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Research on the Impact of Export Technical Complexity of Manufacturing Industry

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***Abstract*—*From a global perspective, this paper matches the World Bank Open Data, the KOF globalization index, the Organization for Economic Cooperation and Development and the data of the IFR, and uses the measurement method proposed by Hausmnn (2007) to measure and analyze the export technical complexity of the world 's major economies from 2000 to 2018.The study found that the application of industrial robots has a significant positive effect on the technical complexity of manufacturing exports, and this conclusion is still valid after a series of robustness tests.*

***Keywords*—** *Export technical complexity; Industrial robot applications; manufacturing.*

I. INTRODUCTION

In order to strengthen the dominant position of domestic manufacturing industry on a global scale, major economies around the world have successively put forward new industrial strategic plans. In 2013, Germany formally proposed the concept of " industrial 4.0 " at the Hannover Messe, emphasizing the integration of manufacturing technology and information and communication technology (ICT). At the same time, the governments of major countries such as the United Kingdom, Japan, and the United States have issued similar reports, including the " Future of Manufacturing: Opportunities and Challenges for the United Kingdom, " the " New Robot Strategy " issued by Japan, and the " Artificial Intelligence Strategy: 2019 Update " and the " National Advanced Manufacturing Strategy " (2022 Edition) issued by the United States. The major economies around the world attach great importance to artificial intelligence, which also shows that intelligent industrial robots have critical practical significance for the transformation and upgrading of traditional manufacturing industries.

Export technical complexity is a comprehensive index that can effectively measure the degree of technological innovation of export products and the quality of export trade. It is also a comprehensive embodiment of the technical content and production efficiency of export products (Hausmnn et al., 2007). Therefore, improving the export technical complexity of manufacturing industry is to improve the technical content of national export products and optimize China 's export trade structure. This is an effective way to change the low-end position of countries in the global value chain division of labor.

II. LITERATURE REVIEW

At present, there are many literatures on the export technical complexity of manufacturing industry, and the influencing factors of export technical complexity are discussed from different angles. Curzi et al. (2012) found that total factor productivity has a positive impact on the export technical complexity of manufacturing industry from the enterprise level. The higher the total factor productivity of the enterprise, the lower the marginal cost, the greater the profit obtained by selling the product, and the enterprise will have more funds for R & D and innovation, so as to promote the export technical complexity of manufacturing industry. Makridakis (2017) found that the higher the degree of global value chain embedding, that is, the more detailed the global division of labor among economies, the more core upstream positions such as technology research and development, and the greater the increase in the technical complexity of manufacturing exports.

The first is the employment effect of industrial robots on the manufacturing industry. For example, Berg et al. (2018) showed that the application of industrial robots can effectively provide higher production capacity and higher production efficiency, and provide more new jobs to promote economic growth. Secondly, the productivity effect, and Kromann et al. (2019) confirmed that the application of industrial robots can promote the improvement of total factor productivity through different methods.

III. THEORETICAL ANALYSIS

Export technical complexity is a discussion of whether the economic development level of a country or region is related to the type of products it produces and exports. It is also a concept that reflects the overall technological content of the economy 's manufacturing export products through the technological content and productivity of export products (Su et al., 2020). Therefore, the technological content and product structure of manufacturing exports will have a direct impact on their export technical complexity. As an iconic technology of the integration of new scientific and technological revolution and manufacturing industry, industrial robots can improve production efficiency and production quality in the manufacturing industry, thus effectively reducing costs, achieving export upgrading, and thus affecting the export technical complexity of the manufacturing industry. From the perspective of technology spillover, the improved productivity and efficiency of industrial robots make it easier for manufacturing enterprises to apply more complex technologies and projects in the manufacturing process (Kailan et al., 2021), thus forcing manufacturing enterprises to optimize R & D, production and management links and upgrade corresponding supporting facilities to meet the requirements of modern and intelligent production ; at the same time, in the face of

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technological changes and organizational changes brought about by the application of industrial robots to large-scale manufacturing production, enterprises will also be forced to increase investment in human capital and improve the level of intelligence of human capital, thus accumulating human resources for technological progress (Wang Jiacheng et al., 2023), thus bringing human advantages to technological innovation. Therefore, this paper proposes the following hypothesis :

H1 : Industrial robot applications can increase the complexity of export technology.

IV. Model Setting and Math

According to the above mechanism analysis and typical facts, the application of industrial robots has an impact on the complexity of export technology. At the same time, the following econometric model is constructed by referring to the practice of Barakat et al. (2023) :

$$\ln Expy_{it} = \alpha + \beta \ln Rob_{it} + \gamma X_{it} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (1)$$

Where i denotes the economy and t denotes the year ; $lnExpy_{it}$ represents the technical complexity of manufacturing export of economy i in t years ; in this paper, $lnRob_{it}$ is the core explanatory variable of industrial robot application level ; X_{it} is the control variable, including global value chain embedding, infrastructure, economic growth, human capital expansion, financial development, information level ; μ_i and v_t represent individual effect and time effect, respectively, to control the individual and time trends that may affect the embodied carbon intensity of manufacturing exports, and ε_{it} represents the random error term.

The explanatory variable is the technical complexity of manufacturing exports, and its measurement method has been improved by scholars from all walks of life on the basis of Hausmann et al. (2007).Therefore, it is clear that the measurement method of Hausmann et al. (2007) is still authoritative and applicable from an international perspective, so this paper still continues its measurement method. Hausmann et al. (2007) believed that the more the number of enterprises involved in a country 's high-productivity industries, the more developed the country 's economy. Based on this, the following indicators are constructed to measure the technical complexity of export products in a sub-sector (*PRODY*) and the overall technical complexity of export products in all sub-sectors of the economy (*Expy*) :

$$PRODY_{kt} = \sum_i \frac{x_{ikt} / X_{it}}{\sum_i x_{ikt} / X_{it}} \times Y_{it} \quad (2)$$

$$EXPY_{it} = \sum_k \frac{x_{ikt}}{X_{it}} PRODY_{kt} \quad (3)$$

Among them, represents the export technological complexity of global manufacturing industry k in period t, x_{ikt}/X_{it} is the proportion of the export volume of k sub-sectors in economy i to the total export volume of the economy, is the per capital real GDP of economy i, and is the export technical complexity of manufacturing industry in economy i in period t.

Global value chain embeddedness (*gvc*) adopts the forward-looking participation index of global value chain, that is, according to the division of foreign exporting countries, the domestic value added of foreign exports accounts for the share of total exports. The infrastructure (*lntran*) is expressed as a composite index of railway and air cargo mileage and is logarithmically processed. Economic growth (*mcv*) is used as a control variable, which is expressed by the ratio of manufacturing value added to GDP. The level of informatization (*ITer*) is expressed as a composite indicator of the percentage of people using mobile broadband and the percentage of people using fixed broadband. Human capital (*lab*) is represented by the percentage of higher education in the labor force. Financial development (*fin*) is used as the control variable, which is represented by the data of the factual level of financial development in the KOFGI database.

The empirical data in this paper cover 56 economies around the world, covering the period from 2000 to 2018. The core explanatory variable of this paper comes from the International Federation of Robotics (IFR) database, which provides industrial robot data for most of the world 's economies and industries, and includes the annual new installed capacity and inventory of industrial robots. It is the most authoritative database for studying robot applications. The intermediary variable total factor productivity comes from the PWT database, and the industrial structure data comes from the WDI database. Other control variables are derived from the WDI database and the OECD database and the KOFGI database.

V. Authentic Proof Analysis

Table 1 shows the baseline regression results of adding control variables in turn to the overall sample. Column (1) examines the impact of the application level of industrial robots on the technical complexity of manufacturing exports. The data show that the coefficient of the application level of industrial robots to the complexity of export technology is positive and significant at the 1 % level. Column (7) is the regression result after gradually adding control variables such as global value chain embeddedness, human capital level, infrastructure, economic growth, informatization level and financial development level on the basis of Column (1).

TABLE 1

variable	(1)	(7)
lnRob	0.0012***	0.0005*
	(4.24)	(1.78)
gvc		0.0027***
		(4.30)
lab		0.0010***
		(2.76)
lntran		0.0677***
		(4.59)
mcv		0.0037***
		(6.87)
iter		0.0003***
		(2.67)
fin		0.0007***
		(3.36)
constant	10.0175***	9.5766***
	(2,717.56)	(176.48)
State fixed effect	yes	yes
Year fixed effect	yes	yes
N	933	761
R-squared	0.925	0.937

Among them, the estimation coefficients of the application level of industrial robots are significantly positive, and the core explanatory variables are relatively stable, which can explain that the application level of industrial robots has a positive effect on the technical complexity of manufacturing exports, which is enough to verify hypothesis 1. Among the seven regression results, the goodness of fit is ideal, which can show that the overall regression fitting of the model is successful.

VI. Robustness Analysis

In this paper, the robustness test is carried out by lagging one period of core variables and dealing with extreme values. First of all, this paper takes the one-period lag of the core variable as the replacement variable. Because the investment cost of industrial robots is high, the requirements for the professional quality of operators are high, and higher operation and maintenance costs and long installation cycles are required. Therefore, there is a possibility that the increase in the density of industrial robots in the current period cannot immediately affect the complexity of manufacturing technology export in the current period. Therefore, this paper uses the application level of industrial robots to lag one period for robustness test. Table 2 column (1) shows the substitution variables, the results are still positive significant. Finally, using the method of eliminating the potential interference of outliers, the bilateral shrinkage of all variables is 1 %, and the results are still positive and significant as shown in column (3). Table 2 shows that the model is always positive and significant, and has passed the robustness test.

TABLE 2

	(1) The core explanatory variable lags one period	(2) shrinkage
L.lnRob	0.0005*	
	(1.9260)	
L.lnExpy		
lnRob		0.0006**
		(2.2952)
gvc	0.0035***	0.0032***
	(5.8443)	(5.1905)
fin	0.0006***	0.0007***
	(2.9969)	(3.3854)
lab	0.0009***	0.0007*
	(2.6029)	(1.9148)
mcv	0.0023***	0.0029***
	(4.2213)	(5.3735)
iter	0.0003***	0.0003**
	(2.8259)	(2.3546)
lntran	0.0766***	0.0726***
	(5.3085)	(5.0590)
constant	9.5909***	9.5984***
	(180.8729)	(183.0629)
State fixed effect	yes	yes
Year fixed effect	yes	yes
N	720	761
AdjustR-squared	0.932	0.934

VII. Endogenous Treatment

About the endogeneity problem, this paper uses two methods, namely the instrumental variable method and the system GMM method. The first is the instrumental variable method, which takes the application level of industrial robots in neighboring countries of GDP as the instrumental variable for 2SLS regression. This is because there is a competitive effect in countries with adjacent GDP: the application of industrial robots is an important factor to effectively improve economic growth, and the application of industrial robots in major manufacturing industries can effectively improve the level of economic development. Therefore, in order to maintain economic growth and manufacturing stability, countries with adjacent GDP will have certain competition in the field of industrial robot applications, that is, there is a certain correlation. However, the application level of industrial robots in other economies will not affect the application level of industrial robots in this economy (ACEMOGLU D et al., 2017). The regression results are shown in Column (2) of Table 3, which show that the results are still positive and significant, and have passed the unrecognizable test and the weak instrumental variable test.

Secondly, using the system GMM method, the explained variables in the previous period may have an impact on the dissolved variables in the current period, that is, there is a certain economic inertia, and the current growth depends on the results of the previous period. Therefore, the dynamic panel data model is used here for robustness testing. It can be seen that the p value of the Hansen test is between 0.1 and 0.25, and the first-order difference of the perturbation term has autocorrelation, that is, the p value of AR (1) is less than 0.1, but the second-order difference of the perturbation term is not allowed to have autocorrelation, that is, the p value of AR (2) should be greater than 0.1, it is obvious that the results of the following table (3) are still positive and significant.

Therefore, the model in this paper assumes that h1 still holds after considering the endogenous problem.

TABLE 2

	(1) IV：FIRST	(2) IV：SECOND	(3) GMM
IV	0.1793***		
	(5.1270)		
lnExpy			0.7823***
			(24.2847)
lnRob		0.0038**	0.0002**
		(2.3429)	(2.2482)
Variable fixed effect	Yes	Yes	Yes
	(4.7865)	(2.1531)	(2.4212)
constant	-31.6570***	9.6506***	2.1147***
	(-4.4574)	(127.6310)	(7.0708)
State fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
N	758	758	721
Adjust R-squared	0.411	0.946	
idstat	27.739***		
widstat	26.286**		
Ar（1）p		0.000	
Ar（2）p		0.944	
hansenp		0.228	

VIII. Conclusions and Implications

Through the above empirical research and theoretical discussion, it can be concluded that the application of industrial robots has a significant positive impact on the technical complexity of manufacturing exports. This paper uses the data of the World Bank, the KOF globalization index, the Organization for Economic Cooperation and Development and the International Federation of Robotics to match the data, and uses the measurement method proposed by Hausmnn et al. (2007) to carry out theoretical discussion and empirical analysis on the export sophistication of major economies in the world from 2000-2018.Finally, the following conclusions are drawn: The first hypothesis proposed in this paper is verified, that is, the application of industrial robots can positively promote the export technical complexity.

Based on this, the following suggestions are put forward.

First, we should combine the local economic development level, formulate a suitable industrial robot strategy, promote the development of industrial robots, so that industrial robots can better promote the development of manufacturing industry, accelerate the upgrading and transformation of manufacturing industry, and optimize the export pattern.

Second, the government should increase the independent research and development of industrial robots, which can more effectively reduce the initial cost of industrial robot applications, while forming a technology spillover effect, faster industrial robots and manufacturing high-speed, high-quality development.

Third, increase the improvement of the quality of the labor force, so that it can adapt to the rapid development of industrial robots, expand the creative effect of industrial robots on jobs, thereby offsetting part of the substitution effect on jobs, and improving the quality of the labor force can accelerate economic development.

Fourth, we should actively carry out the necessary policy adjustments to ensure the rational allocation and flow of all kinds of resources. We should not only rely on the ' invisible hand ' of the market, but also give full play to the role of the government. At the same time, we should also strengthen market competition, increase support for market competition and innovation, identify and further promote advanced technologies and methods that can be saved in the production process, make overall planning and balanced development, promote the improvement of total factor productivity, and improve the technical complexity of manufacturing exports through this path.

Fifth, implement differentiated industrial support policies, give planned support to industries that meet the national key development strategies, high-tech processing and manufacturing, and encourage them to further develop and grow their competitive industries. The country can promote the transformation and upgrading of traditional industries to intelligent and high-quality directions by developing industrial cloud platforms and digital service systems, and at the same time drive the upgrading of industrial services. Then adjust the industrial structure and implement the high-quality development of the manufacturing industry.

Finally, this paper has made corresponding expansions but there are still limitations: First, although this paper starts from a global perspective, it lacks research on specific sub-sectors of the manufacturing industry. The follow-up should strengthen the micro-level of the industry and make more detailed judgments to adapt to the high-quality development of China 's manufacturing industry. Secondly, due to the availability of data, this paper only analyzes the impact of industrial robot applications on the technical complexity of manufacturing exports in 56 economies around the world, and cannot conduct empirical research on all countries.

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