Research on the Influence of Digital Economy on Technological Complexity of China's Manufacture Exports

Abstract : Under thebackgroundof thein-depthdevelopment of economicglobalization, China,asalarge country opentotheoutsideworld, has been activelypromoting export. This paper systematically combs the theoretical mechanism of the digital economy promoting the development of China's manufacturing export technology complexity. Based on China's provincial panel data from 2014 to 2022, this paper constructs a fixed effect model and a mediating effect model, and empirically studies the impact mechanism of the digital economy. The results show that: the digital economy can effectively enhance the technical complexity of China's manufacturing exports, and the results are more robust. In the path of action, product innovation helps to improve the quality of export products, which is an important conduction mechanism for the digital economy to promote the technical complexity of China's manufacturing exports. Further research shows that the impact of the digital economy on the technical complexity of manufacturing exports varies according to the differences in geography and urbanization level.

Key words: Digital economy; Manufacturing; Export technical complexity; Technological innovation.

1. INTRODUCTION

The report of the 20th Party Congress pointed out that China should "promote high-level opening up to the outside world and accelerate the construction of a trade power", and improving the technological complexity of manufacturing exports is undoubtedly an important path to mold China into a "manufacturing power" and "trade power". Export technology complexity can reflect the technical level, innovation ability and production efficiency of national or regional export products, and it is an important index to measure product upgrading. In this context, it is of great significance to enhance the technological complexity of manufacturing exports, realize industrial transformation and upgrading based on the global value chain, and change the situation of "low-end locking" in China's manufacturing industry, so as to cultivate new advantages in international competition in the manufacturing industry in China and become a manufacturing power and a trade power.

The Fourteenth Five-Year Plan proposes that China should adhere to the principle of "promoting the in-depth integration of information technology with China's real economy, creating a new advantage in the digital economy and strengthening the new engine of economic development". Taking digitized knowledge and information as the key factors of production, modern information network as the important carrier, and information and communication technology as the effective means to create a manufacturing development mode of "data + algorithm + arithmetic" and the deep integration of the real economic activities, is an important means to enhance the level of China's manufacturing technology. In recent years, China's digital economy has been developing rapidly, and in 2022, China's digital economy totaled 50.2 billion yuan, accounting for 41.5% of GDP, ranking second in the world in total. The development of digital economy can not only fully mobilize two kinds of domestic and international resources and optimize the allocation of resources, but also optimize the economic structure, improve the quality of export products and international market share, which is an important means to enhance the international competitiveness of China's manufacturing industry.

2. LITERATURE REVIEW

Domestic and international studies are closely related to the following two types of literature. The first type of literature focuses on the influencing factors of export technological complexity. Scholars at home and abroad mainly study from the aspects of manufacturing servitizationdemographic structure, infrastructure, financial development, technological innovation and so on. Ma Yingying[1] empirically analyzed from the perspective of value added, and concluded that the impact of manufacturing servitization on the technological complexity of export products varies with the different factor intensities of products. Zhang Aili[2] studied from the perspective of population structure, and found that the promotion effect of population quality structure on the technical complexity of exports far exceeds the population quantity structure. Wang Yongjin[3]use cross-country data to find that the level of infrastructure development also has a positive contribution to the export technological complexity of each country. Qi Junyan[4] found that financial development can significantly and robustly enhance a country's export technical complexity through empirical tests on cross-country industry data. Ye Lin[5] study the relationship between technological innovation and export technological complexity, and find that the increase of product innovation investment can significantly enhance the international competitiveness of enterprises.

The second category of literature focuses on the impact mechanism of digitization on the technological complexity of enterprises' exports. Shen Guobing[6] believe that the Internetization of enterprises can enhance the ability of enterprises to manage products, thus having a significant promotion effect on enterprise innovation and its exports, and indirectly promote enterprise exports through the innovation selection behavior of enterprises; Han Xianfeng[7] believe that the Internet can reduce the cost of access to information, accelerate the accumulation of human capital, promote the development of finance and industrial upgrading, and enhance the spillover effect of innovation, so as to improve enterprise Production efficiency; Liu Zhijian[8] believe that under the premise of the combination of digital economy and scientific and technological innovation, the export technological complexity of manufacturing products will be synchronized with the development of the digital economy, and the interaction of digital economic development and scientific and technological innovation for the export of technological complexity of the impact of the heterogeneity of the industry; Hong Junjie[9] believe that technological innovation there is a clear U-shaped intermediary role, the more complete the information infrastructure, the more advanced the technological level of the information infrastructure, the more advanced the technology, the more the technology is. The more complete the information infrastructure, the more advanced the technological level of the enterprise can obtain external resources and technical support, the more can improve the quality of export products through innovation.

In summary, the existing literature has achieved some results in the study of the relationship between the digital economy and export technological complexity, but these studies are mainly from the perspective of the application of digital technology within the enterprise and the cross-country data level, the study of the impact of the digital economy on the technological complexity of the manufacturing exports at the domestic inter-provincial level is not yet perfect, and does not provide sufficient mechanisms for the digital economy to affect the technological complexity of the manufacturing exports. Examination. Therefore, this paper selects the panel data of 30 provinces in China to empirically study the mechanism of the digital economy's impact on the technological complexity of manufacturing exports, and the possible contribution of this paper lies in the following three aspects: (1) to study the impact of the digital economy on the technological complexity of exports in the manufacturing industry as an example, and to provide a theoretical research basis for the integration of the digital and real; (2) classify technological innovation into process innovation and product innovation, and through the mediation effect study, it is found that product innovation affects the technological complexity of manufacturing exports more than process innovation; (3) through the heterogeneity test analysis, it explores the impact of digital economy on the technological export complexity of manufacturing industry under the different regions, different ownerships and different levels of urbanization, and it provides empirical support to the government for the precise implementation of the digital technology development policy and the innovation and development policy.

3. RESEARCH MODEL AND HYPOTHESES

3.1Direct Effect

The deeper integration of the digital economy with the manufacturing sector affects export technological sophistication simultaneously from both the supply and demand sides. In the supply perspective, digitalization positively contributes to the increase in the technical complexity of manufacturing exports. Manufacturers can optimize redundant processes and save production costs by using digital technology to monitor and analyze production processes, predict risks and prevent them in real time. When digitalization is applied on a large scale, the manufacturing industry as a whole will develop towards mechanization, intelligence and automation, thus realizing the scale effect and improving production efficiency; in the demand perspective, consumers use digital technology to obtain the latest market information in a timely manner, grasp the changes in product types in the international market and feedback information, so as to invest funds in products with higher technological sophistication and higher added value. Funds through the allocation of market laws flow to the more potential value of the manufacturing enterprises, and then forced other manufacturing enterprises in the market to update product technology and product mix, and constantly optimize and upgrade their products, promote the product to a better quality, higher efficiency upgrades to create new product value, cater to the new market demand, and on the other hand, to promote the export of technological complexity of the enhancement. Thus, we hypothesize that

H1. The development of digital economy can promote the enhancement of the technical complexity of manufacturing exports.

3.2Mediating Effect

Science and technology innovation can, on the one hand, enhance the technological content of products, improve the efficiency of product production, reduce the cost of product production, and improve the technological complexity of manufacturing exports, and on the other hand, it can indirectly improve the technological complexity of manufacturing exports by affecting the level of economic development. There is a significant difference in the cost consumed between different innovation methods, and product innovation requires more factor inputs than process innovation. Process innovation focuses on the optimization and upgrading of the original product, while product innovation is more inclined to the production of new product types that are significantly different from the original product. New products can generally extend the depth of the product value chain, enhance the degree of enterprise specialization and improve the core competitiveness of the industry. Some scholars believe that there is a significant positive relationship between product innovation and export technological complexity, but process innovation is often difficult to achieve an increase in export technological complexity (Xia Jiechang et al., 2022)[10]. Other scholars believe that although both process innovation and product innovation contribute to the improvement of export technological complexity, the innovation that causes changes in product quality promotes export technological complexity much more than other types of innovations (Blyde et al., 2018)[11], and therefore, product innovation is more capable of driving the improvement of export technological complexity than process innovation. Thus, we hypothesize that

H2. The digital economy enhances the technological complexity of manufacturing exports by promoting process innovation.

H3. The digital economy enhances the technological complexity of manufacturing exports by promoting product innovation.

4. METHODS

4.1Empirical models

Benchmark regression model:In order to test the direct impact of the digital economy on the technical complexity of manufacturing exports, this paper constructs the following benchmark regression model:

$$Es_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Controls_{it} + \varepsilon_{it} \quad (1)$$

i represents the province, t represents the time, α_0 is the constant term and ε_{it} is the random error term. Es_{it} is the explanatory variable, which represents the manufacturing export technological complexity of province i in year t; Dig_{it} is the core explanatory variable digital economy; $Controls_{it}$ is the control variable related to export technological complexity and digital economy.

Mediating effect model:As the previous theoretical analysis, the digital economy through the promotion of technological innovation and then improve the manufacturing industry production efficiency and export technology complexity, so this paper selected process innovation, product innovation as the mediating variables, to construct the following mediating effect model:

$$Mid_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 Controls_{it} + \varepsilon_{it} \quad (2)$$

$$Es_{it} = \gamma_0 + \gamma_1 Dig_{it} + \gamma_2 Mid_{it} + \gamma_3 Controls_{it} + \varepsilon_{it} \quad (3)$$

α_1 reflect the total effect of the digital economy on the technical complexity of manufacturing exports. Mid_{it} are mediating variables, including process innovation（Ci）、product innovation（Pi）. γ_1 indicates the direct effect of digital economy on the technological complexity of manufacturing exports, Mid_{it} indicates the effect of mediating variables on the technological complexity of manufacturing exports after controlling for the digital economy.

4.2 Variable definition and measurement

Explained variable: Technical complexity of manufacturing exports (Es). In this paper, we refer to Hausman's (2007) [12] two-step measurement of export complexity: the first step is to measure the export technological complexity of the manufacturing sub-sectors by weighting the average of GDP per capita under each sub-industry. The second step measures the technological complexity of manufacturing exports in province i.

Core explanatory variable: Digital economy (Dig). Drawing on the research of Liu Jun et al. (2023) [13], this paper constructs comprehensive indicators of inter-provincial digital economy from three levels: the level of digital infrastructure construction, the level of Internet development and the level of digital transaction development. Specifically, the length of long-distance fiber optic cable lines, the total amount of telecommunication business and software business revenue of each province are selected to measure the level of digital infrastructure construction, the Internet broadband access ports, cell phone penetration rate, and Internet broadband access users are selected to measure the level of Internet development, and the number of websites, the number of computers in use at the end of the period, the proportion of the number of enterprises with e-commerce transaction activities, and the sales of e-commerce per 100 enterprises are selected to measure the Digital transaction development level. The data of the above 10 indicators are standardized, and then the entropy value method is used to measure the weights. The weights of the indicators at each level are shown in Table 1.

Table 1. Digital economy evaluation index system

Level 1	Level 2	Level 3	properties	weights
Digital Economy	Digital Infrastructure	Total telecommunication services	+	0.093
		Revenue from software operations	+	0.082
		Long distance fiber optic cable	+	0.106
	Internet Development	Internet broadband access port	+	0.103
		Internet broadband access subscribers	+	0.102
		Cell phone penetration rate	+	0.108
	Digital Transaction	E-commerce sales	+	0.091
		Websites per 100 businesses	+	0.111
		Computers in use at end of period	+	0.096
		Proportion of businesses with e-commerce trading activities	+	0.108

Intermediary variable:Science and technology innovation, including process innovation (Ci) and product innovation (Pi). Process innovation (Ci) is to improve and innovate on the basis of the original products and technologies, and the number of utility model patents and appearance patents authorized is selected as the proxy variable for process innovation; Product innovation (Pi) refers to the production of new products with different functions from the original products or functions through innovative activities, and the number of invention patents authorized is selected as the proxy variable for product innovation.

Control variables: (1) Infrastructure level (Inf). This paper uses road miles to measure the level of infrastructure. A complete infrastructure can not only reduce the transportation cost in manufacturing export trade as well as save the cost of warehousing and inventory, but also attract high-tech enterprises and talent concentration, thus improving the export technology complexity. (2) Foreign Direct Investment (FDI). This paper chooses the amount of foreign direct investment in each province and city to measure this indicator. FDI can not only provide the necessary funds for economic development, promote the upgrading of industrial structure and improve the complexity of export technology, but also through the effect of "learning by doing", the demonstration effect and the pressure of competition, prompting the local manufacturing industry to imitate and learn from foreign advanced management technology and experience, thus promoting technological progress and improving the complexity of export technology. (3) R&D investment intensity (Rd). This paper adopts the R&D expenditure of industrial enterprises above designated size to measure the intensity of R&D investment. Generally speaking, the greater the R&D investment intensity, the stronger the industrial innovation capability. (4) Human capital (Hc). This paper adopts the average years of education to measure human capital. The optimization of human capital structure is conducive to the learning and absorption of foreign advanced technology on the one hand, and on the other hand, it can reduce the cost of "learning by doing", improve labor productivity, and thus increase the technological complexity of exports. (5) Industrial Diversification (Div). The measurement of industrial diversification is based on the algorithm of Xu Yuan[14]. Diversified industrial structure on the one hand makes the formation of complementary industries, reducing the transportation cost of intermediate products and transaction costs, on the other hand, the diversified skill demand, diversified knowledge and intellectual agglomeration to promote technological development and technological spillover, to improve the technological complexity of manufacturing exports to create favorable conditions.

4.3Data

Panel data of 30 provinces in China (statistics exclude Hong Kong, Macao and Taiwan, and Tibet is also excluded from the sample due to some missing data in Tibet) from 2014-2022 are selected to conduct an empirical study on the export technological complexity of 16 manufacturing sub-industries (obtained by matching the two codes of HS of customs of manufacturing industry with the classification of national economy). All data are mainly obtained from China Industrial Statistical Yearbook (2015-2023), China Trade and Foreign Trade Statistical Yearbook (2015-2023) and China Statistical Yearbook (2015-2023). The meanings of variables and descriptive statistics are shown in Table 2:

Table 2. Descriptive statistics

Variable		Meaning	N	mean	sd	min	max
Explained variable	LnEs	Technical complexity of manufacturing exports	270	11.25	0.180	10.96	11.67
Core explanatory	Dig	Digital economy	270	0.270	0.120	0.120	0.790
Intermediary variable	LnCi	Process innovation	270	10.10	1.379	6.019	13.37
	LnPi	Product innovation	270	8.341	1.388	4.511	11.17
Control variable	LnInf	Infrastructure level	270	9.200	0.810	6.800	10.84
	LnFDI	Foreign Direct Investment	270	18.02	1.380	14.59	21.41
	LnRd	R&D investment intensity	270	23.63	1.350	20.29	26.24
	Hc	Human capital	270	0.490	0.120	0.180	0.830
	Div	Industrial Diversification	270	2.430	0.170	1.930	2.710

5. EMPIRICAL RESULTS

5.1Baseline results

In this paper, the first correlation test is conducted on each variable, and the variance inflation factor in the test results is less than 10, indicating that there is no multicollinearity between the variables, and the next empirical analysis can be carried out. In order to determine the applicability of the fixed effects model to regression analysis, this paper empirically tests the regression with the help of Hausman test. In the test results, the P-value is less than 0.01, so the fixed effect model is used to start the regression analysis, and the regression results are shown in Table 3. It can be seen that the coefficient of the digital economy (Dig) is always significantly positive at the 1% level, which indicates that the digital economy has a significant positive role in promoting the technical complexity of manufacturing exports. The digital economy can promote specialization and division of labor, stimulate innovation, and increase productivity, so hypothesis H1 is valid.

Table 3. Baseline results

	(1)	(2)	(3)	(4)	(5)	(6)
Dig	2.635***	1.517***	1.213***	1.296***	1.304***	1.161***
	(20.590)	(11.620)	(9.460)	(9.030)	(9.110)	(6.690)
LnInf		0.549***	0.381***	0.410***	0.394***	0.395***
		(12.701)	(8.040)	(7.810)	(7.401)	(7.430)
LnFDI			0.097***	0.096***	0.094***	0.096***
			(6.460)	(6.380)	(6.280)	(6.390)
LnRd				-0.043	-0.046	-0.036
				(-1.270)	(-1.370)	(-1.050)
Hc					0.099	0.091
					(1.460)	(1.340)
Div						0.181
						(1.450)
C	10.552***	5.799***	5.679***	6.428***	6.626***	5.949***
	(303.660)	(15.450)	(16.520)	(9.420)	(9.550)	(7.130)
N	270	270	270	270	270	270
R^2	0.622	0.786	0.821	0.822	0.823	0.824

5.2 Mediating test results

Considering the possible mediating effect in the digital economy's influence on the technological complexity of manufacturing exports, this paper constructs a mediating effect model with process innovation and product innovation as the mediating variables to carry out regression tests, and the regression results are shown in Table 4. As can be seen from column (1), the total effect of digital economy (Dig) on the technical complexity of manufacturing exports (LnEs) is significantly positive at the 1% level, and the total effect size is 1.161.

Columns (2) (3) test the mediating effect of process innovation, and since the coefficient of digital economy (Dig) in column (2) is not significant, the mediating effect of process innovation is not significant, and therefore hypothesis H2 is rejected; columns (4) (5) test the mediating effect of product innovation, and the coefficients of digital economy (Dig) in column (4) are significantly positive at 1% level, and both the coefficients of digital economy (Dig) and product innovation (LnPi) are both significantly positive at the 1% level, and the coefficient of digital economy (Dig) is significantly lower than that of column (1), indicating the existence of a partial mediation effect with a magnitude of 0.48 (obtained by multiplying the coefficient of LnPi in column (4) by the coefficient of LnEs2 in column (5)), which accounts for about 41% of the total effect of the digital economy on technological complexity in manufacturing exports (obtained by dividing the above mediation effect by LnEs2 in column (1)). (obtained by dividing the above mediating effect by the LnEs coefficient in column (1)). This result suggests that a mechanism exists for the digital economy to improve the technological complexity of manufacturing exports by promoting product innovation and that this mechanism explains 41% of the total effect of the digital economy on the technological complexity of manufacturing exports, and hypothesis H3 is tested.

Table 4. Intermediary test results

	Direct effect	Intermediary effect			
	（1）LnEs	（2）LnCi	（3）LnEs1	（4）LnPi	（5）LnEs2
Dig	1.161***	-0.0734	1.171***	2.500***	0.683***
	(6.690)	(-0.130)	(7.480)	(5.390)	(4.270)
LnCi			0.138***		
			(6.891)		
LnPi					0.191***
					(8.460)
Control	yes	yes	yes	yes	Yes
C	5.949***	-14.400***	7.939***	-8.275***	7.529***
	(7.130)	(-5.480)	(9.840)	(-3.710)	(10.130)
N	270	270	270	270	270
R^2	0.824	0.770	0.880	0.750	0.890

5.3 Heterogeneity test results

The impact of the digital economy on the technological complexity of manufacturing exports may vary according to regional differences, ownership differences, and urbanization levels. This paper conducts an empirical study from the perspectives of different regions (East, Central and West), different ownership systems (high nationalization, low nationalization) and different urbanization levels (high urbanization, low urbanization), and the regression results are shown in Table 5.

Columns (1) to (3) show that the development of the digital economy (Dig) in the East, Central and Western regions can enhance the technical complexity of manufacturing exports, but the development of the digital economy in the East and Central regions has a significantly stronger effect on the promotion of the technical complexity of manufacturing exports than that in the Western region, which may be attributed to the higher level of development of the digital infrastructure in the East and Central regions, and the degree of digital-real integration is deeper than in the West, so the digital economy has an important impact on the technical complexity of manufacturing exports. Therefore, the digital economy has a stronger stimulating effect on the technical complexity of manufacturing exports. Columns (4) to (5) show that the coefficients of the digital economy are significantly positive and the difference is not large, which indicates that the mechanism of the digital economy to enhance the technological complexity of manufacturing exports is less affected by the level of nationalization of enterprises. On the one hand, the competitive pressure of low nationalized areas is higher, the enterprise internal innovation power is strong, actively seeking digital transformation development opportunities, can better promote the quality of manufacturing export products; on the other hand, the nationalization level of high places, enterprises to obtain policy support, government subsidies are relatively more opportunities, the enterprise digital transformation can get a certain degree of financial support, so the difference between the two is not significant. The results in Column (6) to Column (7) show that the improvement of digital economy in both high and low urbanization areas can enhance the technological complexity of manufacturing exports, but the promotion effect of digital economy on the technological complexity of manufacturing exports is stronger in high urbanization areas. This may be due to the fact that high urbanized areas have higher levels of economic development and more complete information infrastructure, and are better able to obtain high-quality resources and support for the development of high-end digital industries.

Table 5.Heterogeneity test results

	Regional heterogeneity			Ownership heterogeneity		Urbanization heterogeneity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	East	Central	West	High-nationalization	Low-nationalization	High urbanization	Low urbanization
Dig	1.484***	2.348***	0.884**	1.377***	1.329***	1.073***	0.843***

	(6.934)	(5.171)	(2.207)	(4.610)	(8.470)	(5.070)	(2.890)
C	7.646***	9.470***	6.667***	8.285***	3.680***	5.776***	4.839***
	(5.623)	(5.524)	(3.740)	(6.100)	(5.160)	(5.650)	(3.490)
Control	yes	yes	yes	Yes	Yes	yes	yes
N	99	72	99	135	135	135	135
R^2	0.859	0.905	0.812	0.811	0.924	0.848	0.834

5.4Robustness tests

In this paper, a total of three methods are used to conduct the robustness test by replacing the digital economy measurement method, using the digital economy lagged by one period, and the two-stage least squares (2SLS) method, and the test results are shown in Table 6.

First, replacing the digital economy measurement method, using principal component analysis to measure the digital economy instead of the original digital economy measured by the entropy value method, and re-examining the relationship between the digital economy and the technological complexity of manufacturing exports. Second, using the digital economy of one period lagged as the core explanatory variable, in general, the digital economy of the previous period will have an impact on the technical complexity of manufacturing exports in the current period, but the technical complexity of manufacturing exports in the current period will not have an impact on the digital economy of the previous period. Thirdly, two-stage least squares method, the number of Internet broadband access users per year in each province and city is selected to construct the interaction term with the number of post offices per million people in each province in 1984 as the instrumental variable of the digital economy in the region, and the two-stage least squares method is used to identify the causality between the digital economy and the technological sophistication of manufacturing exports. In general, telecommunication infrastructure has a great impact on subsequent digital technology development, but traditional telecommunication tools do not have a significant impact on the technical complexity of manufacturing exports, and the use of this instrumental variable can avoid the endogeneity problem to some extent. According to columns (1) to (4), the effects of replacing the digital economy measures, using the digital economy with one period lag, and the digital economy after two-stage least squares on the technical complexity of manufacturing exports are all significantly positive, i.e., the digital economy can effectively contribute to the improvement of the technical complexity of manufacturing exports, which is in line with the empirical results in the previous section, which indicates that the findings of this paper are robust.

Table 6. Robustness tests

	Replacement of core explanatory variable	Core explanatory variable lagged one period	2SLS	
	（1）LnEs	(2)LnEs	(3)Dig	(4)LnEs
Dig-1	0.059***			
	(0.015)			
L.Dig		1.320***		
		(0.191)		
Tool			0.001***	
			(0.001)	
Dig				2.534***
				(0.650)
Control	yes	yes	yes	yes
C	4.566***	6.993***	15.037***	12.067***
	(0.914)	(0.904)	(1.365)	(1.042)
N	270	240	270	270
R^2	0.830	0.829	0.674	0.736

L.Dig is the first order lag term of Dig

6. CONCLUSION

This paper reveals the mechanism of the digital economy to promote the technical complexity of manufacturing exports from the aspect of product innovation, and empirically examines the mechanism and path of the digital economy to promote the technical complexity of manufacturing exports by using China's inter-provincial panel data from 2014-2022, and the conclusions are as follows: Firstly, the digital economy can significantly promote the improvement of the technical complexity of manufacturing exports, and the level of infrastructure construction, the level of foreign direct investment level can significantly promote the enhancement of the technical complexity of manufacturing exports; Second, the impact of the digital economy on the technical complexity of manufacturing exports there is a product innovation conduction path, i.e., the digital economy enhances the technical complexity of manufacturing exports by improving product innovation capability; Third, the impact of the digital economy on the technical complexity of manufacturing exports is different in different regions and different urbanization levels, of which in the Third, the impact of digital economy on the technological complexity of manufacturing exports varies across different regions and urbanization levels, with the digital economy's contribution to the technological complexity of manufacturing exports being more obvious in the east-central region and high urbanization level regions.

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