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Evaluation on the impact of digital transformation on the economic eco-environmental benefits of enterprises under the background of sustainable development

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Abstract: Digital transformation (DT), as a key driving force for enterprise innovation and development, has been widely applied in various fields such as agriculture, industry, and services. Although DT has achieved significant results in improving operational efficiency, optimising resource allocation, and reducing costs, its potential negative impact on the ecological environment is gradually becoming apparent, especially in terms of increased energy consumption, intensified resource waste, and rising pollutant emissions. This study investigates the economic and ecological impacts of DT under a sustainable framework, based on surveys and performance data from agricultural, industrial, and service enterprises. Results show improved revenue and reduced costs across sectors, with agricultural firms reporting a 13.87% revenue increase and 5.69% cost reduction in the third quarter, and industrial firms showing an 8.73% revenue increase and 5.89% cost reduction in the fourth quarter. Service firms demonstrated slower yet positive changes. However, 96.13% of employees perceived negative environmental consequences, particularly in air pollution, water shortages, and reduced forest coverage. Findings indicate that while DT enhances economic performance, it imposes environmental pressures. Aligning digital strategies with ecological goals is essential for achieving sustainable enterprise development.

Keywords: sustainable development; digital transformation; enterprise economic benefit; enterprise ecological environmental benefits.

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1 Introduction

With the awakening of human awareness of ecological civilisation and environmental construction, the concept of sustainable development has been deeply embedded in human hearts. In the past, due to people's negligence of the environment, the ecological environment deteriorated. Today, mankind has chosen the sustainable development model, which takes into account both social and economic development and ecological environment protection. The social digital economy is developing with the sustainable development model. The development of scientific and technological strength has promoted the sustainable growth of the economy, which has formed a new era with the sustainable development of ecological and environmental protection as the background and the digital economy as the way forward. In such an environment, enterprises carry out DT to achieve innovation and upgrading.

Although digital transformation (DT) has brought significant advantages in efficiency improvement and cost reduction to enterprises, its potential negative impact on the ecological environment is gradually becoming apparent. Although agricultural, industrial, and service industry enterprises have achieved income growth and cost reduction after DT, this process has exacerbated issues such as air pollution, water scarcity, and declining forest coverage. The contradiction between economic and ecological benefits has become a major research issue facing current enterprises. How to effectively balance economic growth and environmental protection while promoting DT and achieving sustainable development goals has become a core issue that urgently needs to be addressed in both academic and practical fields. This article aims to evaluate the dual impact of DT on the economic and ecological benefits of enterprises, and propose feasible suggestions that balance digital strategy and ecological goals, providing theoretical support and practical guidance for the sustainable development of enterprises.

This paper analysed the economic, ecological, and environmental benefits of enterprises and sorted out the problems caused by the DT to the ecological environment. This paper also sorted out the difficulties that enterprises would face in realising DT, and put forward suggestions for enterprises to realise DT without violating the concept of sustainable development. In order to reflect the impact of DT on the economic,

ecological, and environmental benefits of enterprises, this paper conducted a questionnaire survey. The survey results showed that 96.13% of the 2,000 employees who participated in the survey said that the DT harmed the enterprise's ecological and environmental benefits. Only 3.87% of employees believed that there was no impact or that the impact was small, and the proportion were relatively small. It fully demonstrated that DT harmed the ecological and environmental benefits of enterprises, and was not conducive to promoting the concept of sustainable development. Therefore, based on the negative impact of DT on the ecological environment benefits of enterprises, this paper provided corresponding strategies for the sustainable development of enterprises, and hoped to provide inspiration for the sustainable development of the enterprise ecological environment. The innovation of this article lies in incorporating the economic and ecological environmental effects of DT into a unified analysis framework, breaking through the limitations of previous studies that focused on a single dimension, and revealing the mechanism of DT's dual benefits on the enterprise economy and ecological environment. In terms of research methods, this article combines enterprise performance data analysis with employee subjective perception surveys to construct a comprehensive evaluation model of 'quantitative+qualitative', enhancing the scientific and practical guidance of research conclusions.

The research contribution of this article includes:

- 1 Systematically evaluating the impact of DT on the economic and ecological benefits of enterprises in the context of sustainable development, revealing the environmental pressure brought by DT while improving economic benefits, and providing theoretical support and practical guidance for enterprises to achieve green transformation.
- 2 By quantitatively analysing the performance data of three agricultural, industrial, and service enterprises that have completed DT, based on research findings, this article proposes four feasible suggestions: changing the pursuit of economic hegemony, strengthening environmental awareness, promoting ecological technology, and enhancing economic soft power, providing reference for enterprises to build a sustainable development path that balances digital strategy and ecological goals.
- 3 Integrating the economic and ecological effects of DT into a unified framework for systematic evaluation, and proposing that enterprises should formulate corresponding transformation strategies based on industry characteristics at different stages of development, enriches the theoretical system of sustainable development in the context of the digital economy.

2 Related works

In recent years, the changes in the economic and ecological environment of enterprises with sustainable development have attracted the attention of many scholars. With the continuous deepening of the concept of sustainable development, DT has become an important means to promote the improvement of the economic and ecological benefits of enterprises. However, in this process, the potential negative impact of DT on the ecological environment has gradually emerged, attracting widespread attention from both academia and industry (Brychko et al., 2023; Filipishyna et al., 2020). Current research

mainly focuses on how DT can enhance the economic efficiency of enterprises through technological innovation and business model transformation, and attempts to quantify its actual effectiveness in different industries. Tomislav Klarin said that the concept of sustainable development has gone through different stages of development since it was put forward. The historical development of this concept witnessed the participation of various organisations, which were currently actively engaged in its implementation (Tomislav, 2018). Thacker Scott found that global infrastructure investment was at the highest level in history. Therefore, the number of decisions made now was increasing, and these decisions would lock in the development model of future generations. Although these investments were largely driven by the desire to improve economic productivity and employment, infrastructure directly or indirectly affected the achievement of all sustainable development goals (Thacker, 2019). Polasky (2019) believed that global environmental change had a potentially huge negative impact on future human well-being, and raised the question of whether global civilisation was on the path of sustainable development or was 'consuming too much' by depleting important natural capital. Ebert and Duarte (2018) discussed how DT affected software technology and the software industry. Mihardjo (2019) believed that there was a huge market opportunity in digital capability innovation. Demirel Pelin believed that with the concept of circular economy becoming more and more popular among consumers and producers, small and medium-sized enterprises were increasingly seeking ways to restructure their products and operations to integrate into the circular economy (Demirel and Danisman, 2019). Dey (2020) studied circular economy to promote small and medium-sized enterprises to achieve greater sustainability. Shao (2020) found that the impact of environmental regulations on enterprise innovation was closely related to the competitiveness of enterprises and the sustainable development of the regional economy. With the continuous development of science and technology and society, the requirements of society on the economic and ecological environment of enterprises are also becoming higher and higher. In the past, there were still some limitations in the actual operation of the research and in-depth exploration of the benefits and changes of the enterprise's ecological environment. Most studies focus on the path of improving the economic benefits of enterprises, such as optimising resource allocation and improving production efficiency, while ignoring the ecological costs that may arise during the DT process, making it difficult to reflect the dynamic changes and long-term impacts of enterprises during the transformation process.

The rapid development of the digital era has brought great benefits to the enterprise economy and also affected the construction of the ecological environment. The economy needs development and progress, and the protection of the ecological environment cannot be left behind (Skrynkovskyy et al., 2022; Yin et al., 2024). Otherwise, it would violate the concept of sustainable development that has been respected by society. The impact of DT on the economic, ecological, and environmental benefits of enterprises has also been studied by many scholars. Berawi (2019) believed that the goal of sustainable development was to eradicate poverty and improve health and education, which also promoted prosperity and well-being through environmental sustainability. Wall (2018) said that although sustainable development was a widely accepted paradigm and was reflected in legislation from global to local levels, implementation was still a challenge. Xu (2020) believed that the quantitative realisation of the progress of the sustainable development goals was crucial for tracking global sustainable development efforts and guiding policy formulation and implementation. Liu Jianguo believed that the application

and implementation of the correlation method were still in their infancy. There was no research on the contribution of quantitative contact methods to the achievement of sustainable development goals (Liu, 2018). Furjan et al. (2020) believed that the complexity of the DT paradigm and its relationship with the fourth technological revolution made enterprises face serious challenges when they kept up with competition or became leaders in the operation industry. Nadkarni Swen said that in the past few years, the attention of academia increased steadily, which led to a significant increase in the number of papers on different technologies and organisations involved in DT (Nadkarni and Prugl, 2021). Loonam (2018) believed that digital organisations were supported by new information and communication technologies (called digital technologies), which were increasingly expected to bring huge growth opportunities. Van Veldhoven Ziboud believed that DT was a term used to talk about various changes in business and society caused by the increased use of digital technology (Van Veldhoven and Vanthienen, 2022). Under the conceptual framework of DT, Kotarba (2018) introduced the scope of changes in the business model of contemporary organisations in recent decades due to large-scale technological development. It could be seen that DT had a profound impact on enterprises. Regardless of its advantages and disadvantages, it should adhere to the concept of sustainable development and make contributions to the realisation of social, economic, and ecological win-win. The current mainstream models for evaluating the ecological and environmental benefits of enterprises are mostly designed based on traditional manufacturing or heavy industry backgrounds, and have poor applicability to emerging formats such as service industries and digital economy platform enterprises.

3 Evaluation of enterprise economic ecological environment in the context of sustainable development

3.1 Overview of sustainable development

3.1.1 Concept of sustainable development

Sustainable development is a very complex and broad-based concept, which means ‘meeting the needs of contemporary people without compromising the ability of future generations to meet their own needs’ (Verma, 2019). In other words, society, economy, environment, and resources are the whole. In order to protect the whole, the connection between them cannot be cut off, and the whole should be formed into a circular closed loop. Therefore, while promoting social and economic development, attention should be paid to the protection of the environment and the reuse of resources. However, sustainable development is not about protecting environmental resources. Sustainable development emphasises development, which realises social and economic development on the premise of protecting the environment and saving resources. The theory of sustainable development emphasises the coordinated development between society, economy, and environment, advocating for meeting current needs without compromising the ability of future generations to meet their own needs. This theory requires companies to consider their impact on natural resources and the ecological environment while pursuing economic growth. Therefore, this article places the economic and ecological benefits of enterprises within the same evaluation framework, striving to reflect the

core concepts of sustainable development – ‘intergenerational equity’ and ‘human environment coordination’.

3.1.2 *Principles of sustainable development*

Sustainable development generally follows six principles. Among them, the principle of fairness refers to the equality of opportunity choice, which includes three aspects of fairness:

1 Intergenerational equity

It means that both contemporary and future generations are equal in the use of natural resources, so contemporary people should and must leave enough resources for future generations to survive and develop.

2 Horizontal equity

It means that everyone has equal rights to use resources in the face of contemporary society.

3 Human and natural equity

It means that human beings and all living things in nature have equal status. Human beings cannot decide the life and death of other creatures in nature at will because they are advanced creatures. Human beings cannot control other creatures in nature at will. Human beings and all living things in nature enjoy natural resources equally.

The principle of step means that society is constantly developing, and the level of human needs is also constantly improving. Therefore, sustainable development also contains a hidden meaning, which satisfies the principle of stepping from one stage to another.

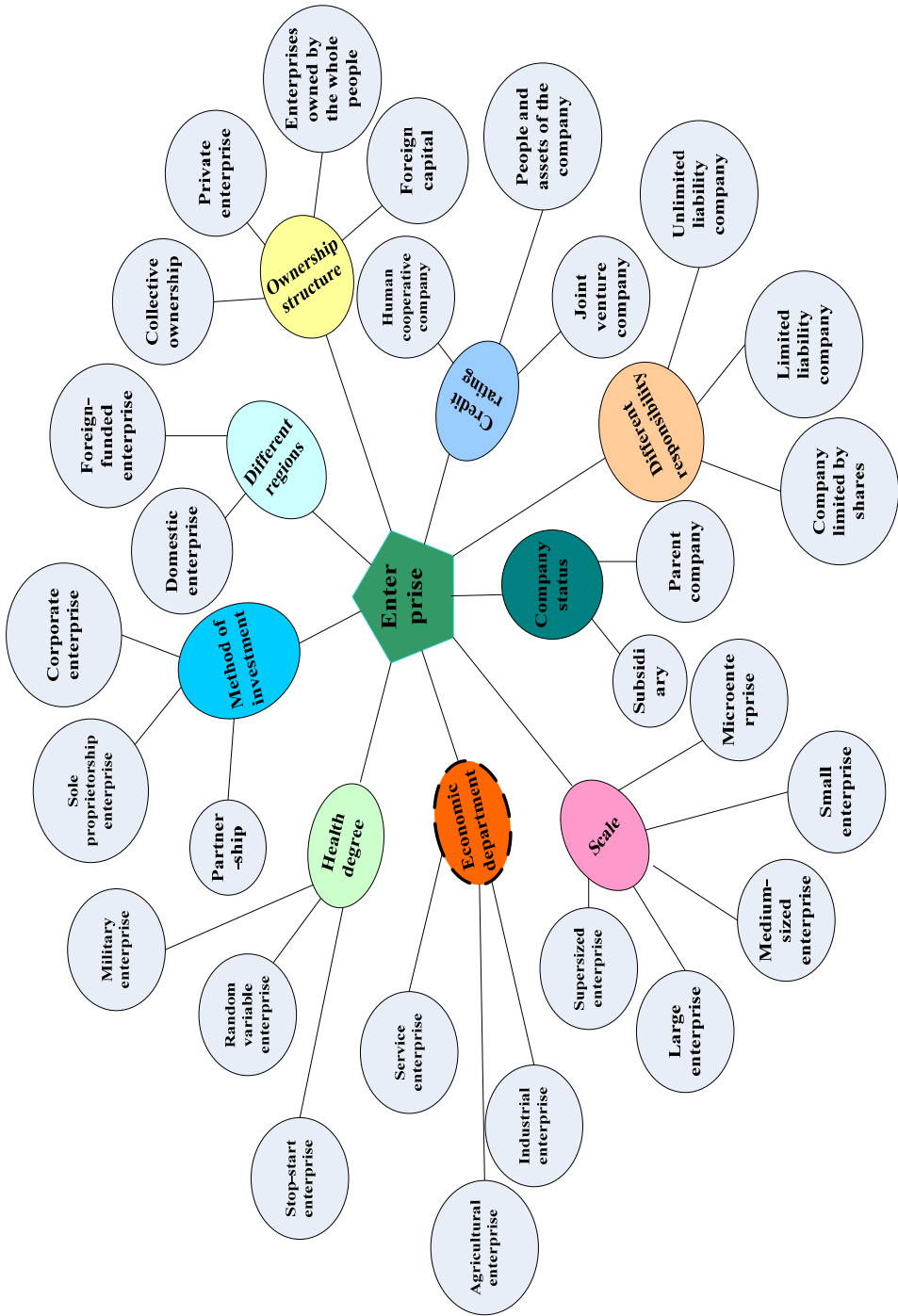
3.2 *Enterprise profile*

Enterprises can be classified according to different conditions, as shown in Figure 1.

From Figure 1, companies can be classified according to investment methods, health degree, economic department, credit ratings, scale, company status, different responsibilities, ownership structures, and different regions. The economic benefit of an enterprise refers to the economic reward feedback obtained by the enterprise through social production, labour, and commodity exchange, which is reflected in the exchange of more economic reward or business results with less labour consumption.

The ecological and environmental benefits of enterprises (Li and Hai, 2023; Klemke-Pitek and Majchrzak, 2022) include the general term of ecological and environmental benefits. Among them, ecological benefits refer to the results of human production activities on the ecosystem and the environment, that is, the benefits brought to the ecological environment by the ecological balance achieved through human efforts. In the enterprise, the ecological balance created by the enterprise through its behaviour for the overall ecological environment of the enterprise is the enterprise ecological benefits; the environmental benefits of enterprises refer to the results that enterprises take certain measures to reduce the environmental pollution formed in the production process of enterprises, and improve the environmental quality from the perspective of environmental protection.

Figure 1 Different classifications of enterprises (see online version for colours)



This article selects the annual emissions of three pollutants, namely exhaust gas, wastewater, and waste residue, as the main evaluation indicators, based on several considerations:

- 1 Strong representativeness: waste gas, wastewater, and waste residue are the three most common types of pollutants in the production process of enterprises, covering almost all the main ways in which industrial activities affect the environment.
- 2 High data availability: compared to some complex ecological indicators, the emission data of exhaust gas, wastewater, and waste residue are usually routine monitoring items in enterprise environmental protection annual reports and local environmental protection bureau statistical reports, which have high authority and continuity, and are easy to obtain and compare.
- 3 Wide applicability: although there are differences in pollution characteristics among different industries, the discharge of exhaust gas, wastewater, and waste residue is universal and suitable for cross-industry comparative analysis of agricultural, industrial, and service enterprises, enhancing the universality of research conclusions.

Generally speaking, the environmental quality QN_{xz} of an enterprise can be calculated according to the average value of the annual emissions of waste gas, waste product, and wastewater. e is the number of enterprises; x is the quantity of pollutants discharged by different enterprises; y represents the type of pollutants discharged by the enterprise; z is the year.

N_{xyz} can be defined as the total value of the y^{th} industrial pollutant emissions of e enterprises in the z^{th} year. The formula is expressed as follows:

$$N_{xyz} = \sum_x^e xe \quad (1)$$

It can be obtained that the average value N_{yz} of the y^{th} industrial pollutant emission of e enterprises in the z^{th} year is as follows:

$$N_{yz} = \sum_x^e N_{yz} / e \quad (2)$$

The average value AN_{xyz} of industrial pollutants of each enterprise, divided by the number of enterprises, is calculated as follows:

$$AN_{xyz} = \frac{N_{xyz}}{N_{yz}} \quad (3)$$

The larger the AN_{xyz} is, the higher the emission of the y^{th} industrial pollutant of enterprise e in the z^{th} year, and it is more serious than other enterprises. The following formula can be calculated:

$$QN_{xz} = \sum_x^k AN_{xyz} \quad (4)$$

Among them, if $k = 3$, the larger QN_{xz} is, the worse the environmental quality of enterprise e is compared with other enterprises.

3.3 Overview of DT

DT (Li et al., 2022; Zhang et al., 2022) is the way to create services and value for consumers through scientific and modern means and communication technology, or it can be considered that DT is the inevitable result of the digital era. With the development of society, enterprises have gradually changed from informatisation to intelligence. The development of various intelligent technologies has brought unprecedented efficiency and convenience to enterprise production. In fact, DT is the process of enterprises transforming from the information technology of the last industrial revolution era to the intelligent technology of this industrial revolution era. Digitalisation has created a new era, which is called the digital era. In the digital era, digital technology is integrated into enterprise products and services, which has changed the way and business results of serving users. DT is not only the transformation within the enterprise, but also the transformation of users. In this process, users' participation is required to enable enterprises to complete the new revolution of DT.

Therefore, it is conceivable that the key to DT is technological innovation (Xie et al., 2023; Zhao et al., 2022, 2025). However, the use of technology is inseparable from human operation, and the introduction of digital talents by enterprises is also one of the keys to the success of DT. How to make good use of digital technology requires a strong connection to digitalisation. The value of human beings is to connect with digitalisation. Therefore, whether it is informatisation, intellectualisation, or digitalisation, technological change cannot be separated from human operation, because human is the centre of social formation. Therefore, in the DT, the people-oriented concept should be adhered to. Digital technology gives human beings convenience in production activities and human beings also give space and value to the development of digital technology. Digital technology is also the result of human innovation. Human beings have endowed digital technology with creativity, wisdom, and the characteristics of connecting with everything. Therefore, in the final analysis, the key to DT can be summarised as people, technology, and digital architecture, and the most important key factor is human. Enterprises are also created by human beings, and enterprises need human beings to realise DT. Digital technology is very important, but human beings are more important.

3.4 Evaluation of enterprises' DT

For enterprises, DT can be realised from three aspects: business model change, information construction, and business model innovation.

1 Change of business model

A business model refers to the logical structure designed by an enterprise to achieve value creation and acquisition, covering nine core elements such as value proposition, customer segmentation, channels, customer relationships, revenue sources, key resources, key activities, key partners, and cost structure. It is the fundamental framework for enterprises to carry out business activities, achieve profitability, and sustainable development. It can be considered to add three more

business segments to the existing business segments, including government project declaration, live broadcast and delivery, and enterprise application software research and development. These three business sectors have their roles. First, the declaration of government projects is to make enterprises and the government reach contact, and establish a foundation for the development of enterprises after formal legal procedures; the second is to follow the trend of modern economic trends and open the route of live broadcast with goods. The purpose of live broadcast is not to sell products, but to promote the enterprise brand; finally, the research and development of its application software is also aimed at creating the exclusive quality of enterprises and brand reputation.

2 Information construction

Information technology construction refers to the process by which enterprises optimise resource allocation, improve management efficiency, and enhance decision-making capabilities by introducing modern information technology. Its goal is to improve the operational efficiency and market responsiveness of enterprises through the integration and optimisation of information flow. The construction of informatisation needs to combine the three business sectors above. To realise DT, modern digital technology must be fully utilised, and enterprises need to add three business segments to be connected with information construction. They are interactive with each other. Therefore, if an enterprise wants to realise DT, it must carry out digital information construction for its business segments, such as adding production systems and business systems.

3 Innovation of business model

The change of business model is the change of enterprise digitalisation, but the digitalisation transformation must be based on the enterprise industry. Therefore, when it comes to the digitalisation of enterprises, it is not possible to study digitalisation alone. Enterprises should be connected to their industries. They should constantly explain how they have changed their industries in the process of DT. Therefore, enterprises should also innovate their business models to realise DT.

Through the research and discussion of three enterprises that have achieved DT (agricultural enterprises, industrial enterprises, and service enterprises), this paper summarises the reasons for the successful realisation of DT in these enterprises:

- 1 Establishing a DT project team.
- 2 Establishing a government project application team.
- 3 Building a brand business application software.
- 4 Realising the construction of an information system.
- 5 Selecting the appropriate target customer group.

4 Investigation on the economic eco-environmental benefits of sustainable development enterprises

4.1 Evaluation of enterprise economic benefits

To explore the impact of DT on the economic benefits of enterprises in the context of sustainable development, this paper took three agricultural enterprises, industrial enterprises, and service enterprises that have achieved DT as the basic dataset. After the implementation of DT, the changes in the economic benefits of enterprises were explored and analysed. In terms of economic benefit evaluation, three core indicators are mainly considered:

- 1 Revenue growth rate: based on the quarterly revenue changes of the enterprise, calculate its growth rate before and after DT.
- 2 Cost reduction rate: by comparing the cost expenditure of enterprises in various stages of DT, measure the cost optimisation brought about by efficiency improvement;
- 3 Trend of profitability changes: analyse the changes in the profit cycle of enterprises under different industry attributes, and identify the impact of DT on long-term operational capabilities.

In terms of ecological environment benefit assessment, this article adopts three evaluation dimensions:

- 1 Monitoring of pollutant emissions: based on the annual emission data of the three main pollutants of enterprise exhaust gas, wastewater, and waste residue, calculate their average emission intensity and establish an environmental quality index QN_{xz} for quantitative analysis.
- 2 Subjective perception survey of employees: design a structured questionnaire to collect employees' perceptions and evaluations of changes in the company's ecological environment, focusing on key ecological issues such as air pollution, water scarcity, and declining forest coverage.
- 3 Identification of obstacles to green transformation: by combining open-ended and closed-ended questions, identify the main challenges faced by enterprises in promoting green digitisation, such as technological bottlenecks, talent shortages, and funding constraints.

The data results were shown in Figure 2, Figure 3, and Figure 4.

4.1.1 Economic benefits of agricultural enterprises

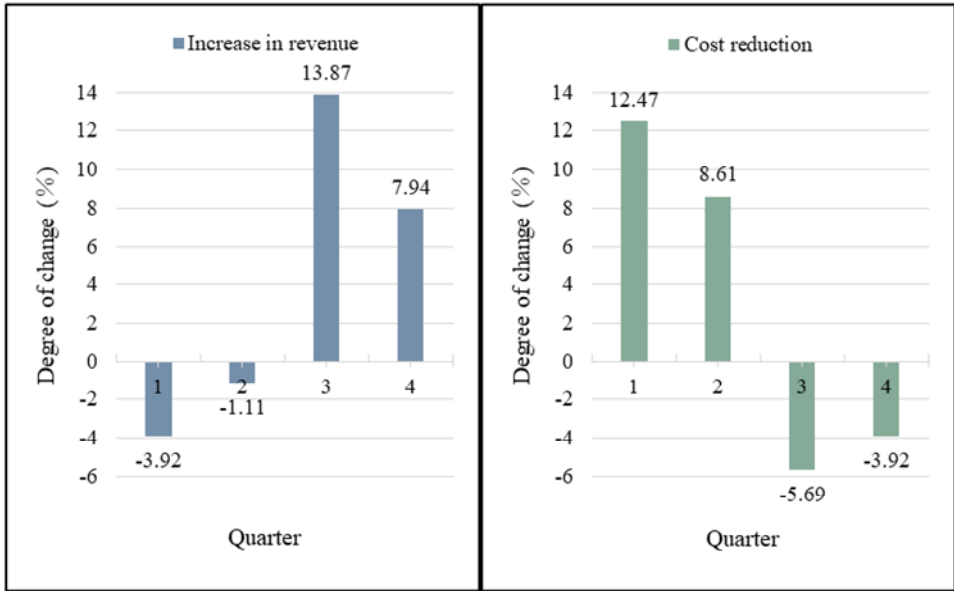
Figure 2(a) shows the revenue changes of agricultural enterprises after DT.

Figure 2(b) shows the cost changes after the DT of agricultural enterprises.

It could be seen from the comparative data in Figure 2 that the agricultural enterprise was in a loss state at the beginning of the DT, that is, in the first quarter. The revenue decreased by 3.92%, but the cost increased by 12.47%, which was due to the large amount of capital investment required in the early stage of DT; the second quarter was still a loss, but the revenue and cost were relatively better than the first quarter; in the

third quarter, autumn was the harvest season for agriculture. The revenue directly increased by 13.87%, while the cost decreased by 5.69%. At this time, the advantages of DT were reflected. In the fourth quarter, it was still profitable, with revenue increasing by 7.94% and costs decreasing by 3.92%. It could be seen that the impact of DT on the economic benefits of agricultural enterprises was obvious, which had substantial help to increase revenue and reduce costs.

Figure 2 Changes in the economic benefits of agricultural enterprises (see online version for colours)



(a)

(b)

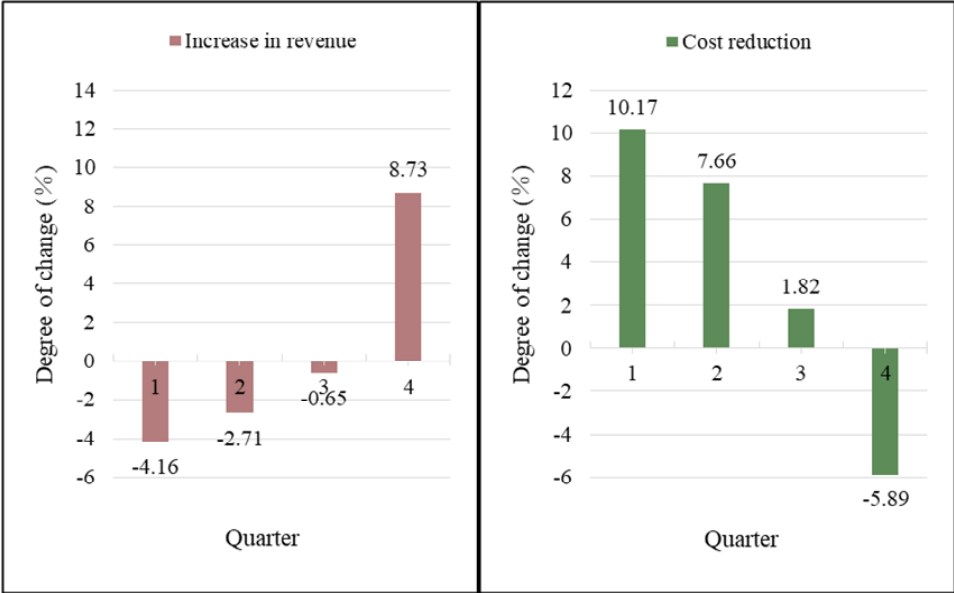
4.1.2 *Economic benefits of industrial enterprises*

Figure 3(a) shows the revenue changes of industrial enterprises after DT.

Figure 3(b) shows the cost changes after the DT of industrial enterprises.

It could be seen from the comparative data in Figure 3 that the DT of the industrial enterprise was successful. Although there were losses in the first three quarters, the economic benefits began to increase in the fourth quarter. DT was a long process. To achieve profitability, enterprises should also be willing to wait. The revenue of the industrial enterprise decreased by 4.16% and 2.71% in the first quarter and the second quarter, respectively; the cost increase was 10.17% and 7.66% respectively; the loss was still relatively large. In the third quarter, the loss decreased. The revenue decreased by 0.65%, and the cost increased by 1.82%; by the fourth quarter, the revenue increased by 8.73% and the cost decreased by 5.89%. The change was obvious. Therefore, for industrial enterprises, DT would also promote economic efficiency.

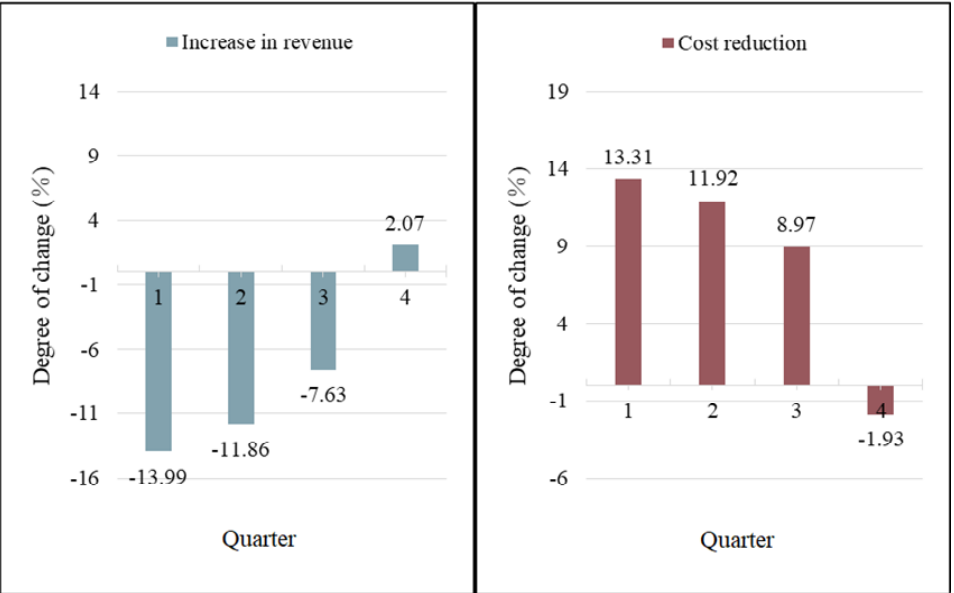
Figure 3 Changes in the economic benefits of industrial enterprises (see online version for colours)



(a)

(b)

Figure 4 Service enterprise economic benefit changes (see online version for colours)



(a)

(b)

4.1.3 *Economic benefits of service enterprises*

Figure 4(a) shows the revenue changes of service enterprises after DT.

Figure 4(b) shows the cost changes after the DT of service enterprises.

From the comparative data in Figure 4, it could be seen that the profit effect of the service enterprise's DT was not obvious. The first three quarters were in serious losses, which was due to the industrial nature of the service industry. To realise the DT of the service industry, it was necessary to invest more costs, mainly in the introduction of intelligent technology. Modern digital intelligence technology was generally expensive, so the economic benefits of the first three quarters were not ideal. However, in the fourth quarter, the revenue increased by 2.07% and the cost decreased by 1.93%, which showed that DT could promote the economic benefits of service enterprises. It was only because of the different nature of the industry that the speed of economic efficiency improvement was relatively slow, but the DT was originally a process that needed to wait. Only by holding the bottom line could people see the future.

4.2 *Questionnaire survey on the ecological and environmental benefits of enterprises*

4.2.1 *Questionnaire reliability*

This article employed a combination of stratified and random sampling to distribute questionnaires to enterprises in the agricultural, industrial, and service sectors that had completed DT. The questionnaires were distributed simultaneously through internal online platforms and offline paper questionnaires, resulting in a total of 2,189 questionnaires. After the return period, 2,100 questionnaires had been collected, representing a 95.93% return rate. The returned questionnaires were first numbered and physically/electronically archived. To ensure the quality of the analytical data, the 2,100 questionnaires underwent rigorous pre-processing and validity screening. Questionnaires with missing key items, logical inconsistencies, or unusual response patterns were deemed invalid and discarded. After individual screening, 89 invalid questionnaires were eliminated. Ultimately, 2,000 valid questionnaires were included in the statistical analysis, achieving a return rate of 91.37% (2,000/2,189), effectively representing the overall perceptions of employees in the three enterprise categories. Data from all valid questionnaires was independently entered and verified by two individuals to ensure accuracy. The results of the questionnaire were analysed by SPSS software, and Cronbach's α was selected as the reliability coefficient. The questionnaire in this study was divided into two parts: a text questionnaire and a table questionnaire, as shown in Table 1. It could be seen from Table 1 that the questionnaire reliability of the three enterprises was good.

4.2.2 *Questionnaire results*

This questionnaire surveyed the employees of enterprises on whether the enterprises after the DT would affect the ecological and environmental benefits. The results of the questionnaire were shown in Figure 5.

96.13% of employees believed that the implementation of DT of enterprises had an impact on the ecological and environmental benefits, and the impact was harmful, as shown in Figure 5. Only 3.87% of employees said that there was no impact or the impact

was not obvious. Only the employees of the enterprise could understand the impact of the enterprise on the environment. It could be seen that the DT would indeed harm the enterprise's ecological and environmental benefits.

Table 1 Questionnaire reliability table

	<i>Reliability statistics</i>	
	<i>Cronbach's alpha</i>	
	<i>Text questionnaire</i>	<i>Form questionnaire</i>
Agricultural enterprise	0.867	0.896
Industrial enterprise	0.871	0.913
Service enterprise	0.911	0.882

From the text survey part of the questionnaire, this paper understood that the DT caused a lot of impacts on the ecological environment of enterprises, and summarised them into three points:

1 Causing serious air pollution

Digitalisation has fundamentally improved the production efficiency of enterprises, and intelligent control has increased the production strength of enterprises while saving labour costs. However, the improvement of enterprise productivity has also brought great pollution to the environment, and various industrial wastes have caused great pressure on the environment. Although the environment can self-regulate, a large amount of waste output also makes the environment unbearable, which affects the air quality and causes environmental pollution.

2 Causing the shortage of freshwater resources

It is undeniable that digitalisation brings convenience and efficiency to enterprise production. However, while productivity has been greatly improved, a large amount of resources have also been wasted. Thousands of industrial wastes and industrial wastewater are poured into the sea, which causes serious pollution of the sea and water shortage.

3 Reducing forest cover

As more and more enterprises begin to transform to digitalisation, the urban area has been unable to meet the expansion of enterprises and has begun to spread to villages and towns, which has led to the occupation of natural resources by factories. The forest coverage has been decreasing, and the greenhouse effect has become increasingly fierce. The rise of global temperature has led to the extinction of marine organisms, which forms a vicious circle.

However, changes in the social environment force enterprises to carry out DT; otherwise, they would be eliminated by social competition. However, it is not easy for enterprises to realise DT, and they also face many problems and challenges:

1 DT cannot turn around.

Enterprises themselves have an insufficient understanding of digitalisation. DT is not just a slogan. It is not only at the technical level, but also at the management level.

To promote the DT of enterprises, a series of strategic decisions must be made. At the same time, enterprises need to have certain digital capabilities. Otherwise, it is difficult to achieve a breakthrough in the transformation. In addition, the enterprise's action and management capabilities are also an important factor affecting the 'inability to turn' of enterprises.

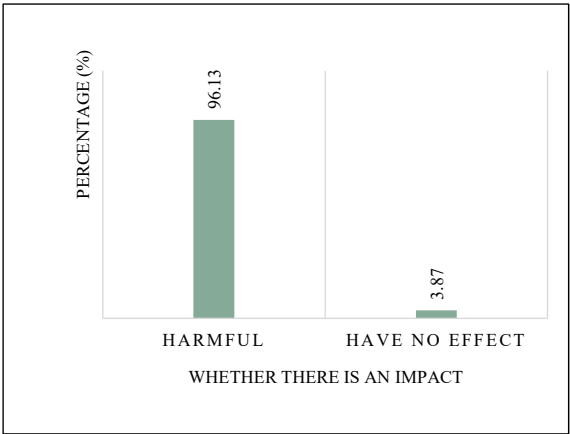
2 DT is not affordable.

DT requires a high capital cost and a long investment cycle. The transformation effect can not be seen in an instant. It needs a quiet and long waiting process. In the process of transformation, enterprises should continue to invest funds to face various unexpected problems encountered in the transformation. Therefore, enterprises need to have certain economic strength to realise DT.

3 DT cannot move.

Digitalisation is a process of transformation from informatisation to intelligence. Therefore, a large number of scientific and technological talents need to be introduced, and the shortage of talents and weak departments are common drawbacks of most enterprises. The implementation of DT is a long-term transformation process, and the existing talents of enterprises find it difficult to support enterprises in completing the transformation.

Figure 5 Questionnaire survey results (see online version for colours)



4.3 Suggestions on enterprise DT

4.3.1 Changing the pursuit of economic supremacy

A survey revealed that a staggering 96.13% of employees perceive DT to have brought about severe negative ecological impacts, including severe air pollution, water shortages, and a decline in forest cover. This deeply reveals the prevailing value orientation of companies in DT, which prioritises economics over ecology. To fundamentally reverse this trend, companies must shift away from their pursuit of sole economic dominance. In the process of development, it is recommended to establish a dual-track

‘economic-ecological’ performance evaluation system: companies should incorporate ecological and environmental benefits into the core performance appraisal systems of senior executives and departments, giving them equal weight to financial indicators. When making investment decisions for DT, companies should establish a comprehensive cost accounting model that not only accounts for direct investments in hardware, software, and manpower but also quantifies and incorporates into total costs the environmental costs of digital operations, such as additional energy consumption, electronic waste disposal, and data centre cooling. This will force managers to prioritise green and low-carbon technological paths when pursuing efficiency gains.

4.3.2 Strengthening environmental protection awareness

Companies can establish ‘green digital’ innovation incentive mechanisms to encourage employees to come up with ‘golden ideas’ that simultaneously improve efficiency and reduce environmental impact. They can directly link environmental contributions to individual promotions and bonuses, making green behaviour an active pursuit rather than a passive compliance. They can also create ‘ecological responsibility’ practice platforms: establish internal environmental protection groups or committees to organise activities such as tree planting, river cleanups, and energy-saving and carbon-reduction challenges. Through personal participation, employees can more intuitively experience the value of the ecological environment, thereby transforming environmental awareness from a ‘company requirement’ to a ‘personal belief,’ fostering a bottom-up ecological culture.

4.3.3 Carrying out ecological technology

The so-called ecological technology is to use the power of technology to realise an ecological environment. That is to say, it fundamentally improves the utilisation of resources and reduces the emission of pollutants. This would minimise the impact of enterprises on the environment and ecology, and flexibly apply science and technology, so as to give full play to the ecological advantages of science and technology, and realise the benefit improvement of the ecological environment.

4.3.4 Improving the internal economic soft power of enterprises

The economy is the foundation of development, and the ultimate goal of enterprises to achieve DT is also to achieve economic benefits. Therefore, enterprises should constantly improve their economic soft power and pave the way for the realisation of DT to form a virtuous circle and achieve a win-win situation of economic and ecological benefits.

5 Conclusions

It is of great significance to analyse the impact of DT on the economic, ecological, and environmental benefits of enterprises in the context of sustainable development. From the experimental data, it could be seen that it was an inevitable trend for enterprises to realise DT. Comparative data showed that DT could effectively increase the revenue interest rate of agricultural enterprises, industrial enterprises, and service enterprises. At the same time, it would reduce costs and increase economic returns. However, the questionnaire

survey showed that DT would harm the ecological environment benefits of enterprises and cause a serious burden and adverse impact on the ecological environment. A survey of 2,000 employees revealed that 96.13% of respondents perceived DT to have negative ecological impacts, including severe air pollution, water shortages, and reduced forest cover. This finding strongly demonstrates that while the current DT process drives economic growth, it also carries significant ecological costs, creating a significant tension between economic and ecological benefits. Therefore, in the process of DT, not only should the improvement of economic benefits be considered, but also the construction of the ecological environment should be considered. While this article provides a valuable reference for assessing the impact of DT on the economic and ecological benefits of enterprises in the context of sustainable development, it still has some limitations. The assessment of ecological and environmental benefits combines subjective employee perception surveys with some objective pollutant emission data, primarily based on data from agriculture, industry, and services. The sample's industry coverage and regional representativeness need to be further expanded. Future research could construct a larger database encompassing more emerging industries and diverse regions, conducting cross-industry and cross-cultural comparative analyses to continuously advance enterprises' DT paths and sustainable development performance. The DT of enterprises could not be completed in a single day, and still needed a long time of practice and decision-making. However, with the continuous development of digitalisation, it was believed that the solution to these problems was only a matter of time. If enterprises want to survive for a long time, they must adhere to the concept of sustainable development and organically combine economic and environmental benefits. The enterprise could not destroy the ecological foundation on which human beings rely for survival in an instant, thus realising the harmonious development of human and nature. In order to have a deeper understanding of the impact of DT on the economic, ecological, and environmental benefits of enterprises in the context of sustainable development, the analysis results should be further improved in the follow-up study based on these issues.

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Declarations

All authors declare that they have no conflicts of interest.

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