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A Research on Driving Factors of China's Digital Technology Innovation and the Evolution of Factors Based on Technology Cycles

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Abstract: Digital technology is a technology system with multiple technology elements compounded and integrated, and is the fundamental driving force of the new round of technological revolution and industrial change, but the factors driving its innovation are highly complex and dynamic. In order to clarify how the internal and external factors of enterprises drive digital technology innovation, and to clarify the laws of digital technology innovation. Using contribution index and logistic model, this paper empirically analyzes the driving factors that may affect digital technology innovation in China based on financial data, patent data, R&D investment data, and corresponding industry data of 214 listed enterprises in three digital technology fields of computer manufacturing, intelligent equipment manufacturing, and electronic components manufacturing in China during 2008-2020. The results show that: overall, enterprise size is one of the key factors determining digital technology innovation in China, while market competition and industrial structure are the key external factors affecting digital technology innovation in China; market competition has a greater impact on digital technology innovation in private enterprises than state-owned enterprises; high-tech industries are more dependent on the gathering of talents brought by education than non-high-tech industries; computer manufacturing technology mainly goes through the maturity period, while intelligent equipment manufacturing technology is mainly in the growth period, and the innovation activities of these two technologies receive more influence from the market environment; electronic components and their equipment manufacturing technology are more dependent on the internal innovation base of enterprises and the effective allocation of capital and talents in both the budding and growth periods. These results provide useful insights for China to develop differentiated guiding policies in digital technology innovation according to the nature of enterprises and industry attributes.

Keywords: Digital technology innovation, Drivers, Technology lifecycle, Contribution metrics.

1. Introduction

In recent years, the integration of digital technology with all areas of the economy and society has been strengthened in both breadth and depth, and has played an important role in stimulating consumption, boosting investment, creating employment, and innovating development, which has greatly changed the operation of the social economy (Zhao et al., 2020). The report of the 20th Party Congress, the Fifth Plenary Session of the 19th Party Central Committee, the 14th Five-Year Plan and the outline of the 2035 Visionary Goals point out that it is necessary to accelerate digital development, promote the deep integration of the digital economy with the real economy, create digital industry clusters with international competitiveness, and form new advantages in the digital economy, so as to provide a strong basis for high-quality development in the new era and the construction of a new domestic The digital economy has the ability to generate new products and services. The digital economy has a huge potential to give rise to new products, new models, new business models and new industries essentially because the continuous breakthrough and development of digital technology has led to industrial transformation and upgrading (Liu et al., 2020), resulting in the elimination or replacement of some traditional processes and the emergence of a large number of new disruptive technological innovations. The emergence of digital technology can be traced back to the end of the 20th century in the longer term, when Don Tapscott, the "father of the digital economy", proposed in 1996 that digital technology would have a significant impact on the economy and society in the future (Tapscott, Don, 1996) . After continuous evolution, technological change and iterative development, the current digital technologies are mainly emerging technologies such as big data, cloud computing, 3D printing, blockchain, social platforms, and the Internet of Things (Xing et al., 2019; Constance, 2018).

In the analysis of the drivers of digital technology innovation, studies now note the disruptive characteristics of digital technologies (Gregory, 2018; Christensen, 1997), and use them as a logical starting point for antecedent cause exploration. Similar to the antecedents of disruptive innovation formation in traditional industries, digital technology innovation requires internal firm capabilities and external environment as support and undergoes cyclical changes. At the internal level, conventional short-term incentives do not motivate executives to take risks for exploratory innovation (Michel, 2009), but executive stock ownership incentives can significantly increase a firm's investment in innovation (Eric, 2010). The ownership structure of firms can also have an impact on disruptive innovation, with state-owned enterprises focusing more on technological innovation and R&D investment due to their attributes and social roles (Sun et al., 2022), while private firms have fewer innovation resources and relatively less resistance to innovation risk（Wu et al., 2021）. In addition, large established firms will rely on existing technologies and thus rarely engage in disruptive innovation (Antonio et al., 2016; Jason et al., 2015)), but will also allocate R&D investment to more disruptive innovations in highly uncertain markets (Li et al., 2021). With respect to the external environment, governments can favor the sustainability of disruptive innovation through public procurement rules, tax incentives, subsidies, or the provision of intellectual property protection (Jonatan et al., 2014), while the impact of market competition on disruptive innovation is not yet clear (Philipp et al., 2013; Shaker, William, 2000). Regional factor endowments also have a driving effect on disruptive innovation, such as regions with greater social demand and more dynamic demographic change have a stronger capacity for creative destruction (Brett, 2012).

In the literature review of factors influencing disruptive innovation in traditional industries, it was found that most studies treat technology homogenization and acyclicality. In contrast, digital technology innovation has two main characteristics of self-growth and convergence (Yoo et al., 2012; Satish et al., 2019; Holmström, 2018), and has now given rise to a variety of industry segments. Therefore, compared with disruptive innovation in traditional industries, digital technology innovation has obvious characteristics of long-periodicity and dynamism and contains a wide range of subechnology fields (Goldfarb, Tucker, 2019; Christian et al., 2018), and the complex technology system further leads to the heterogeneity of the influence mechanism of drivers, so the drivers of digital technology innovation are also multiple and dynamic, then it is difficult to get accurate research conclusions by analyzing the laws of digital technology innovation under the general paradigm. Based on this, this paper intends to take the disruptive characteristics of digital technology innovation as an entry point, explore the dynamic variability and structural variability of innovation drivers from different fields of digital technology and different technology life cycles, and provide policy recommendations for China to grasp the window of opportunity in digital technology development. The academic innovation of this paper is that, on the one hand, from the attribute characteristics of disruptive digital technology innovation, the set of driving factors and the related theoretical analysis and data analysis are proposed, and the applicability of the traditional set of factors affecting disruptive innovation to explain digital technology innovation is tested and discussed, which is a useful expansion of the context of the application of disruptive technology innovation theory; on the other hand, the application of contribution degree analysis of China's digital On the other hand, it is a useful supplement to the current research related to digital technology and digital economy development in developing economies by applying contribution degree analysis to rank the importance of each driver of digital technology innovation in China and exploring the dynamic variability and structural differences of drivers from different fields and different cycles.

2. Study Design

2.1. Variable indicators and model

2.1.1. Contribution index design

In this paper, we apply the contribution index to assess the impact of different factors on digital technology innovation. Referring to the MQ indicator that considers both the level-value contribution and variance-value contribution of variables in existing studies (Feng et al., 2021), the regression model is set as follows:

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon \qquad (1)$$

Where y is the explanatory variable, x_i is the explanatory variable, ε is the error term, and β_i is the regression coefficient. The contribution index MQ was constructed as:

$$MQ(x_i) = \begin{cases} 0.5QV(x_i) + 0.5QS(x_i),\ if\ p_i \le p_0 \\ 0,\ if\ p_i > p_0 \end{cases} \qquad (2)$$

$$其中QV(x_i) = \begin{cases} \frac{Var(\beta_i x_i)}{Var(\varepsilon)} + \sum_{i=\Omega} Var(\beta_i x_i),\ if\ p_i \le p_0 \\ 0,\ if\ p_i > p_0 \end{cases} \qquad (3)$$

$$QS(x_i) = \begin{cases} |\beta_i \bar{x}_i| / \sum_{i=\Omega} |\beta_i \bar{x}_i|,\ if\ p_i \le p_0 \\ x,\ if\ p_i > p_0 \end{cases} \qquad (4)$$

QV is the variable importance indicator in the variance contribution perspective, QS is the importance indicator in the level contribution perspective, Ω denotes the set of all statistically significant variables, p_i is the p-value of variable x, and p_0 is the critical value of statistical significance.

2.1.2. Logistic model

This paper applies the logistic model to analyze the life cycle of three digital technology subfields, namely, computer manufacturing, intelligent manufacturing and electronic component manufacturing. In this paper, we take time as the horizontal axis and the number of patent applications in the three types of technologies at different times as the vertical axis to build visual graphs and reflect the different stages of the technology life cycle with curve changes. The process of technological innovation rate change is usually represented by an S-curve, and the logistic model-based S-curve used in this paper has become a common classical model for fitting technology life curves due to its intuitive and clear characteristics (John et al., 1998). The specific model is:

$$y(t) = \frac{K}{1+e^{-r(t-t_m)}} \qquad (5)$$

In the above expression, Y represents the value of cumulative utility of digital technology, which is expressed in this paper using the number of patent applications; K is the limit value of cumulative utility of technology, r is the growth rate of technology, and t_m is the time to enter the maturity stage. The main development stages of the technology life cycle can be divided into four stages according to the growth of the logistic model: the budding stage (1% to 10%), the growth stage (10% to 50%), the maturity stage (50% to 90%), and the decline stage (90% to 99%), i.e., the time points when the cumulative utility value of the technology reaches 1%K, 10%K, 50%K, and 90%K are the four stages The patent data required for the logistic model analysis were obtained by searching the Derwent patent database.

2.2. Data sources

First, this paper identifies the basic scope of digital technology based on the report "Statistical Classification of the Digital Economy and its Core Industries" released by the National Bureau of Statistics in 2021. In the industrial classification of this report, the core industries of the digital economy include five categories: digital product manufacturing, digital product service, digital technology application category, digital factor-driven industry and digital efficiency improvement industry. In this paper, we mainly study the law of digital technology innovation in China and measure the degree of digital technology innovation by the patent data of digital technology enterprises, so we eliminate the non-technology enterprises from the report's classification and get three categories of computer manufacturing, intelligent equipment manufacturing and electronic components and equipment manufacturing with more obvious technology features as samples, and the three industry categories also better represent different subtechnology fields of digital technology.

Second, the industry codes of the three subtechnologies were determined by comparing the Statistical Classification of Digital Economy and its Core Industries (2021) and the National Economic Classification of Industries (GB/T 4754-2017), and the data were collected through the RESSET database. As shown in Table 1, these three industry categories are 0101, 0104 and 0105 in the middle category of the Statistical Classification of Digital Economy and its Core Industries, which correspond to some subcategories in 34, 35, 38 and 39 in the C-Manufacturing major category of the Industrial Classification of National Economy. Since there is no data of listed companies directly according to the subcategories in the National Economic Industry Code, in order to collect data of Shanghai and Shenzhen listed companies applying three digital technologies of computer manufacturing, intelligent equipment manufacturing and electronic components and equipment manufacturing, this paper analyzes the main business of Shanghai and Shenzhen listed companies by using RESSET database to screen the sample companies.

Table 1. Selected tables of the Statistical Classification of the Digital Economy and its Core Industries (2021)

Code		Name	National economy industry codes and names (2017)
0101		Computer Manufacturing	
	010101	Computer machine manufacturing	3911 Computer machine manufacturing
	010102	Computer parts manufacturing	3912 Computer parts manufacturing
	010103	Computer peripheral equipment manufacturing	3913 computer peripherals manufacturing
	010104	Industrial control computer and system manufacturing	3914 Industrial control computers and systems manufacturing
	010105	Information security equipment manufacturing	3915 Information security equipment manufacturing
	010106	Other computer manufacturing	3919 Other computer manufacturing
0104		Intelligent equipment manufacturing	
	010401	Industrial robot manufacturing	3491 Industrial robot manufacturing
	010402	Special operation robot manufacturing	3492 special operations robot manufacturing
	010403	Intelligent lighting apparatus manufacturing	3874 Intelligent lighting apparatus manufacturing
	010404	Wearable intelligent equipment manufacturing	3961 Wearable smart device manufacturing
	010405	Intelligent vehicle equipment manufacturing	3962 Intelligent vehicle equipment manufacturing
	010406	Intelligent unmanned aerial vehicle manufacturing	3963 Intelligent unmanned aerial vehicle manufacturing
	010407	Service consumer robots	3964 Service consumer robots manufacturing
	010408	Other intelligent consumer equipment manufacturing	3969 Other intelligent consumer equipment manufacturing
0105		Electronic components and equipment manufacturing	
	010501	Semiconductor device special equipment manufacturing	3562 Semiconductor device special equipment manufacturing
	010502	Electronic components and electromechanical components equipment manufacturing	3563 Electronic components and electromechanical components equipment manufacturing
	010503	Power electronic components and equipment manufacturing	3824 Power electronic components and equipment manufacturing
	010504	Photovoltaic equipment and components manufacturing	3825 Photovoltaic equipment and components manufacturing
	010505	Electrical signal equipment device manufacturing	3891 Electrical signal equipment device manufacturing
	010506	Electronic vacuum device manufacturing	3971 Electronic vacuum device manufacturing
	010507	Semiconductor discrete device manufacturing	3972 Semiconductor discrete device manufacturing
	010508	Integrated circuit manufacturing	3973 Integrated circuit manufacturing
	010509	Display device manufacturing	3974 Display device manufacturing
	010510	Semiconductor lighting device manufacturing	3975 semiconductor lighting device manufacturing
	010511	Optoelectronic device manufacturing	3976 Optoelectronic device manufacturing
	010512	Resistor, capacitor and inductor components manufacturing	3981 Resistor-capacitor-inductor component manufacturing
	010513	Electronic circuit manufacturing	3982 Electronic circuit manufacturing
	010514	Sensitive components and sensor manufacturing	3983 Sensitive components and sensors manufacturing
	010515	Electro-acoustic devices and parts manufacturing	3984 electro-acoustic devices and parts manufacturing
	010516	Electronic special materials manufacturing	3985 Electronic special materials manufacturing
	010517	Other components and equipment manufacturing	3979 Other electronic devices manufacturing 3989 Other electronic components manufacturing 3990 Other electronic equipment manufacturing

Note: Data from the report "Statistical Classification of the Digital Economy and its Core Industries" published by the National Bureau of Statistics on June 3, 2021.

In accordance with the common practice, this paper divides the factors affecting the technological innovation of digital enterprises into internal factors and external environmental factors. Internal factors include a total of enterprise size, enterprise age and debt ratio, etc.; external factors include market competition, the degree of marketization, financial development and economic development, etc. The enterprise data used in this paper are mainly from the Guotaian database, and some data are from the Wind database, including the financial data of A-share listed digital enterprises from 2008 to 2020. Among them, the enterprise patent data are from CNRDS database; the marketization index is from the marketization index by province constructed by Wang Xiaolu et al (Wang. Lian, 2012), and since the official data of the marketization index are only from 2008-2016, the marketization index for 2017-2020 is estimated by using the average growth of the marketization index in previous years as the prediction; the variables related to the region where the enterprise is located, such as per capita GDP, property rights protection, etc. are from the China Statistical Yearbook in previous years. Based on the reliability of the data, the following processing was done: (i) removing enterprises in the financial industry; (ii) excluding ST and PT listed companies; (iii) adding one to the patent data and then natural logarithm processing to reduce missing data. The final unbalanced panel data containing 214 sample firms and 1589 year observations are obtained.

2.3. Model construction and variable definition

In this paper, a panel fixed effects model based on the Driscoll-Kraay standard error is chosen as the benchmark model (Liu et al., 2021). Combining the characteristics of the unbalanced panel data "long N and short T" and the results of the Hausman test requiring the fixed-effects model, it is easier to overcome the heteroskedasticity and autocorrelation problems of the panel data by using the Driscoll-Kraay standard error approach in this paper to mitigate the effects of heteroskedasticity and autocorrelation on the estimation The impact of heteroskedasticity and autocorrelation on the estimation results is mitigated. The model in this paper is specifically set up as follows:

$$innovation_{it} = \beta_0 + \beta_1 x_{1it} + \cdots + \beta_k x_{kit} + Firm_i + Year_t + \varepsilon_{it} \tag{6}$$

Table 2. Variable definition and symbolic representation

Variable Name	Variable Definition	Indication Symbols
Enterprise technology innovation	Natural logarithm of the total number of patent applications + 1	patenta_all
Enterprise size	Natural logarithm of the total assets of the enterprise	size
Enterprise age	Number of years of enterprise establishment	age
Assets and liabilities ratio	Assets and liabilities ratio	leverage
Nature of property rights	Whether it is a state-owned enterprise	SOE
Cash Flow	The proportion of cash to total assets of the enterprise	cash
Return on Assets	Ratio of profit to sales	roa
Equity Concentration	Shareholding ratio of the top ten shareholders	topten
Executive incentives	Natural logarithm of top three executives' remuneration	mancomp
Board Governance	Natural logarithm of the number of board of directors	board_scale
Corporate Growth	Growth rate of corporate operating income	sale
Export Intensity	Ratio of overseas revenue to operating revenue	exprt
Government Subsidies	Proportion of government subsidies to operating revenue	subsidy
Profit Margin	Operating profit as a percentage of total operating revenue	proft
R&D investment	R&D investment as a percentage of operating revenue	rd_scale
Fixed Assets	Total fixed assets as a percentage of total assets	tangible
Enterprise Value	Market capitalization to total assets	tobin
Ratio of independent directors	Number of independent directors to the number of board of directors	indept
Institutional shareholding ratio	Shareholding ratio of institutional investors	ins
Total Factor Productivity	Increase in output due to technological progress or changes in technical efficiency (Lu, Lian, 2012)	tfp_ols
Market Competition	Industry Herfindahl Index	compete
Squared term of market competition	Industry Herfindahl index squared	compete2
Economic growth	Growth rate of provincial GDP	gdpr
Property Rights Protection	Ratio of technology market transactions to GDP	ipp
Human capital	Years of schooling of provincial population	hcap
Marketability Index	Provincial marketability composite index	mkt
Economic Development	Real GDP per capita	gdppc
Industrial Structure	Ratio of tertiary sector output to GDP	third

Where $innovation_{it}$ is the explanatory variable, representing the technological innovation of the ith firm in year t. In this paper, we use the total number of patents filed by listed companies and joint venture affiliates in that year to measure the innovation output of the firm. In order to ensure that all variables can be logarithmicized, the patent data are logarithmicized after adding one to the data in this paper, referring to the conventional practice. Based on the knowledge and theories related to financial performance, strategic environment analysis, and industrial structure, 26 influencing factors indicating the internal conditions and external environment of the firm were sorted out to form explanatory variables x_{1it}, ..., x_{kit}. The selection was therefore based mainly on exploring the drivers of disruptive innovation and concentrated on exploring the literature that affects disruptive technological innovation. The relevant literature on the impact of disruptive technology innovation. $Firm_i$ and $Year_t$ denote individual firm effects and year effects, respectively, to control for the effects of firm's own characteristics and unobservable macroeconomic effects. ε_{it} denotes the error term.

According to the literature and related theories, it can be found that digital technology innovation, like disruptive innovation in traditional industries, is affected by both internal and external factors, among which firm size and age may promote digital technology firms to accelerate the speed of innovation, while the degree of market competition may inhibit the degree of innovation, in addition to factor endowment of the region where the firm is located may also have an indirect effect. Therefore, this paper classifies the factors affecting technological innovation of digital technology firms in China into the following 26 (among which the market competition variable has two manifestations), and the variable definitions and representation symbols are shown in Table 2.

3. Validation Analysis of Innovation Drivers

3.1. Descriptive Statistical Analysis

Descriptive statistical analysis of the explanatory variables was conducted by Stata 16.0 software, and the results are shown in Table 3. The mean value of enterprise digital technology innovation is 3.6646 and the standard deviation is 1.55, which indicates that there is a large difference between the outputs of enterprise technology innovation. The mean value of enterprise R&D investment is 0.0762, implying that the average R&D investment intensity of the sample enterprises is 7.62%. Among the remaining variables, the mean value of the natural logarithm of total enterprise assets is 21.8414, the mean age of enterprises is 17.1032, the mean gearing ratio is 35.43%, the mean return on assets is 3.75%, and the cash-to-assets ratio is 19.33%. Compared with the existing study that included all A-share listed companies, the sample of digital-only companies obtained a higher level of technological innovation activity, a higher percentage of R&D investment, a slightly lower mean return on assets than the data of all A-share listed companies, etc.

Table 3. Descriptive statistics

Main variables	Observed values	Mean values	Standard deviation	Main variables	Observed values	Mean values	Standard deviation
Enterprise technology innovation	1589	3.6646	1.5500	R&D investment	1589	0.0762	0.0842
Enterprise size	1589	21.8414	1.1191	Fixed Assets	1589	0.1863	0.1242
Enterprise age	1589	17.1032	6.5170	Enterprise Value	1589	3.0005	2.1340
Assets and liabilities ratio	1589	0.3543	0.1881	Ratio of independent directors	1589	0.3792	0.0534
Nature of property rights	1589	0.3046	0.4604	Institutional shareholding ratio	1589	0.3407	0.2251
Cash Flow	1589	0.1933	0.1331	Total Factor Productivity	1589	10.6437	1.1766
Return on Assets	1589	0.0375	0.0721	Market Competition	1589	0.2645	0.0519
Equity Concentration	1589	0.5752	0.1633	Squared term of market competition	1589	0.0726	0.0292
Executive incentives	1589	14.4918	0.6813	Economic growth	1589	0.0753	0.0296
Board Governance	1589	2.0886	0.1992	Property Rights Protection	1589	0.0246	0.0374
Corporate Growth	1589	0.2375	1.4610	Human capital	1589	9.5948	1.0143
Export Intensity	1589	0.2631	0.2519	Marketability Index	1589	8.8287	1.6710
Government Subsidies	1589	0.0317	0.4164	Economic Development	1589	6.4303	2.4622
Profit Margin	1589	0.0524	0.3700	Industrial Structure	1589	0.5192	0.1076

3.2. Test of innovation drivers

Table 4 shows the results of the analysis of the main factors affecting technological innovation in digital economy firms using MQ indicators, where column 2 is the estimation result of the panel fixed effects model and column 3 is the MQ indicator. The regression results show that: firm size, firm cash flow, firm value and market competition show significant positive correlation with digital technology innovation, i.e., larger firm size, larger proportion of firm cash, higher proportion of market value to total assets and more intense market competition are more favorable for firms to carry out digital technology innovation activities. In addition, export density, industrial structure and the degree of technological innovation are significantly negatively correlated, indicating that a larger share of overseas income and a larger proportion of tertiary industry output have a dampening effect on digital technological innovation.

The results in column 3 are the relative importance of the explanatory variables. At the intra-firm level, firm size is the most important variable. Similar to disruptive innovation in traditional industries, larger digital firms have a higher level of technological innovation capability, and a gradual increase in firm size can lead to a gradual increase in the efficiency of digital inputs and outputs (Liu et al., 2021). In terms of the external environment, market competition and industrial structure are important factors affecting digital technology innovation, with an MQ indicator of 2.64%. It indicates that digital firms are more willing to carry out innovative activities in a competitive market. The MQ indicator of the year fixed effect in the table reaches 6.564%, indicating that macroeconomic cyclical factor shocks have a certain influence on digital technology innovation. The MQ indicator of the residual term is 23.965%, indicating that there are other factors affecting digital technology innovation that are not included in the model of this paper.

Table 4. Test results of the main determinants of digital technology innovation

Variables	Regression results	MQ indicators
Business Size	0.894*** (0.10)	61.201
Cash Flow	0.436** (0.15)	0.045
Number of Board of Directors	-0.416** (0.15)	0.121
Export Density	-0.421*** (0.11)	0.153
Enterprise value	0.043*** (0.01)	0.163
Market Competition	8.471*** (1.64)	2.640
Squared term of market competition	-9.355*** (1.94)	0.984
Industry structure	-4.164** (1.64)	2.850
Residuals		23.965
Constant term	-15.581*** (2.47)	1.314
Year	Control	6.564
N	1589	
R^2	0.4757	

Note: *, **, and *** represent 10%, 5%, and 1% significance levels, respectively, with standard errors in parentheses; firm and year fixed effects are controlled for; the contribution of the year variable is equal to the sum of the contributions of its dummy variables. Only variables that are statistically significant are shown in the table. Same as in the following tables.

Table 5. Main factors influencing digital technology innovation in enterprises with different property rights

Nature of property rights	State-owned enterprises		Private enterprises	
Variables	Regression Results	MQ Indicators	Regression Results	MQ Indicators
Business Size	1.121*** (0.09)	65.752	0.742*** (0.11)	55.292
Cash flow	0.978*** (0.29)	0.172	0.183 (0.20)	0.000
Return on Assets	-0.311 (0.46)	0.000	-2.190*** (0.45)	0.415
Shareholding Structure	-0.458*** (0.10)	0.061	-0.016 (0.20)	0.000
Number of Board of Directors	-0.848*** (0.17)	0.270	-0.313 (0.21)	0.000
Company Growth	-0.098*** (0.02)	0.032	0.008 (0.01)	0.000
Export Density	-0.584 (0.57)	0.000	-0.533*** (0.14)	0.338
Government Subsidies	-0.368 (1.09)	0.000	-0.268*** (0.05)	0.286
Profit Margin	-0.142** (0.06)	0.070	0.867*** (0.14)	0.556
R&D investment	-0.459 (0.34)	0.000	3.664*** (0.68)	1.141
Fixed Assets	1.317** (0.60)	0.311	-0.077 (0.43)	0.000
Enterprise Value	0.042** (0.02)	0.067	0.060*** (0.02)	0.551
Market Competition	-7.909 (15.55)	0.000	11.141*** (1.65)	5.911
Squared term of market competition	14.409 (27.71)	0.000	-12.854*** (1.98)	2.411
Marketability index	0.195*** (0.06)	2.281	-0.102 (0.06)	0.000
Economic Development	-0.237*** (0.06)	5.201	-0.069 (0.04)	0.000
Residual		18.966		23.905
Constant term	-17.112*** (2.73)	0.889	-14.620*** (1.97)	1.947
Year	Control	5.929	Control	7.248
N	484		1105	
R^2	0.6160		0.4470	

3.3. Heterogeneity test

(1) State-owned enterprises and private enterprises. There is significant heterogeneity in access to innovation policy support among different ownership types of enterprises in China (Zhang, 2021), so enterprises with different property rights nature will also have different choices in facing digital technology innovation activities and variables that affect their technology innovation. Table 5 presents the test results of the key factors of digital technology innovation of firms under different property rights nature.

As can be seen from the table, from the enterprise level, enterprise size has a more important influence in both state-owned enterprises and private enterprises, which is consistent with the benchmark empirical results. From the external environment, the degree of economic development is an important macro factor affecting digital technology innovation in state-owned enterprises; while market competition is an important external factor affecting digital technology innovation in private enterprises, which is because market competition not only increases the pressure of private enterprises to increase R&D investment to form a competitive advantage, but also brings R&D signals. Compared with state-owned enterprises, private enterprises are more likely to produce technological innovation results in the case of fierce market competition.

(2) High-tech and non-high-tech enterprises. According to the test results in Table 6, from the firm level, firm size is still the most important factor influencing firms' digital technology innovation, indicating that the main determinants at the firm level do not change with industry characteristics. In terms of the external environment, human capital and economic growth have the greatest impact on digital technology innovation of firms in high-tech industries, suggesting that the talent gathering brought by education in high-tech industries can effectively promote firms to conduct digital technology innovation. This is due to the fact that high-tech firms need more capital and manpower to carry out innovation activities to reduce the risk of failure, while the talent element gathering can lead to the exchange of heterogeneous knowledge (Shung et al.,2012) , which further promotes digital technology innovation within high-tech industries. While for non-high-tech industries, market competition is the most important factor affecting digital technology innovation.

Table 6. Main factors influencing the digital technology innovation of enterprises under different industry characteristics

Industry Characteristics	High-tech industry		Non-high-tech industry	
Variables	Regression Results	MQ Indicators	Regression Results	MQ Indicators
Enterprise size	1.098*** (0.13)	47.950	0.868*** (0.14)	45.582
Cash flow	-0.063 (0.16)	0.000	0.573** (0.23)	0.018
Gearing ratio	-3.137** (1.16)	0.464	0.018 (0.62)	0.000
Export density	-0.763** (0.33)	0.378	-0.120 (0.12)	0.000
Enterprise value	0.101*** (0.02)	0.760	0.019** (0.01)	0.014
Total Factor Productivity	-0.142 (0.14)	0.000	0.187** (0.08)	1.210
Market Competition	-4.196 (6.57)	0.000	-44.349** (14.52)	18.585
Squared term of market competition	1.443 (8.79)	0.000	88.724*** (27.55)	20.088
Human capital	21.084** (7.05)	3.942	-7.758 (4.46)	0.000
Marketability index	0.326 (0.18)	0.000	-0.166** (0.06)	1.582
Economic growth	-0.447** (0.17)	19.971	-0.020 (0.04)	0.000
Industrial structure	-5.135 (5.25)	0.000	-4.970** (2.07)	1.420
Residuals		20.229		7.957
Constant term	-19.133*** (5.20)	1.579	-7.271*** (1.78)	2.020
Year	Control	4.727	Control	1.526
N	512		1077	
R^2	0.4179		0.5595	

3.4. Robustness tests

(1) Replacement of digital technology innovation indicators. In an environment where the state actively encourages enterprises to engage in technological innovation, the innovation dilemma of strategic innovation at the micro level and "quantity is long but quality is lame" at the macro level has emerged (Chen et al., 2020), resulting in the number of patent applications not effectively representing the technological innovation capability of enterprises. The patent system in China has three types of patents: invention patents, utility model patents and appearance patents, among which invention patents have more stringent application standards and their high level of technical content can well represent the real technological innovation ability of enterprises. This paper

uses two indicators, the number of invention patent applications and the number of patent grants applied for, as further measures of corporate technological innovation in order to analyze the influencing factors of digital technological innovation in China. The results show that firm size is still the most critical firm-level factor influencing digital technology innovation, whether using the number of invention patent applications or the number of final patent applications granted. In terms of the external environment, industrial structure remains the most influential factor when using the number of final patent applications granted as an indicator of technological innovation. However, economic development becomes the most important external factor when measuring digital technology innovation by the number of invention patent applications. Overall, the main results of this paper still hold after changing the measurement method of technological innovation.

Table 7. Robustness tests: changing the measurement of numerical technological innovation

Digital technology innovation measurement approach	Number of invention patent applications		Number of final granted patent applications	
Variables	Regression Results	MQ Indicators	Regression Results	MQ Indicators
Firm size	0.978*** (0.10)	60.674	0.738*** (0.10)	35.081
Age of the firm	0.081 (0.06)	0.000	0.131*** (0.03)	31.384
Cash flow	0.311** (0.13)	0.022	0.321** (0.13)	0.025
Gearing	-1.105 (0.59)	0.000	-1.074*** (0.33)	0.081
Executive incentives	0.273*** (0.06)	1.304	0.139 (0.10)	0.000
Number of Board of Directors	-0.406** (0.15)	0.105	-0.218 (0.11)	0.032
Export Density	-0.623*** (0.20)	0.318	-0.271 (0.13)	0.064
Government Subsidies	0.018 (0.07)	0.000	-0.069 (0.03)	0.011
Enterprise value	0.037*** (0.01)	0.110	0.029** (0.01)	0.070
Proportion of sole directors	-1.582** (0.63)	0.094	0.046 (0.52)	0.000
Total Factor Productivity	0.012 (0.07)	0.000	0.182*** (0.05)	1.468
Market Competition	8.392*** (1.54)	2.455	5.636 (3.04)	0.000
Squared term of market competition	-9.621*** (1.96)	0.991	-7.050 (4.19)	0.000
Marketability Index	-0.102 (0.06)	0.000	-0.075** (0.03)	0.449
Economic Development	-0.161*** (0.05)	3.738	-0.061 (0.04)	0.000
Industrial structure	-1.706 (1.83)	0.000	-4.839** (1.81)	3.868
Residuals		25.452		25.815
Constant term	-19.997*** (3.12)	1.402	-14.881*** (1.75)	0.972
Year	Control	3.335	Control	0.679
N	1589		1589	
R^2	0.4680		0.5338	

(2) Changing the statistically significant critical value. In order to avoid the influence of the subjective choice of 5% as the statistically significant threshold, this paper further uses the statistically significant threshold criteria of 2.5% and 7.5% for the regression test and compares the regression results of the three thresholds. According to the empirical results, firm size is still the most important firm-level factor influencing firms' digital technology innovation. In terms of external environment, market competition and industrial structure are the two most important influencing factors. The above results show that the results of this paper on the drivers of digital technology innovation in China do not change significantly after changing the critical value criteria for statistically significant values.

Table 3. Robustness test: changing the statistically significant threshold

Statistical significance criteria	2.5%	5%	7.5%
Variables	MQ Indicators	MQ Indicators	MQ Indicators
Business size	62.213	61.201	60.281
Cash flow	0.048	0.045	0.05
Number of Board of Directors	0.126	0.121	0.119
Export density	0.161	0.153	0.151
Enterprise value	0.169	0.163	0.161
Market Competition	2.781	2.640	2.603
Squared term of market competition	1.038	0.984	0.970
Economic Development	0.000	0.000	1.443
Industrial structure	0.000	2.850	2.810
Residual term	25.291	23.965	23.633
Constant term	1.252	1.314	1.312
Year	5.919	6.564	6.472

(3) Adjustment of the study sample. (1) Excluding the observations with zero patents. In this paper, the natural logarithm of the patent data is done after adding one to the patent data when using the patent data to measure the technological innovation output of enterprises, which avoids the bias caused by the right-skewed distribution of the patent data itself to the results and increases the sample size. However, the results may be biased due to the fact that some enterprises did not generate innovation output from patents in some years. Since zero technological innovation in the data means that the enterprises did not engage in technological innovation activities in that year, this paper therefore removes the observations where the variable is zero and observes whether the results change due to data adjustment. The results show that the contribution of firm size is the highest among the internal factors when the observations with zero technological innovation variable are excluded. In terms of external influences, industrial organization is still the most critical variable influencing firm technological innovation; (2)Excluding observations with 1% at each end of firm age. The results of the baseline regression in this paper show that firm size contributes the most among all internal factors, i.e., it is the most important for firms' digital technology innovation. This result may be caused by the high number of observations at both ends of the firm size in the sample, and the method of removing observations at both ends is referred to previous literature to eliminate the effect of this possibility. For this reason, we remove 1% of the observations at both ends of the sample and conduct the empirical analysis again. The empirical results show that firm size is still the most important internal influence, and market competition and industry structure are the most influential external factors. It can be seen that after adjusting the sample, the key results of this paper still hold.

3.5. Discussion of the results

(1) The empirical test shows that the important factors affecting digital technology innovation in China are enterprise scale, market competition and industrial structure. In fact, countries have launched their digital development strategies one after another in order to enhance their international leadership in the new round of technological revolution. However, due to the different national systems, technological bases, degree of economic development and social environment among countries, the strategic focus of each country has been reflected differently (Liu et al., 2019). For example, the U.S. National Cyber Strategy and the U.K. Industrial Strategy: Action in Artificial Intelligence mentioned the promotion of government-enterprise cooperation and emphasized the important role of government in the development of digital technology; the EU Artificial Intelligence Strategy and the Japanese Comprehensive Innovation Strategy both encouraged the increase of talent training and introduction to stimulate innovation. In addition to the national strategies announced by each country, some foreign scholars have also studied the influencing factors of corporate digital innovation and concluded that the digital innovation capability of companies is related to the personal characteristics of entrepreneurs (João et al., 2019). Similar to the leading countries in digital technology development, in the empirical results this paper also found the role of government subsidies in different technology life cycle stages and the important driving influence of human resources. However, in the context of our country, it is found that the transformation of the industrial structure to tertiary industries inhibits the development of digitalization in manufacturing.

(2) Although both digital technology innovation and disruptive innovation in traditional industries are influenced by the internal and external environments of firms, the empirical evidence reveals that the conclusions drawn from previous literature are not fully applicable to the digital technology field. First, in the same way as disruptive innovation in traditional industries, firm size plays a dominant role in driving innovation, while the impact of firm age on digital technology innovation is not significant. In fact, most of the current innovations in digital technology in China are concentrated in large enterprises and some young enterprises have the potential to innovate; second, the empirical results found that market competition plays a more important role in the process of digital technology innovation, because compared with the disruptive innovation in traditional industries, digital technology innovation iterates rapidly and new products are updated more frequently, and digital enterprises Finally, unlike the existing literature that emphasizes the driving role of government subsidies on disruptive innovation, the empirical results show that the impact of government subsidies on digital technology innovation is not significant. The reason may be that the incentive effect of government subsidies is influenced by firms' own resource abundance and willingness to invest, while digital technology innovation generally departs from the original technology track to integrate new knowledge and technology, which is characterized by long investment cycle,

high payback risk and high exit cost. These characteristics affect the enthusiasm of enterprise executives to carry out innovation activities, and may lead to "rent-seeking" behavior of enterprises, i.e., the government subsidies received by enterprises are not used for digital technology innovation, but for low-quality innovation activities, which has a "crowding-out" effect on digital technology innovation. The "crowding out" effect on digital technology innovation.

In summary, digital technology innovation and traditional technology innovation have both similarities and differences in terms of drivers, based on which this paper further explores the driving law of digital technology innovation by taking different technology fields and life cycles as research objects.

4. Differences in Innovation Drivers Under Different Technology Cycles

Historically, the innovation and development of emerging technologies in each major technological revolution is a long and dynamic process with cyclical characteristics. There are also significant differences in the dominant factors driving technological innovation in different cycle stages, and the innovation and development of digital technology is no exception. However, it is worth noting that digital technology is a multi-dimensional technology system composed of different subtechnology fields, and although different subtechnology fields share or support each other in terms of technical elements, or even complement each other in terms of market demand, they are not synchronized in terms of technology maturity and innovation progress. Therefore, in this paper, with the help of Loglet Lab 4.0 software, the technology life cycle of three digital technology subfields in the overall sample, computer manufacturing, smart device manufacturing, and electronic components and equipment manufacturing, is divided into different cycles during 2008-2020, and if so, the innovation drivers of the three digital technology subfields in this time period are examined in groups. to analyze the differences in digital technology innovation drivers under different cycle stages.

4.1. Life cycle of computer manufacturing technology and changes in innovation drivers

In order to predict the life cycle of computer manufacturing technology in China, this paper uses the Derwent database to collect the patent application data of this technology in China, and retrieves the keywords of computer whole machine manufacturing, parts manufacturing, peripheral equipment manufacturing, industrial control computer, etc., and then uses Loglet Lab 4.0 software to fit. According to the fitting results, the budding period of China's computer manufacturing technology is 1993-2002, the growth period is 2003-2010, the maturity period is 2011-2018, and the decline period is 2019-2026, which is currently in the decline period. The goodness-of-fit R2 value is 0.741, which is a relatively good fit. From the patent saturation value K, the saturation value of computer manufacturing is 564, which indicates that China is currently active in innovation activities in this technology area. The technology growth rate r is 0.277, and the innovation efficiency in the field of computer manufacturing technology is more obvious. The technology life cycle curve is obtained as shown in the figure. 1993 is a key node, and the number of patent applications for computer manufacturing in China grows from relatively blank to low; 2010 is the turning point of the growth rate of this technology, and the growth rate gradually slows down thereafter; the development of this technology tends to saturate in 2019.

Table 9. Computer Manufacturing Technology Life Cycle Fitting Results

Fitting parameters	K	t_m	$t_{0.1\text{-}0.9}$	r	R^2
	564	2010	15.9	0.277	0.741
Phase division	Budding stage	Maturing stage	Mature stage	Declining stage	Current stage
	1993-2002	2003-2010	2011-2018	2019-2026	Declining stage

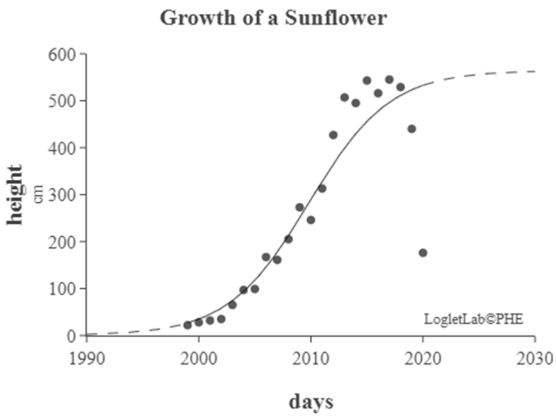

Figure 1. Digital Product Manufacturing Technology Life Cycle Curve

According to the fitting results, China's computer manufacturing technology has experienced the budding, growing, maturing and declining periods. After the development of the first decade of the 21st century, the global technological innovation pattern has changed significantly, international trade has become increasingly intense, and the breakthrough of core technologies in key areas has become an important support for latecomer countries to catch up (Zhang, Yan, 2022); China has started to take the independent innovation path with Chinese characteristics, and the innovation-driven development concept has become the consensus of Chinese enterprises, while China's computer manufacturing technology mainly belongs to the maturity period during this period. Therefore, this paper mainly lists the driving factors of computer manufacturing technology innovation in the maturity period, and the conclusions obtained can give better suggestions for China to carry out independent innovation. The regression results show that the age of enterprises is the main influencing factor in the maturity stage of computer manufacturing technology in China, besides the marketability index and economic development are also important, with MQ indicators of 3.805% and 4.977% respectively. China's computer manufacturing technology form has been very mature, it is more difficult to innovate at this time, and the innovation activities are only concentrated among a few mature enterprises at this time.

Table 10. Main determinants of technological innovation under different stages of computer manufacturing technology life cycle

Computer manufacturing technology	Mature stage	
Enterprise Age	Regression results	MQ indicators
Export Density	0.386^{**} (0.11)	56.364
Enterprise value	-0.948^{**} (0.34)	0.190
Total Factor Productivity	0.104^{**} (0.04)	0.164
Market Competition	0.278^{**} (0.12)	1.046
Marketability Index	3.698^{***} (0.65)	0.097
Economic Development	-0.455^{***} (0.05)	3.805
Residuals	-0.422^{***} (0.11)	4.977
Constant term		32.736
Year	-4.292 (6.14)	0.444
Computer manufacturing technology	Control	0.177
N	326	
R^2	0.5129	

4.2. Life cycle of smart device manufacturing technologies and changes in innovation drivers

In order to predict the life cycle of smart device manufacturing technology in China, this paper uses the Derwent database to collect the patent application data in this field in China, and retrieves the keywords of industrial robot manufacturing, special operation robot manufacturing, and wearable smart device manufacturing, and then uses Loglet Lab 4.0 software to fit. The fitting results are shown in the table. The budding period of smart device manufacturing in China is 2001-2009, the growth period is 2010-2018, the maturity period is 2019-2026, and the decline period is 2027-2034, and it is currently in the maturity period. The goodness-of-fit R2 reaches 0.9, which is a very good fit. The patent saturation value K for smart device manufacturing is only 399, indicating that the innovation activity in this area is not particularly active in China at present. The technology growth rate r is 0.283, and the technology life cycle curve also shows that smart device manufacturing is developing very rapidly and the innovation efficiency is very obvious.

Table 11. Smart Device Manufacturing Technology Life Cycle Fitting Results

Fitting parameters	K	t_m	$t_{0.1\text{-}0.9}$	r	R^2
	399	2018	15.6	0.283	0.900
Phase division	Budding stage	Maturing stage	Mature stage	Declining stage	Current stage
	2001-2009	2010-2018	2019-2026	2027-2034	Mature stage

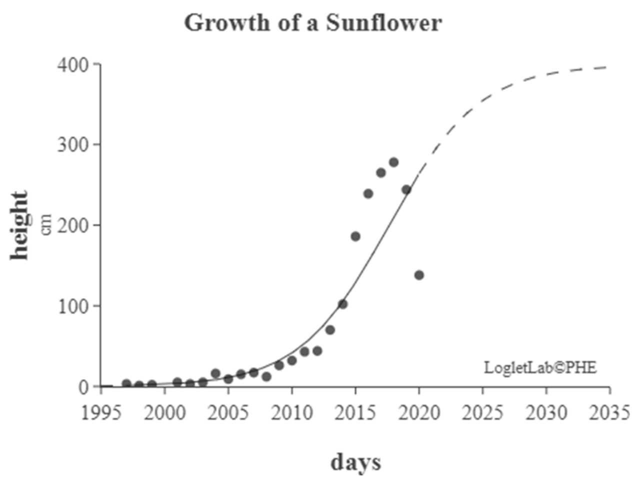

Figure 2. Smart device manufacturing technology life cycle curve

"Made in China 2025" released in 2015 clearly proposed to accelerate the deep integration of new generation information technology and manufacturing industry, and specified to promote intelligent manufacturing as the main object. Since the implementation of "Made in China 2025", China's smart manufacturing has shown good and strong development momentum, and it is found that China's smart manufacturing technology is in the growth period through the technology life cycle judgment, and the smart manufacturing technology is mainly in the growth period in the sample time period, so this paper mainly analyzes the innovation driving factors of smart device manufacturing technology in the growth period to summarize the experience of smart device manufacturing technology development. The regression results are shown in Table 12. In the growth period of smart device manufacturing technology, enterprise size and enterprise age are the two most important internal influencing factors, and total factor productivity and economic development are the two key external influencing factors. Robotics in smart device manufacturing is one of the truly competitive products in China's digital technology development, but China's current innovation input intensity in this area is high, but output conversion is difficult, so total factor productivity becomes a key external factor.

Table 12. Main determinants of technological innovation under different stages of smart device manufacturing technology life cycle

Intelligent device manufacturing technology	Maturing stage	
Enterprise size	Regression results	MQ indicators
Enterprise age	0.827*** (0.21)	12.271
Asset Debt Ratio	0.375** (0.14)	49.238
Return on Assets	-1.240** (0.42)	0.212
Board Governance	-2.834** (1.02)	0.156
Corporate Growth	-0.741** (0.31)	0.119
Government Subsidies	-0.231*** (0.07)	0.023
Proportion of sole directors	1.581** (0.48)	0.022
Total Factor Productivity	1.870** (0.71)	0.041
Economic Development	0.723** (0.24)	6.229
Industrial Structure	-0.525*** (0.14)	7.942
Residuals	-9.528** (4.00)	2.295
Constant term		20.830
Year	-7.705** (3.32)	0.483
Intelligent device manufacturing technology	Control	0.139
N	146	
R^2	0.7908	

4.3. Life cycle of electronic components and equipment manufacturing technology and changes in innovation drivers

In order to predict the life cycle of electronic components and equipment manufacturing technology in China, this paper uses the Derwent database to collect the patent application data in this technology field in China, and the search keywords are special equipment manufacturing for semiconductor devices, electronic components and electromechanical components equipment manufacturing, and power electronic components manufacturing, etc., and then uses Loglet Lab 4.0 software to fit. The fitting results are shown in the table, the budding period of electronic components and equipment manufacturing in China is 2008-2014. The growth period is 2015-2020, the maturity period is 2021-2026, and the decline period is 2027-2032, which is currently in the growth period. The goodness-of-fit R2 value is 0.830, which is a very good fit. The patent saturation value reaches 4660, indicating that the technological innovation activities of electronic components and equipment in China are still very active. The technology growth rate reaches 0.383, which is the fastest growth rate among the three technologies, and the innovation efficiency is more obvious. However, the technology life cycle shown in the fitted results does not match the actual development of electronic components and equipment manufacturing technology in China. After analysis, it is found that the patent data retrieved according to the scope of electronic components and equipment manufacturing technology given in the Statistical Classification of Digital Economy and its Core Industries (2021) mainly reflects the innovation of two types of technologies in electronic components and equipment manufacturing, namely integrated circuits and chips. Therefore the fitted technology life cycle represents probably the development history of integrated circuit and chip technologies in China, and the fitted results are similar to the realistic development of integrated circuits and chips in China.

Table 13. Electronic Components and Equipment Manufacturing Technology Life Cycle Fitting Results

Fitting parameters	K	t_m	$t_{0.1\text{-}0.9}$	r	R^2
	4600	2020	11.5	0.383	0.830
Phase division	Budding stage	Maturing stage	Mature stage	Declining stage	Current stage
	2008-2014	2015-2020	2021-2026	2027-2032	Mature stage

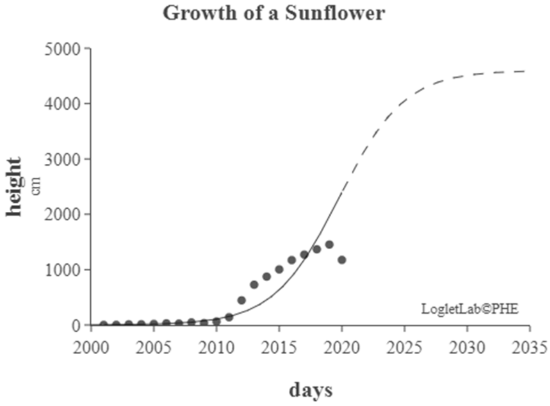

Figure 3. Electronic components and equipment manufacturing technology life cycle curve

According to the fitting results, China's electronic components and equipment manufacturing technology has gone through two stages, the budding stage and the growth stage. Table 14 shows the results of the analysis of the main factors affecting technological innovation in electronic components and equipment manufacturing using the MQ indicator. The regression results show that the most critical internal factor influencing technological innovation in the budding stage of this technology is enterprise size, and it is noteworthy that human capital is the external factor with the greatest degree of influence, with the MQ indicator reaching 26.724%. In the growth stage, enterprise size is still the most important internal influencing factor, and total factor productivity and property rights protection are the two most critical external influencing factors. Electronic components and equipment manufacturing in integrated circuits, chip technology has been the weak link in the development of China's digital technology, the investment in innovative projects and scientific talent directly affect the breakthrough of core technology. At the same time, the same as robot manufacturing chip technology also faces the problem of difficult input conversion output, so the improvement of total factor productivity in electronic components and equipment manufacturing technology growth period has a very important impact on innovation.

Table 14. Main determinants of technological innovation under different stages of the technology life cycle of electronic components and equipment manufacturing

Electronic components and equipment manufacturing technology Enterprise Size	Budding stage		Maturing stage	
	Regression results	MQ indicators	Regression results	MQ indicators
Government Subsidies	0.626** (0.21)	28.242	0.706*** (0.10)	53.710
R&D investment	-1.809** (0.66)	0.030	-0.510 (0.61)	0.000
Total Factor Productivity	0.865 (0.55)	0.000	3.469*** (0.76)	1.018
Market Competition	-0.297 (0.33)	0.000	0.306*** (0.07)	6.283
Squared term of market competition	-75.141** (22.46)	16.853	-102.369 (48.81)	0.000
Economic growth	132.084*** (35.22)	12.939	188.152 (90.59)	0.000
Property rights protection	-8.221** (2.70)	0.183	4.660** (1.90)	0.271
Human capital	-19.840** (6.01)	2.650	-16.409*** (3.59)	5.557
Residuals	0.915*** (0.14)	26.724	-0.274 (0.17)	0.000
Constant term		11.108		32.814
Year	-0.573 (3.84)	0.140	2.536 (6.30)	0.306
Electronic components and equipment manufacturing technology	Control	0.226	Control	0.042
N	314		887	
R^2	0.3347		0.4364	

4.4. Discussion of Results

The above analysis also reveals that the factors that play a dominant role in the life cycle of different sub-technologies differ. Firstly, since the retrieved electronic components and equipment manufacturing patent data focused on the innovation of two technologies, integrated circuits and chips, the fitting obtained only the life cycle of these two types of technologies. Comparing the technological innovation drivers in the growth period of smart device manufacturing and electronic component and device manufacturing, we can find that IC and chip technologies rely more on the influencing factors that have a direct role in technological innovation, such as intellectual property protection and corporate R&D investment, while the empirical results of technological innovation drivers in smart device manufacturing show the importance of the innovation environment, such as corporate governance, economic development and industrial structure all indirectly influence the innovation capability of firms. These two technologies are the key core technologies of digital technology, and they are also in the "neck" dilemma of China’s digital technology development. The empirical results show that the coordination between internal innovation resources and external environment of enterprises needs to be further strengthened.

5. Conclusions and Prospects

5.1. Conclusion

The development of digital economy depends on the continuous disruptive innovation and industrial application in the field of digital technology. This paper determines the main drivers of digital technology innovation in China based on the set of disruptive innovation drivers, combined with the factor contribution index evaluation method, and applies the logistic model to visualize the life cycle of three key technologies, examines the importance degree of each driver through the data of listed companies, and analyzes the structure of factors caused by different property rights nature, industry characteristics and technology life cycle stages changes. The main conclusions obtained are:

(1) Through the validation analysis of innovation drivers, it is found that firm size is the key internal factor determining digital technology innovation in China, and market competition and industrial structure are the key external factors determining digital technology innovation in China, which is different from the conclusion that firm strategic orientation and dynamic capabilities drive disruptive innovation reached in general contexts, and also explains to some extent the current digital transformation faced by Chinese firms in the The dilemma that Chinese companies are facing in digital transformation.

(2) The nature of property rights and industry characteristics can change the main influences on digital technology innovation. Specifically, in digital technology innovation in China, market competition has a greater impact on digital technology innovation in private enterprises; high-tech industries are more dependent on the talent gathering brought by education than non-high-tech industries.

(3) With regard to the empirical analysis of the drivers under different technology life cycles, the results show that the main factors influencing technological innovation vary among different subtechnologies and at different stages of the technology life cycle. Specifically, technological innovation activities in computer manufacturing technology are more likely to be influenced by market environment factors in the maturity stage; similarly, the external environment plays an important role in technological innovation in the growth stage of smart device manufacturing technology; while technological innovation in the nascent and growth stage of electronic component and equipment manufacturing technology directly depends on internal R&D investment and intellectual property protection factors.

5.2. Suggestions for countermeasures

(1) Further strengthen the main position of enterprises in digital technology innovation and establish a guarantee mechanism for innovation of leading enterprises in digital economy. This study shows that larger digital technology enterprises have more motivation and ability to promote disruptive innovation in digital technology, and are conducive to promoting innovation in the whole industry, reducing production costs and improving the local industrial ecology. Therefore, we should clarify the main position of leading digital technology enterprises in innovation, improve the digital technology industry chain innovation chain to form an internationally competitive digital technology innovation ecology through measures such as intellectual property protection and opening up a large national unified market; improve the institutional mechanism for conversion of digital technology innovation results, accelerate the improvement of digital technology talent training supply capacity, and promote the convergence of scientific and technological talents of leading digital technology enterprises. Cultivate and enhance their fundamental motivation to lose the disruptive innovation of digital technology; focus on guiding and promoting R&D cooperation between digital technology leading enterprises, R&D institutions and universities to promote the aggregation of digital technology innovation elements.

(2) Give full play to the institutional and institutional advantages of innovation breakthroughs in key segments of digital technology, and promote the enhancement of China’s innovation competitiveness in key areas of digital technology. This paper shows that property rights structure, industry characteristics and subtechnology categories all have a perturbing effect on innovation drivers. In the context of digital technology self-growth giving rise to a series of segments, such perturbations lead to a high degree of uncertainty in the direction of innovation and breakthroughs in digital frontier technologies, time windows, and the waxing and waning of competitive ability among countries. We should give full play to the advantages of the institutional mechanism of key technology innovation, apply the new nation-raising mechanism, "unveiling the list to hang" and so on to strengthen the convergence of innovation resources in the key areas of digital technology, increase the intensity of investment and policy incentives in the fields of integrated circuits and artificial intelligence, accelerate the training of talents in the key areas of digital technology, social capital guidance to Concentrate on breaking technical bottlenecks, and break the "neck" dilemma faced in some fields of digital technology as soon as possible.

(3) Seize the window of opportunity for dynamic adjustment in different subfields and development cycles of digital technology innovation, and promote the leapfrogging

of digital technology innovation capability. In the different stages of digital technology development, due to the differences in internal resources and external environment, the driving factors and innovation opportunities of technological innovation show significant dynamic characteristics. For the digital technology subfield in the budding stage, the training reserve of human resources should be guaranteed, while for the digital technology subfield in the rapid growth stage, a favorable institutional environment should be created for enterprises and the main status of innovation should be guaranteed to strengthen the motivation of enterprises to promote digital technology innovation and to promote the continuous development of innovation activities, and the government and enterprises should strengthen cooperation to promote the coordination of internal and external resources and technology The government and enterprises should strengthen the cooperation to promote the coordination of internal and external resources and knowledge, narrow the gap between China and the world's leading countries, and achieve high-quality development of digital technology.

5.3. Limitations and Prospects

First, digital technology is the result of continuous reorganization, evolution and innovation of technologies in multiple fields in the past decades, and it is a technology system that integrates multiple technological elements, and the set of factors that drive its innovation is highly complex and dynamic. This paper proposes the possible set of factors that drive digital technology innovation in China based on the factors that drive disruptive technological innovation proposed in the existing studies, whether these factors can comprehensively summarize Second, with the further evolution of the technology system, the key forms of digital technology may also undergo important changes and form newer sub-domains, such as quantum computing, virtual reality, and some unknown fields, and subsequent studies can continue to focus on and discuss the driving factors of digital technology innovation with new technology fields as the research objects. Third, due to the availability of data and the limitations of the research method, this paper does not consider the situation of non-listed companies on the one hand, and the correlation between computer manufacturing, intelligent manufacturing and electronic components and equipment manufacturing technologies on the other hand, as well as the possible dynamic changes of the drivers of digital technology innovation in the new sample space after the inclusion of non-listed companies and the existence of technological correlation, which is also worth improving and expanding in future research. This is an area worth improving and expanding in future research.

References

[1] Zhao T, Zhang Z, Liang Shangkun. Digital economy, entrepreneurial activity and high quality development - empirical evidence from Chinese cities[J]. Management World, 2020, 36(10):65-76.

[2] Liu Y, Xie K, Deng H-L. Data-driven product development transformation: a case study of adaptive organizational practice change perspective[J]. Management World,2020,36(3):164-183.

[3] Tapscott, Don. The digital economy: Promise and peril in the age of networked intelligence [M]. New York: Mc Graw-Hill, 1996.

[4] Xing, Xiaoqiang, Zhou, Pinglu, Zhang, Zhu, Tang, Xinhui. Digital technology, BOP business model innovation and inclusive market construction [J]. Management World, 2019, 35(12):116-136.

[5] Constance E Helfat, Ruth S Raubitschek. dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems[J]. Research Policy, 2018, 47(8) : 1391-1399.

[6] Gregory Vial. Understanding digital transformation: a review and a research agenda [J]. Journal of Strategic Information Systems, 2019, 28(2) : 118-144.

[7] Christensen C. The innovator's dilemma: When new technologies cause great firms to fail [M]. Boston, MA: Harvard Business School Press, 1997: 56-57.

[8] Michel Avital, Dov Te'eni. From generative fit to generative capacity: Exploring an emerging dimension of information systems design and task performance[J]. Information Systems Journal, 2009, 19(4) : 345-367.

[9] Eric A Fong. Relative CEO Underpayment and CEO Behaviour Towards R&D Spending[J]. Journal of Management Studies, 2010, 47(6) : 1095-1122.

[10] Sun, Linjie, Peng, Lixia, Sun, Wanjun. Study on the correlation between R&D cost stickiness and technological innovation performance[J]. Scientific Research,2022,40(04):695-703.

[11] Wu W.W.,Zhang T.I.. A study on the asymmetric effects of non-R&D subsidies and R&D subsidies on innovation output of start-up firms[J]. Management World, 2021,37(3):137-160+10.

[12] Antonio Ghezzi et al. A role for startups in unleashing the disruptive power of social media [J]. International Journal of Information Management, 2016, 36(6) : 1152-1159.

[13] Jason Dedrick et al. Adoption of smart grid technologies by electric utilities: factors influencing organizational innovation in a regulated adoption of smart grid technologies by electric utilities: factors influencing organizational innovation in a regulated environment[J]. Electronic Markets, 2015, 25(4) : 335-335.

[14] Li YH, Jane Z. From incremental innovation to disruption. From incremental to disruptive innovation: a mechanism for technological breakthroughs[J]. China Industrial Economics, 2021(9):5-24.

[15] Jonatan Pinkse, Rene Bohnsack, Ans Kolk. The Role of Public and Private Protection in Disruptive Innovation: The Automotive Industry and the Emergence of Low-Emission Vehicles[J]. Journal of product innovation management, 2014, 31(1) : 43-60.

[16] Philipp Klenner, Stefan Hüsig, Michael Dowling. Ex-ante evaluation of disruptive susceptibility in established value networks- When are markets ready for disruptive innovation? When are markets ready for disruptive innovations? Research Policy, 2013, 42(4) : 914-927.

[17] Shaker A Zahra, William C Bogner. Technology strategy and software new ventures' performance[J]. Journal of Business Venturing, 2000, 15(2) : 135-173.

[18] Brett Anitra Gilbert. Creative destruction: Identifying its geographic origins[J]. Research Policy, 2012, 41(4) : 734-742.

[19] Yoo Y, Boland R J, Lyytinen K , et al. Organizing for Innovation in the Digitized World[J]. Organization Science, 2012, 23(5) : 1398-1408.

[20] Satish Nambisan, Mike Wright, Maryann Feldman. The digital transformation of innovation and entrepreneurship: progress, challenges and key themes[J]. themes[J]. Research Policy, 2019, 48(8) : 103773-103773.

[21] Jonny Holmström. Recombination in digital innovation: Challenges, opportunities, and the importance of a theoretical framework[J]. Information and Organization, 2018, 28(2) : 107-110.

[22] Avi Goldfarb, Catherine Tucker. digital economics [J]. Journal of Economic Literature, 2019, 57(1) : 3-43.

[23] Christian Hopp et al. Disruptive innovation: conceptual foundations, empirical evidence, and research opportunities in the digital age[J]. Journal of Product Innovation Management, 2018, 35(3) : 446-457.

[24] Feng, Gen-Fu, Zheng, Ming-Bo, Wen, Jun, and Zhang, Cun-Bing. What factors actually determine Chinese firms' technological innovation--re-empirical evidence based on data from nine authoritative Chinese economics journals and A-share listed companies[J]. China Industrial Economics, 2021 (1):17-35.

[25] Wang Xiaolu, Fan Gang, Yu Wenjing. China marketization index report by provinces (2016) [M]. Beijing:Social Science Literature Press,2017.

[26] John C. Driscoll and Aart C. Kraay. Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data[J]. The Review of Economics and Statistics, 1998, 80(4) : 549-560.

[27] LU Xiaodong, LIAN Yujun. Total factor productivity estimation of industrial enterprises in China:1999-2007[J]. Economics (Quarterly),2012,11(02):541-558.

[28] Liu, S.C., Yan, J.C., Zhang, S.X., and Lin, H.C.. Can digital change in enterprise management improve input-output efficiency[J]. Management World,2021,37(05):170-190+13.

[29] Zhang J. A study on the mixed incentive effects of government innovation policies in China[J]. Economic Research,2021,56(08):160-173.

[30] Shung J Shin et al. Cognitive team diversity and individual team member creativity: A cross-level interaction [J]. Academy of management journal, 2012, 55(1) : 197-212.

[31] Chen QY, Lin ST, Zhang S. Technology innovation incentives in China: quantity or quality[J]. China Industrial Economics,2020(4):79-96.

[32] Liu Hongqin,Tang Zhiwei,Cui Xi,Guo Yuhui,Wu Yufeng. The foreign experience of building a smart society in China[J]. E-Government,2019(4):9-17.

[33] João J.M Ferreira, Cristina I Fernandes, Fernando A.F Ferreira. To be or not to be digital, that is the question: firm innovation and performance [J]. Journal of Business Research, 2019, 101(C) : 583-590.

[34] Zhang Z-X, Yan S-L. New development pattern of double cycle and technological innovation of Chinese enterprises[J]. Journal of Southwestern University (Social Science Edition), 2022, 48(01):113-122.