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Digital Economy, Technological Innovation and the Upgrading of Global Value Chains

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Abstract: With the rapid development of the digital economy (DE) and global value chain (GVC), the global structure of traditional value chains and the geographical nature of participating GVC countries are changing. However, GVC's technological innovation and management principles have not changed. Moreover, even new trade protectionism has emerged in various regions, which will inevitably bring additional obstacles to the development and innovation of the global economy. The trend of participating in the development of GVC regional characteristics is evaluated by promoting the development of DE, laying the foundation for the orderly promotion of regional or global integration agreements. This article explores the relationship amongst DE, technological innovation and GVC potential enhancement. This study elaborates on the relationship between DE and technological innovation. In addition, the study analyses the direct and indirect effects of DE on technological innovation, the relationship between DE and GVC and the relationship between technological innovation and GVC. This study proposes the construction of a GVC heterogeneous model under DE. Finally, experimental analysis is conducted on the heterogeneous model under DE. The study found that over time, the effect of DE on technological innovation and GVC potential continues to grow. The average effect of DE on technological innovation is approximately 1.56, and the average effect of DE on GVC potential is approximately 1.70, both of which have promoting effects. The average effect of technological innovation on GVC potential is approximately 1.57, and technological innovation also has a positive promoting effect on GVC potential.

Keywords: Technological Innovation, Digital Economy, Global Value Chain, Potential Improvement

1. Introduction

The digital economy (DE) is transitioning from a service economy to an information economy, becoming a new direction for global value chain (GVC) modernisation. Technological innovation has become an important factor affecting the operation of GVC with the development of world trade. Improving the level of technological innovation plays an important role in enhancing the position of GVC. In addition, investigating the effect of the manufacturing industry's participation in the regional-level GVC division of labour will help the manufacturing industry formulate appropriate global regional development strategies in the digital age. This article analyses the relationship between DE and GVC, explores the relationship between technological innovation and GVC and proposes constructing a heterogeneous GVC model under DE. The results show that the DE environment can not only create certain competitive pressure on enterprises, thereby achieving changes in internal technological innovation, but also continuously optimise and improve the technology of enterprises. Furthermore, the position of GVC is shifting from agglomeration to regionalisation. These results all confirm the positive role of DE in technological innovation and GVC.

Technological innovation affects the growth of the regional economy, and various scholars have explored its different influencing factors. Goudarz and Francesco (2017) conducted a fine-grained analysis of the mediating role of organisational innovation based on the radicality and breadth of technological innovation. They used structural formula modelling to test hypotheses about the relationship between organisational and technological innovation and firm export performance. Edsand (2017) analysed the slow diffusion of wind energy in Colombia by assessing the functioning of technological innovation systems and the effect of landscape factors. Lindroos, Hera and Häggström (2017) examined the three main drivers believed to have brought a major technological change in mechanised timber harvesting. They highlighted the changing degree of automation brought about by technological innovation by providing examples of entry-level products for computer-aided motion control and semi-automation. After conducting an international comparison of technological development and innovation paradigms, Xia, Liu and Zhu (2017) found that the innovation characteristics of various technological fields in the solar energy industry were different. They proposed relevant policy recommendations for latecomers to implement catch-up strategies. After systematic research, Ho and Kressel (2018) found that well-designed clinical research can not only ensure patient benefit and safety but also avoid any accidental harm. Qiao and Yongzhong (2017) analysed the maintenance status of knowledge patents. The technological innovation ability of the patent owners obtained from China is evidently weaker than that of their counterparts obtained from other countries only from the perspective of patent maintenance time. Guo, Qu and Tseng (2017) developed an integrated model to study the relationship among regional green growth performances. This study can effectively examine the relationship between observed and latent variables, including the relationship between latent variables simultaneously. The above studies have all expressed the promoting effect of technological innovation on the economy, but they have not linked DE with technological innovation.

Currently, the manufacturing industry under GVC has few technological innovations, and most focus on technology. Wang and Thangavelu (2021) estimated an approximate value-added trade gravity model to capture the role of human capital in determining cross-border production linkages through value-added trade. The results showed that skills have a greater positive effect on GVC value-added trade in developing economies. Dai et al. (2021) applied a hypothetical approach to determine sector-induced CO_2 emissions. They found that the CO_2 emissions from exports in other countries were mainly from services, but in China, these emissions were from manufacturing. Wu et al. (2021) improved the GVC status of firms through the innovation effect, and the increase in the university-educated workforce had a heterogeneous effect on firms' GVC status. Zhang, Yan and Cheung (2022) constructed an index of other countries' financial services adoption in manufacturing using an input–output framework and recent GVC results. He (2021) summarised the effect of the epidemic on GVC and then discussed the status of China and ASEAN countries in GVC by calculating the proportion of

global intermediate products. Margarida, Looi and Deborah (2021) examined the determinants of countries' participation in GVC. They found that factor endowments, free trade policies and China's industrial capabilities are very important in determining GVC participation. Nonnis et al. (2021) obtained a proxy for total factor productivity by estimating a production function that takes labour and non-communication technology capital as inputs. Estimated total factor productivity is used to assess how several types of intangible assets and GVC indicators affect productivity. The above studies have described various influencing factors of GVC, but they have not integrated DE into GVC.

This article examines technological innovation and its influencing factors in the manufacturing industry from the perspective of GVC to analyse the DE, technological innovation and the improvement of GVC's position. This study identifies the gaps and spaces in technological innovation based on empirical research, further deepening the technological innovation and DE growth in the manufacturing industry. This study helps to improve the international environment for manufacturing development and enhance the international status of GVC by optimising the energy structure of the manufacturing industry and ensuring its sustainable development. Experiments show that DE has a promoting effect on technological innovation and GVC's potential through DE to promote technological innovation and improve the construction environment of GVC. With the continuous optimisation and improvement of enterprise technology, DE is also constantly developing, and both jointly promote the advancement of GVC potential.

2. Relationship between DE and Technological Innovation

(1) The effect of DE on technological innovation

DE is a series of economic activities with information communication as the technical carrier. Amongst them, digital knowledge and information are important factors of production. A modern information network is an important tool, and the effective use of information and communication technology is an important factor in improving efficiency and optimising economic structure (Jiyoung, J & Suna, 2022). As shown in Figure 1, technological innovation is particularly important in DE development (Rudnichenko, Melnyk, & Havlovska, 2021). On the one hand, innovation provides technical support for the development of DE. The collection, development and use of data resources are key production factors that require innovative technology and talent. Raising the level of innovation is conducive to replacing the digital update process and can meet the needs of DE development. On the other hand, technological innovation provides new opportunities for the development of DE. New technologies and new resources generated through innovative activities can stimulate the development of renewable energy industries and models and deepen the environmental dimension and content of renewable energy. The results show that technological innovation is the foundation and key to DE development, and the continuous development of technological innovation promotes the sustainable development of DE.

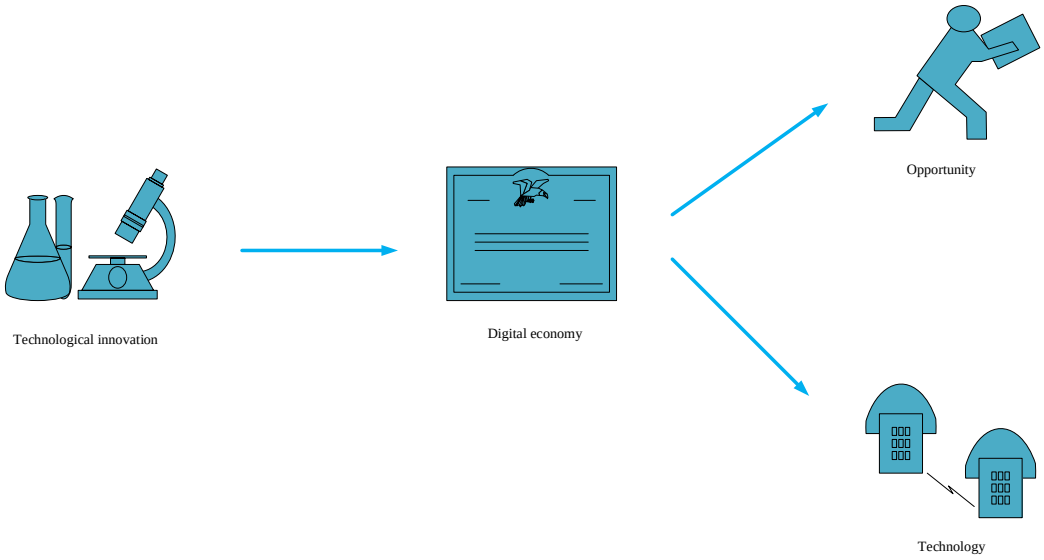

Fig. 1: DE's effect on technological innovation

(2) The direct effect of DE on technological innovation

From the perspective of direct effect, DE's companies are mainly knowledge-based, have considerable innovation resources and technological innovation capabilities and outperform other traditional industries. The development of DE increases the industrial share and the level of technological innovation in the entire economy (Vasin et al., 2021). In addition, information technology products are integrated into the economic system as intermediate products, constantly promoting the formation of 'new fields' and triggering technological innovation. Moreover, DE has great potential for innovation. New information technology products would continue to enter production systems as intermediate goods, enhancing other industries and fostering technological innovation. The direct effect of DE has a positive effect on technological innovation. On the one hand, industrial innovation is very powerful; on the other hand, DE can bring new technological innovations.

(3) The indirect effect of DE on technological innovation

A strong link exists between the indirect effect of DE and technological innovation, as shown in Figure 2. Firstly, the development of information technology has improved management capabilities and created conditions for organisational innovation. Organisational innovation enhances management efficiency, ensures technological innovation and reduces innovation resistance. Secondly, the development of communication and information exchange has been greatly accelerated, the flow efficiency of innovation resources has been improved and the innovation value of relevant resources has been brought into full play. In addition, DE reduces the cost of resource search and promotes technological innovation. Thirdly, various micro-mechanisms improve the market's ability to allocate resources, reduce the information asymmetry between supply and demand, increase the possibility of new products entering the market quickly and reduce the risk of technological innovation. Fourthly, the development of DE leads to the improvement of the level of social development and the rapid dissemination of new knowledge. DE is conducive not only to improving the innovation ability of scientific researchers but also to the formation of a new social identity. DE is objectively conducive to forming an innovation culture (Tandon & Tandon, 2021).

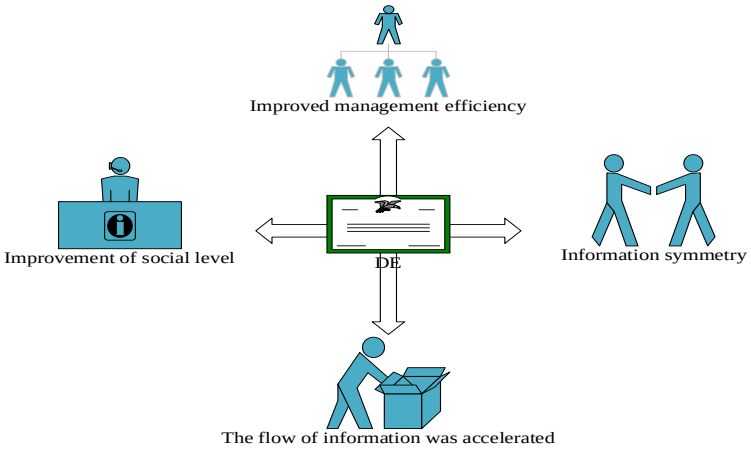

Fig. 2: DE's indirect effect of technological innovation on technological innovation

3. Relationship between DE and GVC

This study analyses four aspects to better understand the relationship between DE and GVC, as shown in Figure 3.

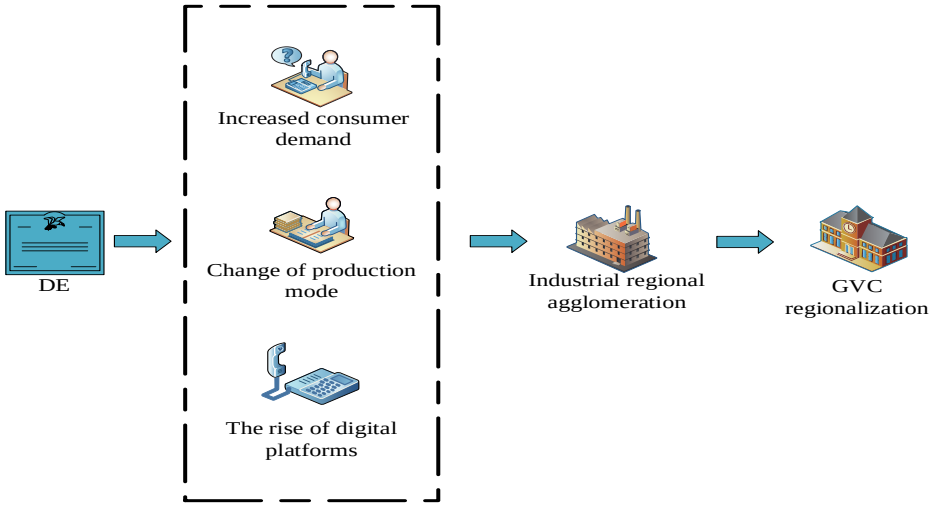

Fig. 3: Relationship between DE and GVC

(1) Increased consumer demand

The growth of consumer demand in DE is not only to improve product quality and meet market demands but also to meet individual and enterprise demands with higher demands. Manufacturers with low labour costs are gradually concentrated in regions close to major markets globally to quickly meet the needs of consumers, which is a new trend in the development of GVC. Relying on the large middle-income population and the prominent market influence alliance, the GVC division of the manufacturing industry in China and its surrounding areas is constantly clear (Galloway, Schmitt, & Herman, 2020). Therefore, China's manufacturing industry gradually moves from global decentralisation to regional integration.

(2) Change the production mode

As production methods change, the existing labour cost advantage is not important in determining the global distribution of manufactured products. The corresponding data volumes, digital technologies and digital infrastructure have become the keys to the success of the manufacturing industry. Hence, the world's manufacturing industry would gradually shift from the low–labour cost realm to the more advanced digital technology realm, enabling wider regional data integration through improved digital infrastructure. China's digital infrastructure is also relatively developed, and the amount of data is larger

than that in other countries. This case would undoubtedly attract more production processes from neighbouring countries, encourage Chinese manufacturers to participate in GVC and demonstrate a broader trend of GVC regionalisation.

(3) Emergence of digital platforms

Digital platforms are blurring the boundaries of traditional industries, which is not only a new way to integrate value chains into manufacturing but also an important way to directly link production and consumption. Whether the existence of large digital platforms can establish a complete digital ecosystem with neighbouring countries is an essential factor affecting the structure of international production (Li, Sapkota, & Knaap, 2020). In addition, the number of companies involved in promoting unicorn digital platforms is quite large, and the growth rate is impressive. This case not only attracts Chinese and surrounding enterprises to gather but also encourages the development of China's GVC regionalisation to a certain extent. In addition, this trend has made the added value of Chinese manufacturing more concentrated in Southeast Asian countries. This event has not only led to the regionalisation trend of China's participation in GVC but also made China a leading regional value chain.

In general, China's digital technology advantages are becoming increasingly evident, and the manufacturing industry is also improving in digital transformation. Numerous digital platforms continue to focus on global manufacturing in and around China. In addition, trends in Chinese manufacturing participating in GVCs are more regional. In addition, the weak GVC position of China's manufacturing industry in developed economies such as Europe, the United States and Japan has gradually transformed into a regional value chain, which would also help the GVC of Chinese manufacturers to move from globalisation to regionalisation.

4. Relationship between Technological Innovation and GVC

(1) Analysis of technological innovation embedded in the global chain

At present, the technological innovation effect of embedded GVC is divided into four parts, as shown in Figure 4.

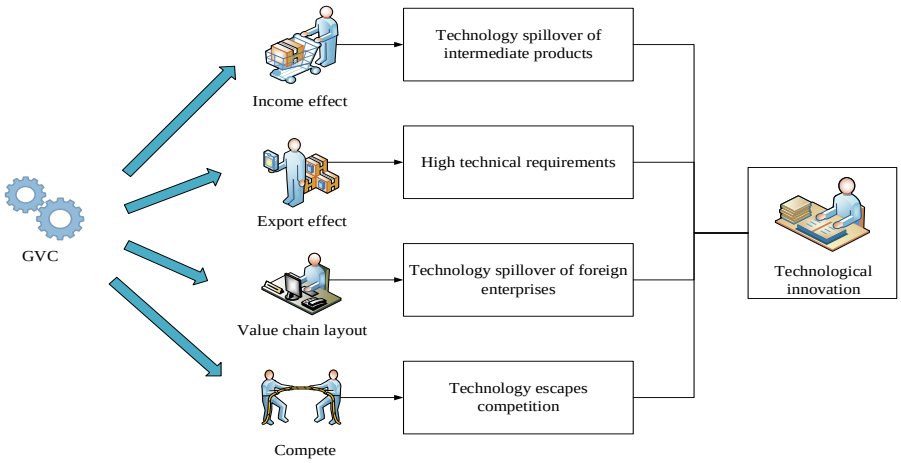

Fig. 4: Technical innovation effect of embedded GVC

1) Income effect

The theoretical mechanism of the influence of GVC integration on enterprise innovation activities is mainly the 'knowledge introduction effect'. Most intermediates imported by developing countries from developed countries are key components, including advanced technologies and innovative knowledge. This case would also help lower the cost of innovation for developing country firms, import intermediate goods and increase their innovation capacity. Companies in developing countries can

optimise their own production solutions, purchasing or outsourcing intermediate products that are not in their own interests or are not closely related to technological capabilities to meet the high demands of consumers in developed countries. On the one hand, this case reduces the company's production costs; on the other hand, it helps the company concentrate its limited resources on its own advantageous areas, thereby achieving greater profits and new opportunities for innovation.

2) Export effect

Technological innovation can be divided into exogenous innovation and endogenous innovation. Companies in developing countries have adopted an 'import and export' strategy and imported many high-tech intermediate products to meet the higher standards and requirements of consumers in developed countries for imported goods. In other words, products imported from developed countries are usually high-tech products (Lo, Yu, & Soh, 2020). From another aspect, companies can also achieve higher standards through internal innovation. Thus, companies in developing countries can increase their research and development (R&D) investment and improve their technology. According to the export standards of developed countries, this event improves the quality of export products from the source of design and production and does not rely on imported intermediates. In the process, enterprises can also enhance the level of technological innovation. In addition, increased exports by developing country firms can generate economies of scale, helping firms reduce export costs, generate more profits and increase R&D investment. Finally, they form a positive driver of technological innovation in enterprises to achieve higher levels of technological innovation.

3) The effect of value chain layout

This transfer of production components or industries would also affect technological innovation by developing country firms. With the industrial transfer of developed countries and the inflow of international advanced innovation resources, developing countries can accept the transfer of industrial resources and technologies and seize the opportunity to develop their innovation capabilities. In addition, the influx of other countries' companies into developing countries has brought more products for local companies to imitate and learn from. Absorbing other countries' advanced technology and management experience through imitation and learning is more beneficial for local companies to invest in R&D, thereby achieving greater spillover effects and accelerating their own DE development.

4) The effect of competition

Chinese enterprises face more intense market competition when exporting products to other countries' markets owing to the evident difference between the technical level and the international market. Enterprises would play the role of 'losing competitors' in technological innovation to eliminate the competition of the same type of companies to obtain more production orders and better cope with the competitive pressure in the international market. They improve the level of technological innovation, increase the core competitiveness of enterprises and enable enterprises to gain more competitive advantages in the fierce international competition by increasing investment in technology R&D. After the integration of GVC with DE and technological innovation, the strong international competition from enterprises has had a positive effect on the technological innovation of the company.

(2) The status quo of technological innovation of enterprises embedded in GVC

In general, the independent innovation capability of Chinese enterprises is lower than that of developed countries. Owing to the lack of systematic technological innovation capabilities, producing components and raw materials required for high-tech applications is difficult for local companies integrated into GVC. Moreover, local companies cannot produce products that meet the strict requirements of consumers in developed countries. The enterprises themselves cannot make up for the technological gap in time. Hence, local Chinese enterprises can only import many key components, raw materials and high-quality production facilities from developed countries to make up for the 'quality gap' and 'technology gap' in product exports.

(3) The relationship between technological innovation and GVC improvement under DE

The technological innovation community is divided into technological innovation investment and technological innovation achievement. Figure 5 shows the relationship between different forms of technological innovation and GVC under DE. Technological innovation can improve the overall efficiency of production. However, the cost of technological innovation must be considered, particularly the differential input cost between the government and enterprises. However, in the medium and long term, these effects are negligible. In times of technological innovation and market uncertainty, R&D investment that emphasises talent advantages and technological innovation and R&D have a different effect on GVC than government investment. Therefore, the manufacturing industry needs to use technological innovation to promote the development of DE to achieve the rise of GVC's status.

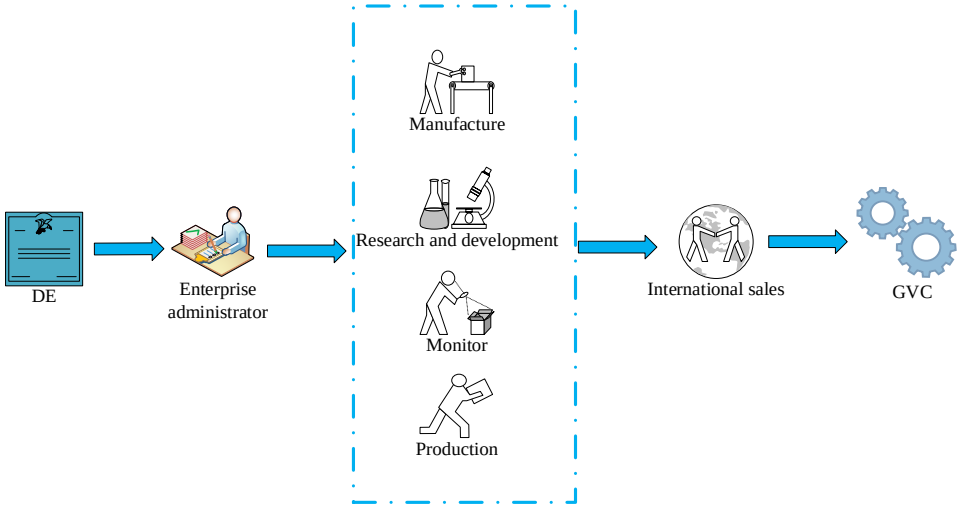

Fig. 5: Relationship between technological innovation and GVC improvement under DE

5. GVC Heterogeneous Model Construction under DE

This study analyses the specific relationship amongst DE, technological innovation and GVC by constructing a GVC heterogeneous model to further understand the relationship amongst the three. Firstly, a monopoly demand model that replaces enterprise competition is constructed to analyse the relationship between product demand and GVC status.

$$\delta_a = \frac{P_a^{-\varepsilon}\mu_a^{\varepsilon-1}}{P}R. \quad (1)$$

Then, according to the heterogeneity of the firm, the marginal cost function of the firm is constructed as follows:

$$A(\alpha,\beta) = \frac{c}{\beta}\alpha_A. \quad (2)$$

a_A is the quality elasticity of cost, and then, the fixed cost function is found according to the following marginal function:

$$B(\alpha,\vartheta) = \frac{f}{\vartheta}\alpha_A + B_0. \quad (3)$$

By integrating the above formulas, the profit of the enterprise can be obtained as follows:

$$\eta(\beta,\vartheta) = \delta(P_a - A_a) - B_a. \quad (4)$$

Then, the function when the profit is maximised can be obtained as follows:

$$\alpha = \frac{f}{\vartheta}\left(\frac{\varepsilon-1}{\varepsilon}\right)^{\frac{1-a_A}{a_A}}\frac{\beta}{c}. \quad (5)$$

Then, according to the profit function of the enterprise, the theoretical model of DE for productivity and technological innovation is established.

$$\beta = \left(\int_0^1 X_i di\right)^n. \quad (6)$$

$$\vartheta = \left(\int_0^1 X_i di\right)^m. \quad (7)$$

Then, Eqs. (6) and (7) are combined to obtain the economic factor function.

$$X = \begin{cases} M, DE \\ N, \overline{DE} \end{cases}. \quad (8)$$

Therefore, Eqs. (6) and (7) can be transformed into:

$$\beta = \left[\theta\left(\frac{M}{\theta}\right) + (1-\theta)\left(\frac{N}{1-\theta}\right)^n\right]^n. \quad (9)$$

$$\vartheta = \left[\nu\left(\frac{M}{\nu}\right) + (1-\nu)\left(\frac{N}{1-\nu}\right)^m\right]^m. \quad (10)$$

By bringing Eqs. (9) and (10) into Eq. (5), the input M function of DE can be obtained as follows:

$$\alpha = \frac{f}{\nu\left(\frac{M}{\nu}\right)+(1-\nu)\left(\frac{N}{1-\nu}\right)}\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{1-a_A}{a_A}\frac{\theta\left(\frac{M}{\theta}\right)+(1-\theta)\left(\frac{N}{1-\theta}\right)}{c}. \quad (11)$$

Then, DE, technological innovation and GVC can be used to construct evaluation indicators, and the standardised indicators can be obtained as follows:

$$Y_{ij} = \frac{(Y_{ij}-min\{Y_{ij}\})}{max\{Y_{ij}\}-min\{Y_{ij}\}}. \quad (12)$$

Then, the proportion of the jth indicator in the ith year can be obtained as follows:

$$Z_{ij} = {Y_{ij}}\Big/{\sum_{i=1}^n Y_{ij}}. \quad (13)$$

According to Eq. (13), the information entropy of the index can be obtained as follows:

$$r = -m\sum_{i=1}^n\left(Z_{ij} \times ln\, Z_{ij}\right). \quad (14)$$

The redundancy of information entropy is as follows:

$$q_j = 1 - r. \quad (15)$$

Then, through Eq. (15), the index weights of DE and GVC can be obtained as follows:

$$e_i = \frac{q_j}{\sum_{j=1}^n q_j}. \quad (16)$$

Finally, the score of the single indicator and the comprehensive level score of GVC in the i year are obtained.

$$S_{\text{ij}} = e_i \times Y_{ij}. \quad (17)$$

$$S_i = \sum_j^n S_{ij}. \quad (18)$$

6. Experimental Analysis of the GVC Heterogeneous Model under DE

This study surveys a certain enterprise to further understand the effect of DE and technological innovation on the GVC potential, using a questionnaire to evaluate its production mode, technological innovation ability and economic benefits. The maximum score is 5, and 50 employees of the enterprise are surveyed. The average value of the survey is selected as the overall score, as shown in Table 1. In addition, both the highest and lowest scores are eliminated.

Table 1. Basic information about the enterprise

	Production mode	Technological innovation ability	Economic performance
2021	4.6	3.8	3.9
2020	4.2	2.8	3.1
2019	3.8	2.1	2.4

Table 1 shows that the production model, technological innovation and economic benefit scores of enterprises are increasing yearly. This increase is also because of the continuous development of DE, which has accelerated the technological innovation and development of enterprises, promoted the economic benefits of enterprises and improved the core competitiveness of enterprises to a certain extent. With the continuous innovation and reform of technology, the international status of enterprises is also rising, which also plays a positive role in improving GVC's position.

(1) The effect of DE on technological innovation and GVC potential

This study investigated DE to further analyse the influence relationship between technological innovation and GVC potential improvement. This article analyses the changes in technological innovation level and GVC potential of enterprises under DE from 2017 to 2021. A total of three enterprises were surveyed, and the mean of these three enterprises was used for data analysis. From a macro perspective, DE promotes technological innovation, which in turn promotes the improvement of GVC potential, as shown in Figure 6.

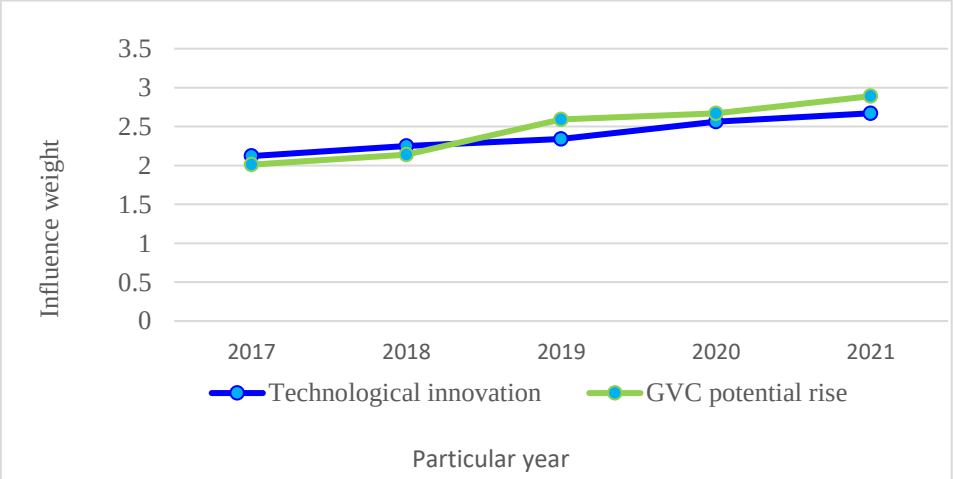

Fig. 6: DE's influence on technological innovation and GVC potential

According to Figure 6, with the growth of time, the potential of technological innovation and GVC is constantly improving, and the growth of potential is higher than that of technological innovation. Moreover, the average weight of technological innovation is approximately 2.39, whereas the potential weight of GVC is approximately 2.46. This case also shows that DE can promote the technological innovation of enterprises, thereby increasing their competitiveness, and then also conducive to the improvement of GVC potential. In addition, DE can promote the transformation of enterprises into industrial clusters.

(2) GVC heterogeneous model analysis under DE

This study analyses the redundancy and overall indicators of GVC to further understand the model effect of technological innovation under DE on GVC. Figure 7 shows the specific analysis.

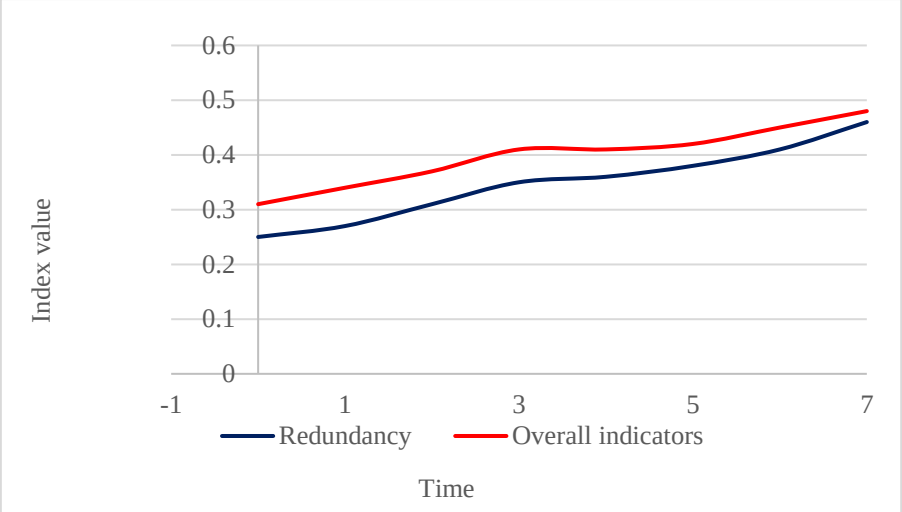

Fig. 7: Analysis of the GVC heterogeneous model under DE

As shown in Figure 7, in the DE environment, the redundancy and overall indicators of GVC are increasing with time. The growth rate of the overall index is higher than that of the redundancy, the mean of the redundancy is approximately 0.35 and the mean of the overall index is approximately 0.40. The DE environment can not only cause certain competitive pressures to enterprises to realise changes in technological innovation within enterprises. With the continuous optimisation and improvement of the company's technology, the potential of its GVC is constantly changing from agglomeration to regionalisation. These results confirm that DE plays a positive role in technological innovation and GVC.

(3) Regression analysis of the effect of DE and technological innovation on GVC status

This study compares and discusses the three through regression analysis to further understand the specific effects of DE and technological innovation on the status of GVC, as shown in Figure 8.

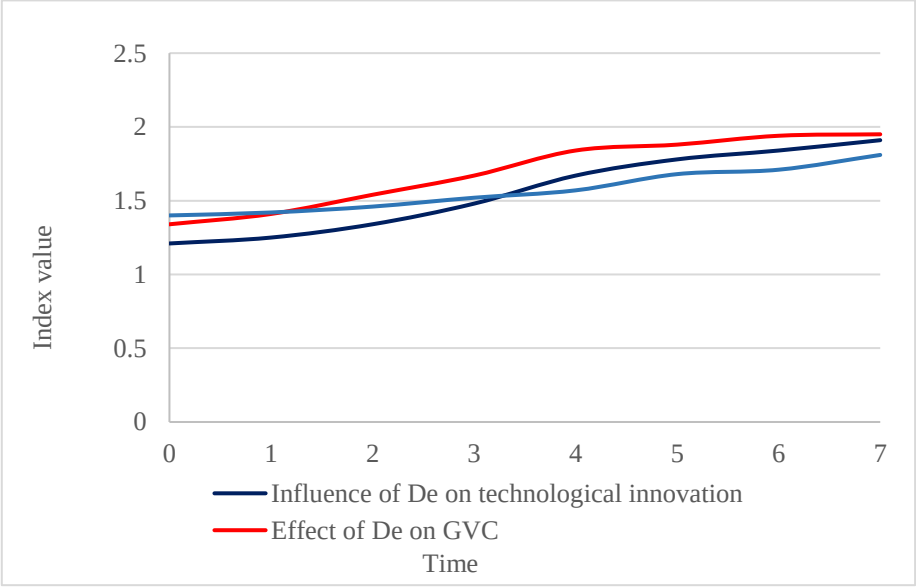

Fig. 8: DE and regression analysis of the effect of technological innovation on the GVC status

According to Figure 8, with the growth of time, the effect of DE on technological innovation and GVC potential is increasing. Amongst them, the average effect of DE on technological innovation is approximately 1.56. Moreover, the average effect of DE on GVC potential is approximately 1.70, both of which are promoting effects. The average effect of technological innovation on GVC potential is

approximately 1.57, and technological innovation has a positive effect on GVC potential. This figure also confirms that DE plays a role in promoting technological innovation and GVC potential. With the continuous optimisation and improvement of the technology of enterprises, DE is also constantly developing, and the two jointly promote the advancement of GVC potential.

7. Conclusion

GVC work is an important form of economic activity organisation that provides new impetus for sustainable economic development but also leads to imbalances in economic development and the transfer of environmental pollution. The transition from globalisation to regionalisation has played a positive and important role in promoting the regional transformation of manufacturing towards GVC. The higher the degree of digitisation, the more evident the regional characteristics of participating in the manufacturing industry. In addition, government regulation is positive for technological innovation in the manufacturing industry but has no significant effect. Under GVC conditions, technological progress has a negative effect on technological innovation in the manufacturing industry. In GVC, market incentives have no significant effect on technological innovation in the manufacturing industry. Under GVC conditions, DE clearly has a positive effect on technological innovation in the manufacturing industry. Therefore, achieving the growth of manufacturing DE through technological innovation in the manufacturing industry and strengthening the capacity building of GVCs play an important role in improving the international manufacturing development environment and enhancing the status of GVCs.

On this basis, this article also draws the following inspiration: firstly, when formulating the development plan of the DE, fully identifying the industry differences in the penetration of the DE and appropriately enhancing the digital investment in medium- and low-tech manufacturing and information communication service industries are essential. Secondly, consolidating the foundation of digital technology development, focusing on strengthening R&D support for basic and cutting-edge digital technologies such as artificial intelligence and 5G, improving professional talent cultivation and high-quality labour force construction, enhancing the intensity of national digital competition and improving the innovative environment for DE development are crucial. Finally, trade barriers are reduced by aligning with high-standard international rules for service trade, particularly increasing the opening up of the service industry, achieving high-level trade openness within border measures and fully leveraging the role of DE penetration in enhancing the division of labour in the GVC.

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