, potentially affecting the accuracy of the findings. Future research could focus on integrating both internal and external factors into a modeling analysis, such as automation and globalization, to better understand the interplay between these factors, educational attainment, and wage inequality. Furthermore, future studies could explore the nonlinear relationship between education and wages, especially at higher education levels. A higher level of education does not always lead to proportionately higher wages; sometimes, there might be diminishing returns or income saturation effects. Capturing such nonlinear relationships would require more sophisticated statistical models.

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Impact of Macroeconomic Conditions on the US-Japanese Yen Exchange Rate

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Abstract: In 2024, the yen exchange rate is affected by Japan's exit from the eight-year negative interest rate policy and the possible interest rate cut in the United States, which is related to the global economy and financial market volatility. In this context, it is necessary to reassess the mechanisms that influence fluctuations in the US-yen exchange rate. This study examines the fluctuation of the US-yen exchange rate from 2010 to 2024, focusing on significant growth periods between 2012-2016 and 2020-2024, and a stable phase from 2016-2020. Utilizing the ADF test for stationarity, ACF, and PACF analysis for ARIMA parameter determination, data decomposition by using window and decompose function in R studio, the research reveals the influence of macro factors such as "Abenomics", QQE and YCC policies on exchange rate trends. The study finds that monetary policy, especially the differences between the United States and Japan, has a significant impact on exchange rates, with the depreciation of the yen and periods of economic stability attributed to the combined effects of global economic challenges and policy responses. The research provides valuable insights for investors and policymakers, emphasizing the importance of macroeconomic conditions on exchange rates in the context of a constantly changing global economy.

Keywords: Exchange Rate Fluctuations, ARIMA Model, Decompose Function, Monetary Policy Impact, Abenomics.

1. Introduction

1.1. Research Background and Motivation

In the current global economic landscape, characterized by the interconnectedness of financial markets, the US-yen exchange rate has exhibited notable volatility, particularly during the periods of 2012-2016 and 2020-2024, with a period of relative stability in between. This volatility is a critical area of interest due to its implications for international trade, investment, and the formulation of economic policies in an era of globalization. The study is motivated by the need to dissect the complex interplay of macroeconomic conditions, especially the divergent monetary policies of the US and Japan, and their profound influence on exchange rate dynamics. By examining the impact of policies such as "Abenomics," QQE, and YCC, this study aims to uncover the mechanisms behind exchange rate fluctuations and provide actionable insights for investors and policymakers. The analysis will delve into the use of advanced statistical methods such as the ADF test for stationarity, ACF and

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PACF for ARIMA modeling, and data decomposition techniques in R, to offer a comprehensive understanding of the factors driving these economic movements and their broader economic significance.

1.2. Literature Review

It is known from existing studies that macro conditions will have a great impact on the exchange rate, taking RMB as an example, it is concluded that expansionary fiscal policy and expansionary monetary policy will exert depreciation pressure on RMB exchange rate through various factors affecting exchange rate changes, including inflation rate differences, interest rate differences, market expectations, etc. Under the floating exchange rate system, the local currency exchange rate will also decline [1]. And the main progress and challenges since China launched the reform of the RMB exchange rate formation mechanism on July 21, 2005. These reforms are aimed at restoring price elasticity in the foreign exchange market and correcting distortions in supply and demand. In 2007, the price range of the inter-bank foreign exchange market was widened and the market players diversified, which promoted the RMB exchange rate formation mechanism to mature. In the same year, the US subprime mortgage crisis broke out and quickly spread to the world, triggering financial and economic turmoil and having a major impact on the RMB exchange rate [2]. In recent years, the Japanese economy has undergone significant shifts in monetary policy, especially in 2024 when the Bank of Japan made a historic decision to end the eight-year era of negative interest rates, raising the benchmark interest rate to a range of 0% to 0.1%. This policy change was a response to the moderate recovery of the Japanese economy and the sustained moderate rise in inflation expectations. With the diversification of market participants and the maturation of the yen exchange rate formation mechanism, this decision by the Bank of Japan has also had a significant impact on the yen exchange rate.

At the same time, the outlook for US interest rate policy in 2024 indicates that the Federal Reserve may initiate a rate-cutting cycle. This policy shift, combined with the Bank of Japan's interest rate hike, could have profound implications for the yen exchange rate. In the context of global financial market and economic fluctuations, the patterns of yen exchange rate changes may have altered, necessitating a reexamination of the mechanisms governing the yen exchange rate.

Faced with severe turmoil in the international economic and financial environment, the mechanisms by which various macroeconomic factors affect the yen exchange rate have undergone significant changes, urgently requiring a new perspective to analyze the trend of US-yen exchange rate fluctuations. However, in current research on yen exchange rate fluctuations, single-factor analysis forecasts and purely technical methods still dominate, while comprehensive multi-factor research on the US dollar to yen exchange rate is relatively scarce. This study aims to fill this gap by deeply analyzing the intrinsic mechanisms of US dollar and yen exchange rate fluctuations, providing a new perspective for understanding exchange rate movements.

1.3. Research Significance

Understanding the fluctuation of the US-yen exchange rate is of great significance for forecasting economic trends, formulating investment strategies and macroeconomic policies. Especially in the context of globalization, exchange rate fluctuations have a profound impact on international trade and capital flows.

1.4. Research Methods

The core methodology of this study involves the construction of an ARIMA model to analyze and forecast the fluctuations in the US-yen exchange rate. Initially, the stationarity of the exchange rate

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data was assessed using the Augmented Dickey-Fuller (ADF) test to ensure it met the fundamental prerequisites for the ARIMA model. Subsequently, an in-depth analysis of the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) was conducted to ascertain the precise parameters of the ARIMA model, delving into the data's autoregressive and partial autoregressive properties. Furthermore, leveraging R language's data decomposition capabilities, the study revealed trends in exchange rate movements across various time periods. Finally, by integrating policy analysis, key determinants of exchange rate changes were discussed, including the policies of "Abenomics," Quantitative and Qualitative Easing (QQE), and Yield Curve Control (YCC). This comprehensive approach not only provides a basis for understanding historical exchange rate movements but also offers a scientific model for predicting future trends.

2. Methodology

2.1. ARIMA Model

The ARIMA model is a method used for forecasting time series data, which combines autoregressive terms, differencing, and moving average terms to represent the observed values of a time series. It is denoted by the form ARIMA (p, d, q), where "p" represents the order of the autoregressive terms, "d" represents the degree of differencing, and "q" represents the order of the moving average terms [3]. By accurately determining these parameters, the ARIMA model can reveal the intrinsic structure of the time series and provide a reliable basis for future trend predictions.

Generally speaking, modeling with ARIMA involves the following four main steps: First, the stationarity test of the original trend data; second, model identification, which is determined by the autocorrelation and partial autocorrelation plots of the stationary data to decide the values of parameters p, q, P, and Q; according to practical parameter identification experience, it is rare for parameters p, q, P, and Q to be taken to higher orders above 3. Therefore, in practice, models can be built by iterating through orders 0 to 3, and the best fitting model can be selected using the minimum criterion of BIC or AIC, supplemented by residual white noise test and the significance of coefficients for a comprehensive judgment. Next, parameter estimation of the model. Finally, testing and optimization of the model [4].

The ARIMA model has a simple structure and has a certain reference value for predicting the trend of time series data. However, the effectiveness of the ARIMA model in practical applications depends on the quality of the data, the characteristics of the data, especially the stationarity of the time series data, and the rationality of the three parameters p, d, and q [5].

2.2. Data Selection and Sources

In order to generate a model that can better explain the overall data, this study analyzes a time series of the US-yen exchange rate based on average monthly prices. All the data is extracted form Yahoo Finance(https://hk.finance.yahoo.com), from January 2010 to August 2024.

The study's examination of the US-yen exchange rate from 2010 to 2024, as shown in Figure 1, highlighted significant increases in 2012-2016 and 2020-2024, with stability from 2016-2020. These trends sparked interest in the correlation between growth phases.

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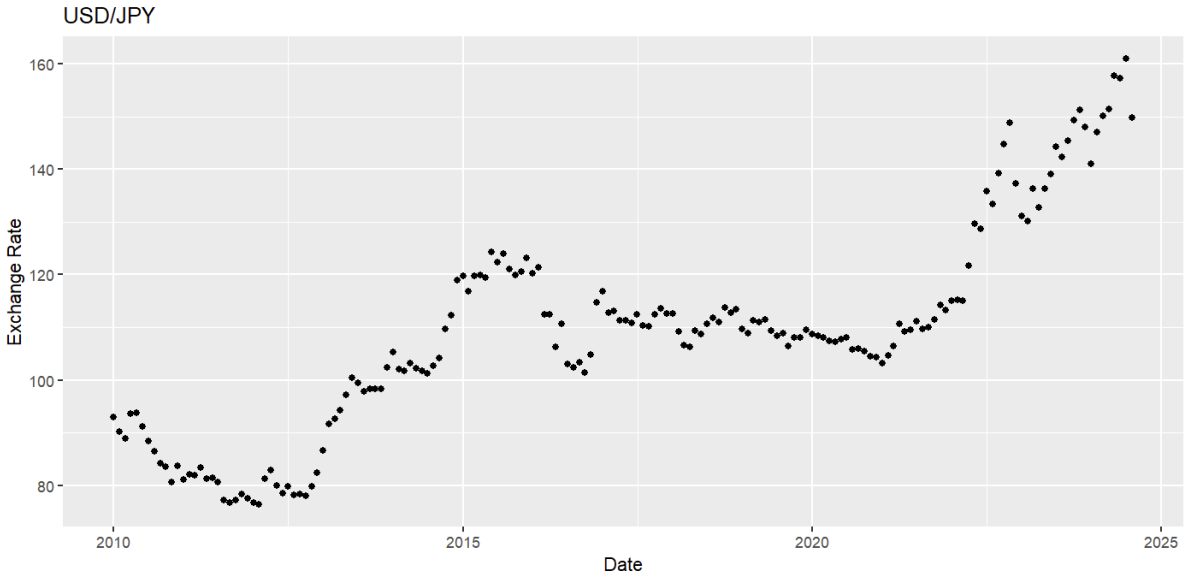

Figure 1: Trends in 2010–2024.

2.3. Stationarity Test

In the field of time series analysis, the ADF test is crucial for evaluating data stationarity. In table 1 the initial ADF test showed a P-value of 0.6357, indicating non-stationarity against the 0.05 threshold. To meet the ARIMA model requirement for stationarity, the data was differenced, resulting in a P-value of 0.01, suggesting stationarity akin to white noise within the 95% confidence interval.

Table 1: ADF test result.

Dickey-Fuller	P-value	Conclude
-1.8576	0.6357	Stationary

Note: Lag order=5

3. Empirical Analysis

3.1. Correlation Test

For ARIMA parameter determination, the paper deeply analyzed the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots, which indicated an AR(1) model due to the trailing ACF and truncated PACF, pointing to short-term autocorrelation decay. Selecting the AR(1) model provided a strong foundation for historical data analysis and future exchange rate forecasting, essential for accurate financial and economic predictions.

3.2. Decomposition Method Analysis

When it is found that the predicted value of exchange rate is different from the actual value, and it can be intuitively seen from Figure 1, that there is an obvious growth trend from 2012 to 2016 and from 2020 to 2024, while the trend from 2016 to 2020 is relatively flat. The window and decompose functions in R were then used to decompose and decompose data during this period, comparing trends between the three periods and exploring the reasons behind them. Figures 2-4 obtained by the decompose function show a more moderate increase from 2012 to 2016, followed by a sharper increase from 2020 to 2024, after a relatively flat increase from 2016 to 2020.

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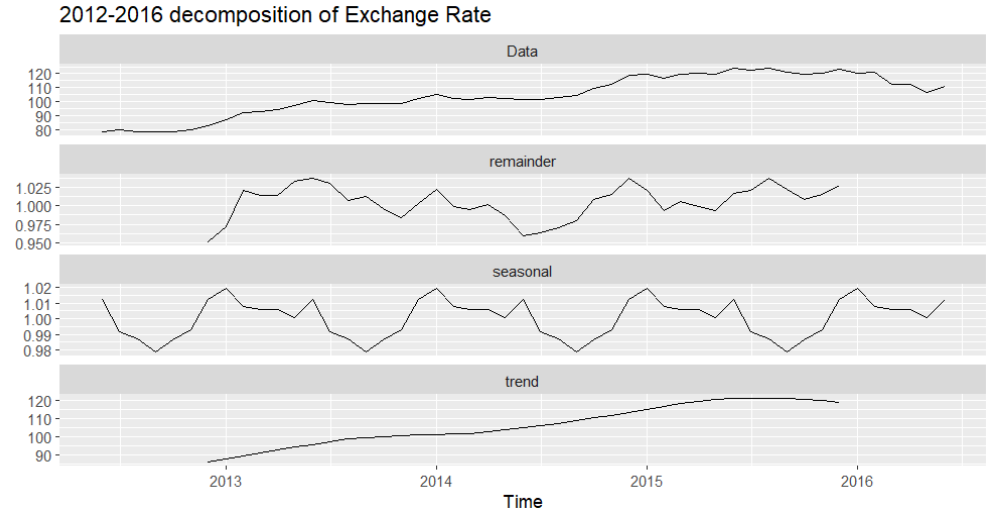

Figure 2: 2012-2016 decomposition of exchange rate

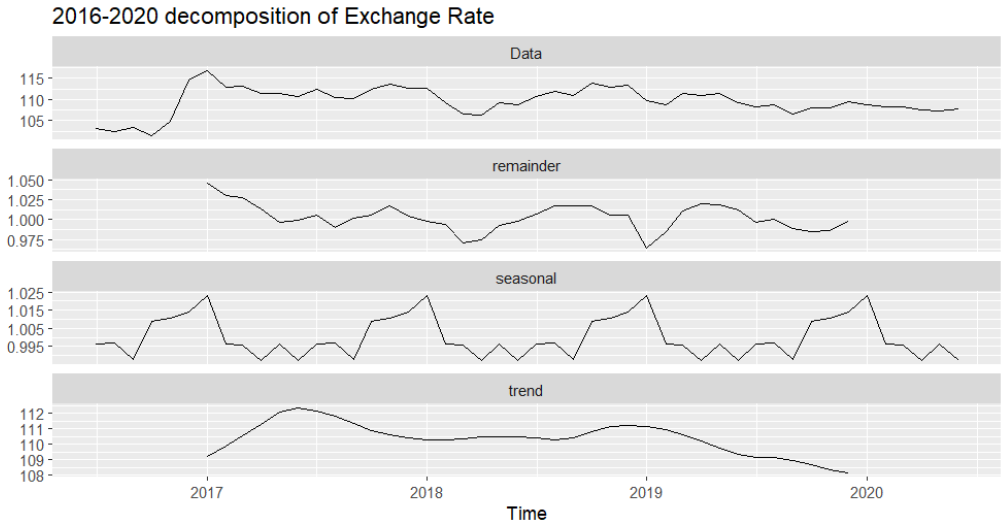

Figure 3: 2016-2020 decomposition of exchange rate

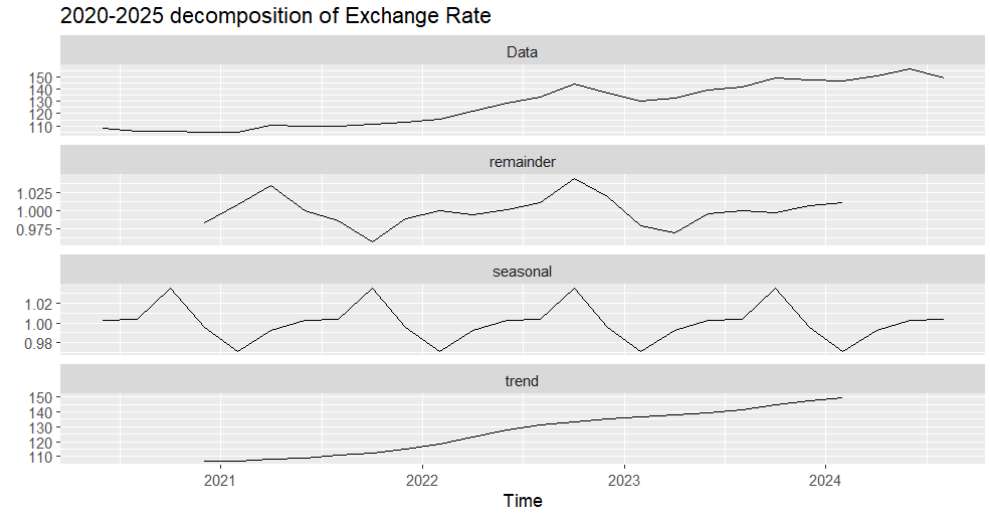

Figure 4: 2020-2025 decomposition of exchange rate

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4. Macroeconomic Factor Analysis

4.1. Trend Factor Analysis from 2012 to 2016

Analyzing the underlying reasons, it is found that the reason for the rise of US-yen exchange rate from 2012 to 2016 is related to the policies of Shinzo Abe after he took office. During this period, Japan implemented loose monetary policies, including continuous and stable negative interest rates and the depreciation of the yen, provided ample liquidity and flexibility for the Japanese market. To be specific, from September 28, 2012, the US dollar was worth 77.96 yen, which has been depreciated until June 5, 2015, when the US dollar was worth 125.64 yen, a depreciation of 61.16% [6]. In addition, his implementation of Abenomics is also an important reason for the appreciation of the exchange rate.

Abenomics refers to the series of stimulus policies that Shinzo Abe, Japan's 96th prime minister, has accelerated since he took office in late 2012, most notably monetary easing that has accelerated the depreciation of the yen [7].

The policy includes a bold monetary policy, flexible fiscal policy and a growth strategy to spur private investment, aimed at stimulating economic growth by increasing government spending and lowering interest rates. These policy measures have, to a certain extent, promoted Japan's economic recovery and development, also affected the exchange rate trend.

The impact of qualitative and quantitative monetary easing (QQE) in Abenomics on the Japanese exchange rate between 2012 and 2026 is significant. The implementation of the QQE policy, especially since 2013, marked a more aggressive monetary policy move by the Bank of Japan to combat chronic deflation and slow economic growth. These include large-scale purchases of government bonds and other risky assets, as well as the implementation of a negative interest rate policy that has flooded the market with liquidity. The initial implementation of the QQE policy put downward pressure on the yen, as the market expected that the BOJ's easing policy would increase the money supply, resulting in a decline in the yen's exchange rate against the US dollar.

Generally speaking, the appreciation of Japan's exchange rate between 2012 and 2016 was the result of a combination of factors, the loose monetary policy, the depreciation of the yen, and the "Abenomics" policy implemented by Shinzo Abe after he took office.

4.2. Trend Factor Analysis from 2016 to 2020

Continuing to explore why exchange rates are relatively flat between 2016 and 2020, between this period, the global economy faced multiple challenges, including Brexit, global trade tensions, and the outbreak of COVID-19. These factors may have had a dampening effect on fluctuations in the Japanese exchange rate.

The yen is often seen as a safe haven currency and may be bought by investors in times of increased economic uncertainty, thus supporting the yen's exchange rate.

Since 2016, although Japan has increased its quantitative easing monetary policy, the yen has appreciated significantly under the influence of negative interest rate policy and international hedging demand. Brexit may trigger a series of domino effects, global economic and financial risks will increase, and the yen as a safe haven currency will face greater appreciation pressure [8].

Another reason is that while the Federal Reserve gradually raised interest rates during this period, the Bank of Japan maintained a relatively loose monetary policy in order to support the domestic economy. This policy divergence usually leads to a depreciation of the yen relative to the dollar, but exchange rate movements may be limited by market expectations of policy effects and global economic uncertainty.

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A Fed rate hike would hardly put downward pressure on the yen. On December 15, 2016, the Federal Reserve announced a 25-basis point interest rate hike, raising the federal benchmark interest rate to a range of 0.5% to 0.75%, and expected at least three more rate hikes in 2017. The impact of the rate hike on the yen can be predicted by referring to the trend of the US dollar against the yen after the Fed raised interest rates in 2004. At that time, after the Fed raised interest rates, the market expected depreciation trend of the yen did not occur, and the fluctuations of the exchange rate between the US dollar and the yen were relatively stable. Compared with the 2004 Federal Reserve interest rate hike, although the purpose of this Federal Reserve interest rate hike is different, it is still in the form of gradual interest rate hikes. Because of this, investors are more sensitive to the expectation of the first interest rate hike, and the number of international investment flows into the United States is relatively large, and the subsequent interest rate hike expectations will weaken, and the number of international investment flows into the United States will gradually decline. Therefore, after this rate hike, the fluctuation of the exchange rate between the US dollar and the yen is still difficult to expand, and the depreciation pressure of the yen will not offset its appreciation pressure, and the yen will still have an appreciation trend in the foreseeable period [9].

Japan's economic growth has been relatively stable during this period, despite some structural problems, but there has been no large-scale economic turbulence, which may help maintain the stability of the exchange rate.

4.3. Trend Factor Analysis from 2020 to 2024

The significant increase in the Japanese exchange rate between 2020 and 2024 may be influenced by a variety of factors, and the following is a specific analysis combined with relevant policies:

The Federal Reserve's monetary policy adjustment: The Federal Reserve began to raise interest rates in 2022 in response to high inflation, and successive rate hikes led to a widening of the Japanese interest-rate spread, which was the direct cause of the sharp depreciation of the yen against the dollar. The pace of the Fed's rate hikes and its actions to reduce its balance sheet usually lead to a stronger dollar.

Bank of Japan's ultra-loose monetary policy: The Bank of Japan maintains its ultra-loose monetary policy, including the Yield Curve Control (YCC) policy, which keeps short-term interest rates near -0.1% and 10-year rates near 0%.

Because the Bank of Japan has maintained an accommodative monetary policy for most of 2022, coupled with the Federal Reserve's successive sharp interest rate hikes, the monetary policy paths of Japan and the United States have diverged significantly, and the bond yields of the two countries have also widened, causing the yen to weaken sharply against the dollar [10].

This divergence from Fed policy has led investors to seek higher-yielding dollar assets, pushing up the value of the dollar against the yen.

Changes in global economic conditions: The COVID-19 outbreak in 2020 and the subsequent global economic recovery have had an impact on exchange rates. With the gradual opening of the economy and the resumption of trade activity, the market has increased demand for risk assets, which may have supported the strength of the dollar to some extent.

Japan's trade situation: Japan's successive trade deficits, especially the rising cost of energy imports, have increased demand for the US dollar, thereby putting pressure on the yen.

5. Conclusion

The rise in the yen exchange rate between 2012 and 2016 was closely related to the policies of Shinzo Abe, the loose monetary policies and QQE measures of his "Abenomics", which increased market liquidity, economic growth and stock market performance. The yen exchange rate was relatively

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stable between 2016 and 2020, which may be related to global economic challenges, the difference in monetary policy between the United States and Japan, the safe-haven nature of the yen, and the steady growth of the Japanese economy. The significant depreciation of the yen against the US dollar between 2020 and 2025 is related to the Fed's rate hike policy, the Bank of Japan's ultra-loose monetary policy, changes in the global economic situation, and Japan's trade deficit, among other factors.

This study fills the gap in the analysis of exchange rate fluctuations in a specific period, and the research results provide an in-depth perspective for understanding exchange rate fluctuations, especially the direct impact of monetary policies on exchange rates. For investors, understanding the causes of exchange rate fluctuations is helpful to better assess risks and formulate investment strategies. For policymakers, research provides key factors to consider when formulating macroeconomic policies, especially in the context of globalization.

In future work, with the changing global economic environment, monetary policy will continue to be an important factor affecting exchange rates. Central banks are expected to continue adjusting their policies in response to economic volatility. Technological progress and the trend of globalization may bring about new economic models and trading methods, which may have a new impact on exchange rates. Considering the impact of political events and uncertainties on exchange rates, future studies can further explore how these non-economic factors interact with economic policies to jointly shape exchange rate trends. In summary, this study not only reveals the causes of past exchange rate movements, but also provides valuable insights for future economic analysis and policy making. As the global economy continues to develop and change, continuous monitoring and research on exchange rate dynamics will become increasingly important.

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Disaster Types and Resilience Evaluation in Guangzhou

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Abstract: The impact of natural disasters on urban areas had been profound throughout history, significantly affecting daily life and causing substantial economic losses, thereby impacting economic development. Therefore, was is important to fully understand and predict the types of natural disasters that will occur. At the same time, cities also need to be resilient in order to return to pre-disaster levels as much as possible in all aspects, while minimizing the impact of natural disasters. This paper delved into the various types of natural disasters resulting from climate change, focusing on case studies in Guangzhou. It conducted a comprehensive analysis of the potential impacts and hazards, dissecting the recovery capabilities of different regions in Guangzhou in terms of economic, social, ecological, and infrastructure aspects. This paper found that the resilience of various districts in Guangzhou was significantly different at different levels. The resilience of economy, society and infrastructure in the central urban area was higher than that in the urban fringe area due to the higher economic level, residents' education level and infrastructure perfection. The paper evaluated the effectiveness of various measures that had been taken to cope with natural disasters and identified the strengths and weaknesses of recovery in different regions. Additionally, it proposed strategies for enhancing the resilience of cities in dealing with disasters, particularly in the areas of social, infrastructure, risk assessment, and ecology, aiming to improve Guangzhou's resilience to natural disasters and provide feasible solutions. And this will improve the overall post-disaster resilience of Guangzhou and help achieve better recovery.

Keywords: Resilience, Natural disaster, Guangzhou.

1. Introduction

In today's world, the complexity of climate change had led to a growing impact of natural disasters on human societies. Understanding and addressing global environmental challenges was crucial through climate change research [1], which helped governments predict the frequency and intensity of extreme weather events, enabling more effective decision-making to minimize their impacts on human societies and ecosystems. Studies had shown that due to a lack of understanding of earthquakes, not only did they result in substantial material losses but also severely disrupted urban infrastructure and social order, with the number of earthquakes increasing annually [2]. Natural disasters also posed a threat to human health, most directly through casualties [3]. In China, an average of approximately 300 million people (occurrences) were affected by various natural disasters each year, with about 300,000 houses collapsing and 8 million people being temporarily relocated, a

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massive figure. Moreover, after natural disasters, disaster victims often experienced a decline in resistance due to environmental degradation, water pollution, scarcity of drinking water and food, and psychological trauma, leading to the outbreak of infectious diseases that significantly affected public health [4].

The concept of resilience, derived from the Latin term resilio, which means the action of jumping back, had been introduced into the field of ecology by Holling , treating it as the capacity of an ecosystem to remain unchanged while enduring alterations in quantity.[5]. Currently, it is a focal point in multiple disciplines including climate change, disasters, and more. In the study of resilience, Folk [6] had reviewed resilience as a valuable topic in a lot of academic areas, and it was a beneficial characteristic for both natural systems and humans, promoting sustainable development, and thus, it was worth in-depth study. The resilience of cities in dealing with disasters referred to their ability to effectively recover to their pre-disaster state or even higher levels after suffering from natural or human-induced disasters. This resilience encompassed not only the reconstruction of physical infrastructure, such as repairing roads, bridges, and buildings, but also involved comprehensive recovery in social, economic, and environmental aspects. This highlighted the need for the government to develop cross-sectoral recovery strategies, coordinating efforts across various domains [7]. Resilience manifested in multiple dimensions: firstly, the establishment of a rapid response mechanism to ensure swift organization of rescue and recovery efforts after disasters; secondly, the enhancement of community resilience, emphasizing the importance of disaster resilience in community response [8], which could help implement measures to reduce the impact of disasters on the community; thirdly, support from policies and urban planning, requiring the government to formulate scientific and reasonable post-disaster recovery plans to ensure the effective allocation of resources. In addition, restoration also included the restoration of the ecological environment. The second IHDP Update in 2003 had described the importance of ecosystem restoration in resource utilization, risk response, reducing vulnerability, and improving the integrity of future ecosystems [9].

Guangzhou, located in the southern part of China, was characterized by a subtropical monsoon climate with warm and humid conditions, distinct seasons, and abundant rainfall. Due to its diverse natural climate, Guangzhou frequently encountered various natural disasters. This paper would analyze the situation based on Guangzhou's disaster occurrences, evaluating the city's capability to cope with natural disasters.

2. Analysis of disaster situation in Guangzhou

Guangzhou, one of China's four major cities, played a significant role in the economy, driving the development of surrounding cities. Moreover, Guangzhou had boasted a well-developed transportation network, including Guangzhou Baiyun International Airport and Guangzhou South Railway Station, establishing it as a key aviation and railway transportation hub in southern China, contributing significantly to economic development. The types of disasters that Guangzhou frequently encountered included typhoons and geological disasters.

(1) During the summer months, Guangzhou was often affected by tropical cyclones and typhoons, leading to heavy rainfall, strong winds, and tsunamis. During the typhoon season, strong rainfall and winds caused floods, landslides, and road disruptions, significantly impacting daily life and property. Additionally, flooding disasters were common in Guangzhou due to its low-lying terrain and inadequate drainage systems, leading to frequent urban flooding and waterlogging in low-lying areas, causing inconvenience and losses in urban traffic and daily life. Furthermore, given its location near the Pearl River Delta, Guangzhou was prone to heavy rainfall, especially during the rainy season (typically from May to September), which could lead to floods, particularly in low-lying areas and river banks. Many roads were submerged, houses were destroyed, and people's homes were severely damaged. In many severe areas, the safety of people's lives was also threatened. Furthermore,

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Guangzhou was located along the coast of the South China Sea, frequently affected by typhoons. The strong winds brought by typhoons resulted in severe wind disasters, affecting transportation and infrastructure. The strong winds caused many billboards and plants to be blown over, resulting in significant damage to public facilities and impacting daily life. At the same time, typhoon disasters triggered heavy rainfall, especially in the summer, leading to urban flooding, traffic paralysis, and crop damage. Heavy rainfall caused some roads to be flooded, causing traffic congestion, making it difficult for vehicles to travel and affecting citizens' mobility. Heavy rainfall also caused the closure of shops and markets, affecting commercial activities and causing economic losses. At the same time, it caused agricultural losses: heavy rainfall led to flooded fields, affecting the growth and harvest of crops. Additionally, in the hilly areas, heavy rainfall often led to frequent geological disasters such as landslides and mudslides, posing a threat to the safety of residents and buildings.

(2) As a major city in southern China, Guangzhou faced various geological risks due to its complex geological conditions. Firstly, earthquakes, with Guangzhou located on the Pacific Ring of Fire, although with relatively low seismic activity, earthquakes still posed a risk. Historical records of earthquakes in Guangzhou indicated that these earthquakes could cause damage to buildings and infrastructure. Secondly, landslides and rock falls were frequent in the hilly areas of Guangzhou due to uneven geological structures and high rainfall, leading to landslides that could damage roads, farmland, and buildings, affecting residents' lives and production. In summary, these geological disasters had a significant impact on the lives of Guangzhou's people, even threatening their safety.

3. Resilience evaluation in Guangzhou

This paper analyzed and evaluated Guangzhou's resilience across four dimensions: economy, ecology, infrastructure, and society, based on the city's overall characteristics. Each dimension was assessed using specific indicators, and the overall resilience of Guangzhou was derived from these evaluations.

(1) Economic Evaluation: By examining Guangzhou's attributes over the past decade, this paper utilized the average annual comprehensive energy consumption as an indicator of economic stability. It gauged the richness of economic resources through per capita GDP, disaster prevention investment, and economic density over the past decade. The annual average value added of the tertiary industry was also considered to measure economic resilience. Through weighted calculations, the economic recovery index for each district was determined. Liu's research revealed significant spatial disparities: central areas > peripheral areas. Districts such as Tianhe, Huangpu, and Yuexiu showed higher economic recovery visibility, whereas districts like Chaohu and Zengcheng exhibited weaker economic recovery [10].

(2) Ecological Recovery Evaluation: This section analyzed the quality of Guangzhou's urban characteristics and its resilience against various disasters, including flood, meteorological, earthquake, and geological events. The paper assessed ecological resilience and carrying capacity using the combined comprehensive air quality index. The urban built-up area's ecological source area and green coverage rate were indicators for measuring ecological elasticity. Liu's research indicated that the overall ecological resilience of Guangzhou's districts was moderate, with districts in the southern and central areas (Baiyun, Zengcheng) and the eastern part of Chaozhou (Dongcha) performing relatively better. Ecological resilience was negatively correlated with proximity to the city center.

(3) Infrastructure Recovery Evaluation: After scrutinizing the distribution and current status of Guangzhou's infrastructure, the paper measured infrastructure resistance using the average daily water usage per person. The number of 5G base station facilities, the distribution of emergency shelters, and the distribution of medical institutions were used to gauge infrastructure adaptability. The total length of urban roads, the amount of demolished illegal construction buildings, and the number of large hospital beds were indicators for post-disaster infrastructure resilience. Liu's research showed significant regional differences in infrastructure recovery capabilities, generally at a moderate

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level, with districts like Baiyun, Huangpu, and Panyu demonstrating high recovery levels, while districts like Liwan and Haizhu showed low recovery levels [10].

(4) Social Recovery Evaluation: Focusing on Guangzhou, the paper analyzed the city's average annual population density (indicative of social resistance decline), urbanization rate, and structural characteristics to conduct a vulnerability analysis of vulnerable groups. It evaluated the adaptability of society and resource storage capacity using the past decade's average social security level and public safety investment. The annual average natural population growth rate and the number of college students over the past decade were used to measure social resilience. The paper's weighted calculations resulted in the social recovery index for each district. Liu's research indicated that social recovery capabilities tended to cluster around the city center, with districts like Tianhe, Yuexiu, Liwan, and Haizhu showing significantly higher social recovery capabilities, while peripheral areas exhibited lower levels [10]. Most districts had a moderate level of social recovery capability.

4. Strategies to improve the resilience of Guangzhou to cope with disasters

Based on the analysis presented in this paper, there are three primary approaches that can assist cities in augmenting their resilience against natural disasters:

(1) Undertaking risk evaluations and preemptive planning. Cities must conduct thorough natural disaster risk assessments to enable governmental decision-makers to predict potential disasters, pinpoint vulnerable areas and facilities, and gauge the potential extent of damage. This includes risks from floods (both coastal and flash), earthquakes, and even typhoons. The outcomes of these disaster assessments can serve as the bedrock for the government to formulate more comprehensive disaster preparedness strategies, encompassing measures such as fortifying infrastructure, enhancing public safety education, establishing emergency shelters at strategic intervals along transportation networks, stockpiling essential supplies, and improving communication networks to ensure the successful execution of rescue operations.

(2) Investing in infrastructure development and technological advancements. The sophistication of a city's infrastructure is the bedrock of its disaster resistance. Cities should allocate resources to strengthen infrastructure, including improving the seismic resilience of buildings, reinforcing water supply and drainage systems, and enhancing the power grid for reliability. Additionally, leveraging modern technology to augment disaster response capabilities: for instance, employing remote sensing technology for real-time monitoring of disaster occurrences, providing accurate geographic information, enabling rapid identification of affected areas. Utilizing big data analysis to amalgamate historical data with real-time information to forecast disaster trends and efficiently allocate resources. Crucially, the implementation of artificial intelligence, which can offer swift decision support in disaster response, automatically pinpoint damaged areas, and predict the movement of victims.

(3) Elevating community engagement. Communities are the first line of defense for cities confronting natural disasters, and bolstering community resilience is pivotal to enhancing disaster resilience. Firstly, education and training are indispensable. Regular disaster response knowledge instruction for local residents can enhance their self-rescue capabilities and mutual aid capacities. It is also crucial to encourage public participation in the creation and implementation of disaster response plans, fostering community awareness to expedite community response times.

Implementing these strategies in cities not only significantly reduces the direct losses incurred by natural disasters but also ensures the smooth functioning of disaster-impacted organizations, guarantees the safety and basic living security of residents, and promotes sustainable urban development.

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5. Conclusion

To evaluate Guangzhou's resilience to natural disasters, this paper analyzed the types of natural disasters that Guangzhou frequently encountered, including geological disasters and typhoons, and delved into their impacts on society and the ecosystem. At the same time, the paper evaluated the recovery capabilities of different regions in Guangzhou in terms of natural disasters, using various indicators to analyze the resilience of disaster recovery in different regions. The paper thus provided an overall assessment of Guangzhou's resilience to natural disasters. From the economic point of view, the resilience of the central area of Guangzhou was greater than that of the marginal area; From the ecological perspective, the ecological resilience of each district in Guangzhou was negatively correlated with the proximity of the city center. From the perspective of infrastructure, the overall infrastructure resilience of all districts in Guangzhou is at a medium level, and Baiyun, Huangpu and Panyu districts were relatively high. From a social point of view, the social resilience of central urban areas slightly exceeded the resilience of remote areas.

Furthermore, the paper proposed strategies for enhancing the resilience of cities in dealing with disasters, particularly in the areas of social, infrastructure, economics, and ecology, aiming to improve Guangzhou's resilience to natural disasters and provide feasible solutions. The first action was to conduct risk assessment and planning, providing early warning for potential natural disasters, and making preparations in terms of materials and facilities. Evacuation and recovery plans were also planned. Secondly, cities worked on strengthening the development and upgrading of infrastructure, aiming to improve reliability and also utilizing modern technology, data analysis, decision support, and thinking assistance. Finally, Guangzhou increased the community's participation in preventing natural disasters. Pre-disaster education was implemented, allowing people to enhance their self-rescue abilities and mutual awareness, thus better preparing them to face disasters when they occurred.

Due to the lack of specific meteorological data and internal planning schemes from the government, the paper could not provide a precise assessment of the disasters Guangzhou had experienced or fully evaluate the effectiveness of the government's measures against natural disasters.Future research was hoped to focus on the integration of smart cities and disaster resistance, developing a reliable and intelligent scheme to cope with the variability of natural disasters. Additionally, future research was expected to further analyze the patterns and causes of natural disasters, more accurately predict them, and provide a better disaster response plan, transforming Guangzhou into a sustainable city. The aim of this paper was to provide an analysis of potential natural disasters that coastal cities like Guangzhou might face, as well as corresponding strategies to enhance their resilience. Through the analysis of different regional resilience, a plan was provided to improve the resilience of cities in dealing with natural disasters.

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Forecasting China's Monetary Over-Issuance After the Pandemic Based on ARIMA Model and Exponential Smoothing Model

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Abstract: The excessive issuance of a country's currency will lead to the decline of the purchasing power of the currency and the rise of prices, which will lead to the reduction of the living standard of the people and the widening of the gap between the rich and the poor. In order to ensure the economic growth rate after the epidemic, most countries choose to issue more currency, and China's currency issue is particularly serious. This paper aims to predict the Monetary Over-issuance (MOI) in China after the epidemic by means of time series analysis. In this experiment, some basic time series model prediction methods such as ARIMA model and exponential smoothing model were used to predict the MOI situation in China in the post-epidemic era, aiming to explore the impact of the epidemic on China's MOI. The forecast results show that the Chinese government's stimulus actions for economic phenomena such as the decrease of GDP growth caused by the epidemic have increased China's MOI, and compared with before the epidemic, China's MOI will still maintain a steady growth in the future.

Keywords: Monetary Over-issuance, Time Series, Auto ARIMA Model, Exponential Smoothing Model.

1. Introduction

1.1. Research Background and Significance

Whether China is in the midst of currency over development has always been a hot topic in academic circles. Since the subprime crisis in 2008, China's M2 growth rate has continued to rise at a high growth rate. If the traditional judgment method is used, there is no doubt that China is in a state of currency oversupply for a long time. But some Chinese scholars have other ideas.

Among them, two views have a higher audience. The first is the Chinese economist Wen Bin proposed that the excess of money and inflation rate is related, China's CPI growth rate continues to be less than 2%, indicating that China's current inflation rate is relatively low, and there is no excess of money [1]. The other, put forward by Ximiao Dong, chief researcher at China Merchants Bank, is that unlike other countries, China's money supply is mainly affected by commercial bank credit, rather than cash injection by the central bank. Thus, there is no currency overshoot in China [1].

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Although the traditional method of judging the excess of money has been questioned, it has to be admitted that China's M2 growth rate has been growing at an alarming rate since the subprime crisis in 2008, and for the country, too fast M2 growth is not a good thing. As a developing country, the government often needs to consider more about the trade-off between economic growth and inflation. Excessive currency over-issuance may lead to high inflation or even economic crisis. Based on this, the prediction of China's currency over-issuance can determine whether the government's economic stimulus to the epidemic is reasonable, and if China's MOI after economic stimulus is significantly different from that before the epidemic, how the government should make countermeasures according to the two different economic structures.

Therefore, the subsequent prediction of MOI in this paper is still based on the traditional view, that is, the recognition that China is currently in a state of monetary over-issuance.

1.2. Literature Review

This paper aims to predict the situation of currency over-issuance in China after the epidemic. Recent studies and some on monetary excess have revealed the relationship between national monetary policy and inflation. Many scholars have realized that the epidemic is highly likely to have a correlation with China's currency over-issuance. For example, Chinese scholar Cui Baisheng et al. predicted and warned China's MOI in the post-epidemic era by studying the American economy [2]. However, these studies have not separated from the binary relationship between MOI and CPI. In fact, due to the differences between China and the United States in economic system and national financial control policies, China's MOI and CPI seem to have almost no correlation [3]. Therefore, this paper starts from the Chinese MOI itself and predicts it according to the historical data of MOI, which can reduce the importance of CPI in experiments in previous studies by scholars, which will help deepen the understanding of MOI itself [4-6].

2. Methodology

2.1. Data Source and Interpretation

MOI needs to be calculated by M2 data and GDP data. All the data in this experiment were selected from the data of the National Bureau of Statistics of China (https://data.stats.gov.cn). Due to the complexity of GDP growth statistics, there is no monthly GDP growth data available, in order to obtain more data sets to improve the accuracy of the forecast, the data of M2 and GDP will be used as quarterly data instead of one year.

The MOI growth rate is equal to the ratio of the M2 growth rate to the nominal GDP growth rate. Plugging the acquired data into this formula can be used to plot Figure 1.

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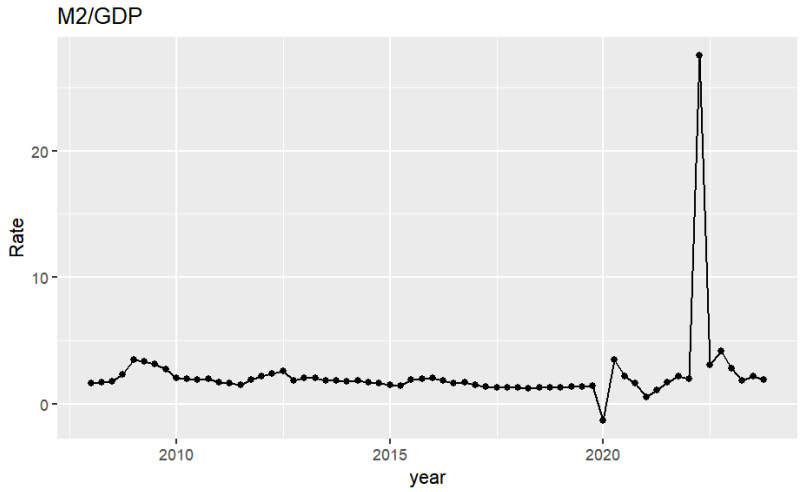

Figure 1: M2/GDP (MOI Growth rate).

This time series covers the period from 2008 to the first quarter of 2008. Several fluctuations in the figure have corresponding historical events, such as the subprime mortgage crisis in 2008, the epidemic in 2020 and the government's regulation behavior after the epidemic. Excluding the outliers for these particular time periods, the MOI for the rest of the time appears to be very stable.

2.2. Model Selection and Establishment

2.2.1. Auto ARIMA Model

ARIMA model is called auto regressive moving average model, which regards the data series formed by the prediction object over time as a random sequence. The advantage of ARIMA model is that it can consider the influence of historical data, especially for the series with more historical data and a long time line, the prediction has a high accuracy.

The ARMA model is a simple combination of Auto Regression Model (AR) and Moving Average Model (MA), containing both historical value terms and error terms. Since AR model has the stationarity requirement for time series, and ARMA model also has this limitation, the author extend it to ARIMA model and introduce the difference concept as a method to obtain time series. One of the most commonly used difference methods is to calculate the difference between the current term and the previous term to obtain a new set of time series. The mathematical formula is as follows. In the actual analysis process, the ARIMA model is usually used, because AR, MA, ARMA are a special case of it. ARIMA has three parameters p, d and q, written as ARIMA (p,d,q), where p stands for AR(p), auto regressive order, d stands for Integrated (d), difference order, q stands for MA(q), moving average order. The operation should ensure that these three parameters as small as possible to avoid overfitting, a criterion for parameters is, do not let d exceed 2, p and q exceed 5, and p and q try to ensure that one is the dominant term of the model and the other is relatively small [7,8].

While the time series of MOI data covers a period of more than ten years, the ARIMA model has a finer processing of the details of such series.

As mentioned above, the MOI growth rate data during the epidemic period are relatively extreme, so before the difference, the author removes these extreme values and performs first-order difference for the sake of stationary and universality.

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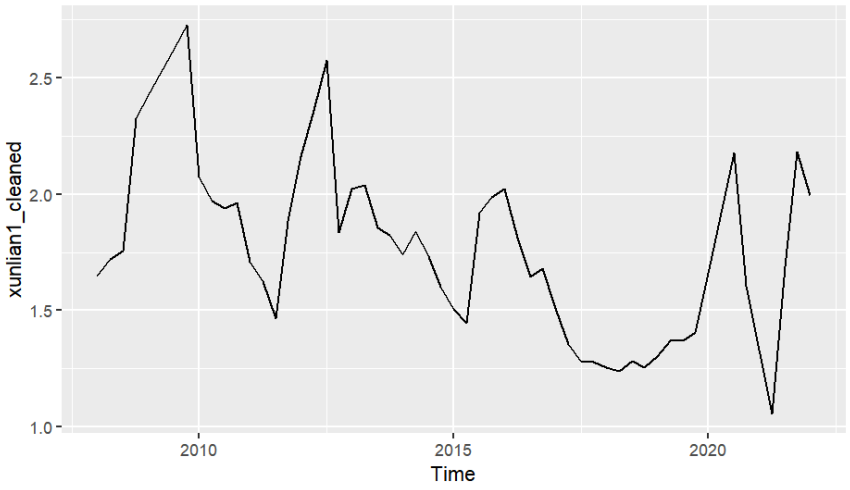

Figure 2: Difference plot with extreme values removed.

It can be seen that the time series in the Figure 2 is relatively stable. The author conducted stationary test and Lygung-Box test for this time series. The time series did pass the stationary test, but surprisingly the differential time series did not pass the Lygung-Box test, meaning that the differential image was an unpredictable white noise sequence. So, the deleted points were restored, and rerunning the stationary test and the Lygung-Box test. The plot is shown as Figure 3.

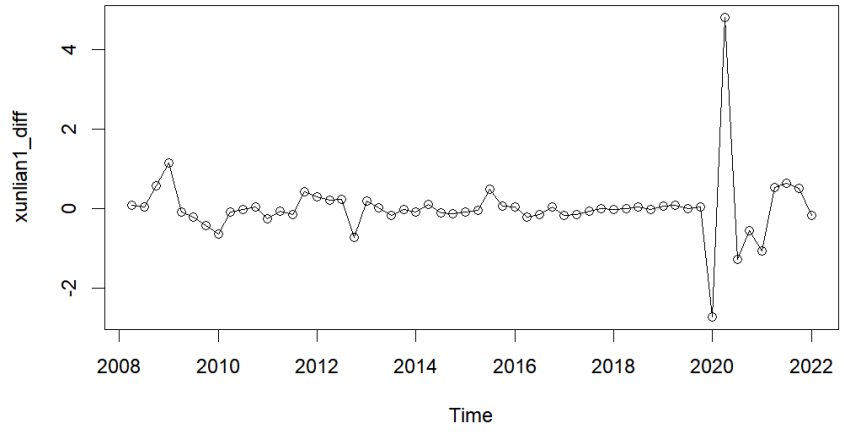

Figure 3: The difference graph retains the initial data.

It can be seen from the test results that the time series after difference can pass the stationary test and white noise test after the outlier recovery. After the parameters are given by Auto ARIMA model, the Figure 4 shows the forecasting result.

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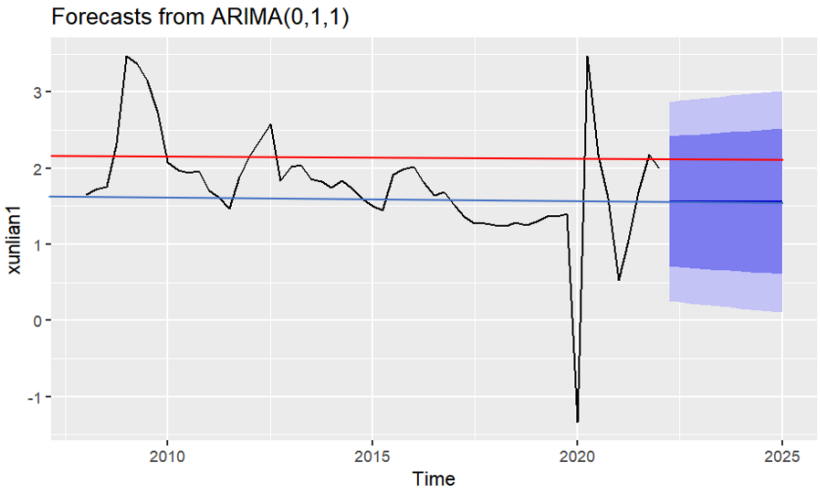

Figure 4: Auto ARIMA Model.

The accuracy of prediction was verified by the images. The blue line of Figure 4 is the ARIMA model's prediction of the future growth rate of MOI, with an average value of about 1.56, and the red line is the true value retained in the test set, with a value of about 2.1. The red line of Figure 4 is within the 95% confidence interval of the prediction, indicating that the prediction is valid.

Despite the success in building a predictive model for MOI, something is till confusing: why can a training set with outliers be able to successfully build a predictive model, but an image with a difference is displayed as a white noise sequence when outliers are removed? After reviewing the test process, the author put forward the idea: It is not difficult to find from the growth rate image of MOI that if the impact of special historical events (such as subprime crisis, currency crisis and epidemic, etc.) is removed, the growth rate of MOI appears to be very stable, which actually conforms to the law of macroeconomics, that is, if there is no abnormal situation, the growth rate of GDP, currency and other macro indexes will be quite stable. The growth rate of MOI, calculated by GDP and M2 growth, should also be stable [9]. Allowing a certain amount of error, when M2 and GDP growth rates are close to each other, MOI growth rate will approach a fixed average, and its trend cannot be judged by the model in the short term, but in the long run, MOI growth rate will remain stable or even parallel to the X-axis. For a country, too fast growth of MOI is not a good thing, China is still in a period of rapid economic development, even if the government does not reduce the growth rate of MOI in order to ensure GDP growth, it will not be allowed to grow wantonly. However, due to the impact of the epidemic, the GDP growth rate plummeted. In order to ensure the GDP growth rate, the government must stimulate the economy, which is shown in the figure, the growth rate of MOI rose sharply after reaching the trough, and the increase was unprecedented. The author believes that this stimulus behavior changes the growth rate of MOI from a stable series to a series with an upward trend in the long run, which shows that the mean value of real data is higher than the previous mean value. That's why the addition of these so-called outliers changed the image from a sequence of white noise to predictable.

2.3. Exponential Smoothing Model

To confirm the above view, the authors construct a new MOI growth time series model using four exponential smoothing models using the same data set. The exponential smoothing model was chosen because it amplifies the impact of events near the timeline on the overall model, and in recent years, there have been events such as epidemics and government stimulus actions. The author will discuss them by category.

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2.3.1. Holt Damped Forecast Method & Simple Exponential Smoothing Forecast Method

By performing exponential smoothing model prediction on the original data, The Figures 5-6 of these two models are followed. It is surprised to find that the prediction results given by the simple exponential smoothing model and the damped Holt model are basically consistent, and the two sets of results are almost consistent with the results given by the ARIMA model, with an error of less than 0.2. This result confirms the conjecture. First of all, ARIMA model and exponential smoothing model give almost the same prediction results, which means that exponential smoothing does not cause large errors in the overall prediction when increasing the influence weight of short-term events. In other words, the epidemic and government stimulus have changed the nature of MOI growth rate in both the long and short term. The growth rate of MOI has increased significantly compared with that before the epidemic, and will remain stable in the future after the increase. Additionally, in general, the forecast result of simple exponential smoothing model should have a far clearer trend than that of damped Holt model, if these two models are similar to each other means that although there is a upward trend in the figures 5-6, it's too gentle to be noticed [10].

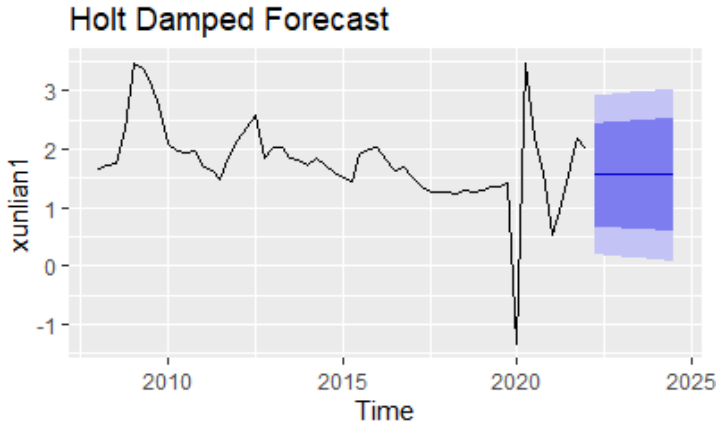

Figure 5: Holt Damped Forecast Method.

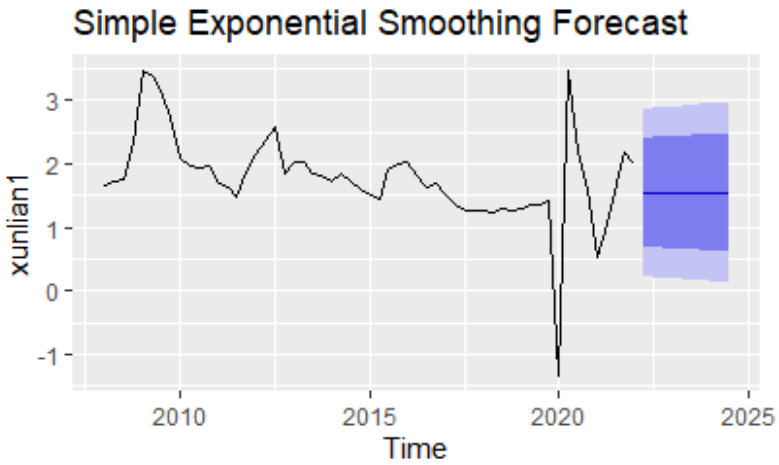

Figure 6: Simple Exponential Smoothing Forecast Method.

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2.3.2. Holt Linear Trend Forecast & Holt-Winters Seasonal Forecast

The Figures 7-8 illustrate the reason why Holt Linear Trend Forecast and Holt-Winters Seasonal Forecast Method are abandoned.

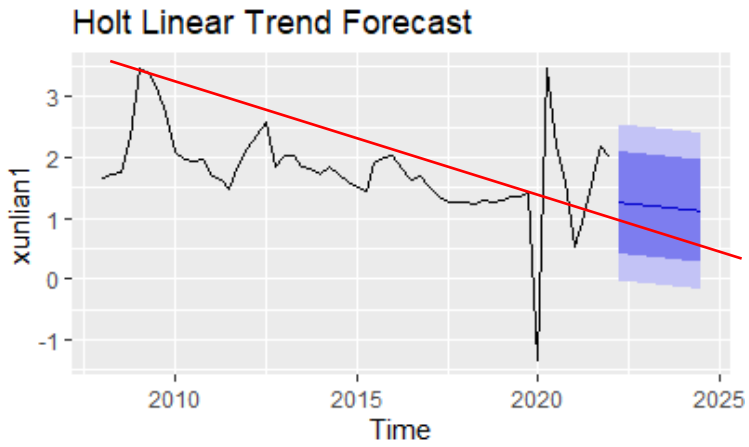

Figure 7: Holt Linear Trend Forecast Method.

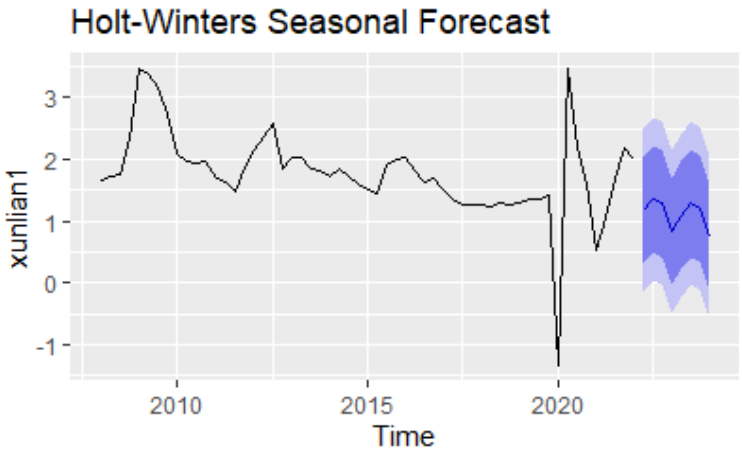

Figure 8: Holt-Winter Seasonal Forecast Method.

Although both time series pictures are stationary, compared to the simple exponential smoothing method and damped Holt method, they have very clear trend. It's against the result author got that the MOI growth rate will increase very gently in the future. The Holt linear trend method take every stimulation behavior of the government into account, and these peaks are accidentally generate a downward trend. By contrast, the Holt winters seasonal method exaggerate the impact of the pandemic and the stimulation, which is shown as frequent fluctuations in the graph, also playing against with the conclusion of the MOI growth rate should be a straight and stationary line.

In addition to the subjective analysis, the numerical data can also support the author's view. As mentioned above, the mean of the training set is about 2.1, and this line is only within the 80% confidence interval of the prediction in the two exponentially smoothing models below. It can be seen that the prediction accuracy of these two smoothing models is much lower than that of the simple smoothing model and the damped Holt model.

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3. Conclusion

To sum up, the models and data show that the epidemic and the government's stimulus behavior have a great impact on the growth rate of MOI, and the growth rate of MOI will maintain a very low growth rate and steady growth in the future after a short-term surge. Although China's CPI growth rate continues to be below 2%, and there is still a long way to go from high inflation, the Chinese government should control M2 growth to avoid unknown risks. This article focuses on MOI itself and makes predictions about it.

In terms of data selection, the sample interval in this article is relatively insufficient due to the availability of data. Meanwhile, only the ARIMA model was used in the research methodology. In the future, with the availability of data resources, the sample size can be increased and research methods can be enriched to deepen the content and richness of this study.

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