Impact of Technological Innovation on the Yangtze River Delta Region's Economy Based on a Quantile Regression

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Abstract. Although the Yangtze River Delta region has an extremely high degree of scientific and technological innovation, its contribution to GDP is not known. Gross domestic product (GDP) is a monetary measure of the market value of all the final goods and services produced and sold (not resold) in a specific time period by countries. GDP per capita at purchasing power parity (PPP) may be more useful when comparing living standards between nations, which is the new specialized of GDP. The differences in the effects of technical innovation at various GDP levels have not been taken into account in much research. We investigate the effect of technical innovation on GDP in various contexts. This study creates a technological innovation index by first using the principal component analysis approach to minimize the dimension according to the number of patents, innovations, individuals working in scientific and technological innovation, and the price of such research and development. Then, to examine the effect of technical innovation on GDP, we created an OLS model and a quantile regression model that took into account time and regional fixed effects. Finally, a robustness test is performed to demonstrate a consistent outcome.

Keywords: Technological innovation · GDP · Quantile Regression

1 Introduction

The Yangtze River Delta region's prosperity depends on technological innovation, and the state has established numerous measures to encourage it [1, 2]. In April 2022, in order to thoroughly implement the integrated development strategy and innovation-driven development strategy of the Yangtze River Delta, and accelerate the construction of Shanghai as a scientific and technological innovation center with global influence, Shanghai issued the "Implementation Opinions on Promoting the Construction of a National Technology Innovation Center in the Yangtze River Delta." In June this year, breathable bio-double membrane technology can use green hydrogen to remove multiple types of refractory pollutants (Plastic bags, plastic bottles, formaldehyde, potassium permanganate, etc.), reduce carbon emissions while purifying water quality, and achieve a "double harvest" of water purification and negative carbon emissions. This

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pioneering technology led by Professor Bruce Rittmann, an academician of the American Academy of Engineering, chose the National Technology Innovation Center in the Yangtze River Delta as the foothold of its industrial application in China, and the major project "Rittmann Technology" of the National Innovation Center was officially launched [3]. Technological innovation is greatly significant to the area's development [4].

There are many kinds of literature that have studied the economic development of the Yangtze River Delta region, the impact of technological innovation on the economy, and the impact of population on the economy [5–7]. But they are seldom combined, and they do not consider the different levels of GDP that would impact the performance of technological innovation. This paper helps to bridge the existing research gap.

The Yangtze River Delta Science and Technology Innovation Corridor currently houses more than 36,000 high-tech businesses, more than 1,300 incubators and maker spaces at various levels, and 339 new and specialized "little giant" businesses at the national level. For instance, Alibaba (China) Co., Ltd., SAIC Motor Corporation Limited, Hengli Group Co., Ltd., Greenland Holding Group Co., Ltd. Songjiang, the source of the source, has a 4.59% R&D investment intensity [8]. Over 2,300 high-tech businesses now exist, having doubled in just six years. There are 40 new, specialized, "small giant," national businesses. Independent innovation, as exemplified by high-growth scientific and technical firms, has evolved into a successful model of technological advancement and has increased the importance of cluster innovation impacts. Therefore, technological innovation is crucial to the economic development of the Yangtze River Delta region. The economic development of the region refers to the increase in population, GDP, local taxation and living standards of residents. From 1978 to 1990, the region's economic development entered a stage of rapid urban development. 1990-Currently, the area is in the stage of high urbanization. However, its impact under different levels of GDP still lacks the support of theoretical literature, and there is also a lack of corresponding literature for exploration. Innovation hubs typically draw on scientific research, science and technology supported by science and education, science and technology, and supporting the inventive ecosystem supported by urban living to take on an organic shape in a particular area. Because science and education and science and trade can promote the development of human society and use the wisdom of various people. It is the hub to improve innovation.

This paper uses the principal component analysis method to first reduce the dimension based on the number of patents, the number of inventions, the number of personnel involved in scientific and technological innovation, and the cost of scientific and technological research and development. Then it creates a technological innovation index to measure Shanghai in the Yangtze River De Innovation in science and technology in the City, Jiangsu Province, Zhejiang Province, and Anhui Province. Then, to test the effect of technological innovation on GDP, we created an OLS model and a quantile regression model that took into account time and regional fixed effects. We also used annual government fiscal receipts, local household registration rates, annual salary levels, population growth rates, and education spending as control variables. Through the use of stability testing techniques like PSM regression and group regression, we further demonstrate the dependability of our model's results.

We also make some recommendations to help the Yangtze River Delta's technical innovation level advance. Accelerating the creation of a new growth pattern that is supported by the Yangtze River Delta's integrated development is important. Under the new circumstances, we must fully utilize the strategic advantages of the Yangtze River Delta and clearly understand how the world is changing, what the requirements of the nation are, and how strong the Yangtze River Delta is.

The remainder of the article is organized as follows. Section 2 shows the data. Section 3 is a method. Section 4 presents the analysis of the results. Section 5 utilizes two methods to conduct a robustness test. Section 6 conducts a discussion. Section 7 summarizes the conclusion.

2 Data

The Yangtze River Delta region, also known as the Yangtze River Delta, is located in the lower reaches of the Yangtze River in China, on the edge of the Yellow Sea and the East China Sea, where the river and the sea meet, and has numerous coastal ports. It includes Shanghai, Jiangsu Province, Zhejiang Province, and Anhui Province. Prior to the Yangtze River flowing into the sea, this alluvial plain was developed.

The Yangtze River Delta had a population of 227 million people and a surface area of 358,000 square kilometers as of the end of 2019. With less than 4% of the country's land area, the Yangtze River Delta region will provide over 1/4 of China's total economic output and 1/3 of China's advancement by 2020, with a GDP of 24.5 trillion yuan and an urbanization rate of permanent population above 60%. Overall exports The Yangtze River Delta region's railway network density in 2019 was 325 km per 10,000 square kilometers, which is 2.2 times the national average. One of China's regions with the most active economic development, the greatest degree of openness, and the greatest capacity for innovation are the Yangtze River Delta. In the general context of the nation's modernization push and the pattern of all-around opening up, it occupies a crucial strategic position.

This paper will examine the significance of technological innovation and its effects on the economic growth of the Yangtze River Delta region. We compile data on the number of patent authorizations, invention authorizations, scientific research people, and funding in Shanghai, Jiangsu Province, Zhejiang Province, and Anhui Province, and utilize GDP as the degree of economic standing to create a technological innovation index. We also collected the number of local household registration population, population growth rate, local annual wage level, government fiscal revenue of the year, and education expenditure as control variables. The data covers the years 2008 through 2021. Data sources include the Shanghai, Jiangsu, Zhejiang, and Anhui statistical bureaus' official websites, the China City Statistical Yearbook, the China Statistical Yearbook, the wind database, and others [9].

Table 1. Descriptive statistic

Variable	Mean	Std. Dev.	Min	Max
GDP	10.44803	0.603383	9.08836	11.66448
patent	11.53545	0.994593	8.377011	13.37066
invention	9.428795	1.063872	6.192362	11.13915
Rdfee	15.57152	0.807519	13.44652	17.11749
Rdpeople	11.99815	0.795641	10.40135	13.32559
people	8.543863	0.470309	7.543517	9.04841
peoplegrowth	3.661071	2.270673	-1.12	8.17
wages	8.517702	0.715776	6.777077	9.61197
arearev	17.50758	0.615551	15.79599	18.4222
edufee	16.41949	0.526579	15.29341	17.40847

The variables are then described: *patent* represents the number of patent authorizations in each province, *invention* represents the number of invention authorizations; *Rdfee* indicates the R&D spending of firms above the designated size, *Rdpeople* represents scientific researchers of enterprises above the designated size in each province. *People* indicates the total number of people who are officially registered in the region, *peoplegrowth* is the population growth rate, *wages* represent the average yearly wage in the area, *arearev* is the total fiscal revenue for the year, and *edufee* is the cost of education by the government. The aforementioned variables have all undergone logarithmic processing.

Table 1 shows the descriptive statistic of each variable. We found that the mean value of the logarithmic GDP in each province and city in 2008–2021 is 10.44803, the standard deviation is 0.603383, the minimum value is 9.08836, and the maximum value is 11.66448. The average number of patents is 11.53545, the average number of inventions is 9.428795, the average value of R&D expenses of enterprises is 15.57152, and the average value of scientific researchers of enterprises above designated size in each province is 11.99815. The numerical characteristics of other variables can also be consulted from Table 1.

Each variable was subjected to a correlation analysis as well, and the pertinent outcomes are displayed in Table 2. We can deduce that technical innovation has a favorable impact on economic development since a number of indices for assessing technological innovation have a significant positive connection with it. The population growth rate is negatively correlated with GDP.

Table 2. Correlation between each variable.

	GDP	patent	invention	Rdfee	Rdpeople	people	peoplegrowth	wages	arearev	edufee
GDP	1									
patent	0.9446*	1								
invention	0.8709*	0.8778*	1							
Rdfee	0.9884*	0.9526*	0.9055*	1						
Rdpeople	0.9234*	0.9179*	0.7259*	0.9223*	1					
people	0.4938*	0.4075*	0.1024	0.4124*	0.6370*	1				
peoplegrowth	-0.5032*	-0.4737*	-0.5205*	-0.5273*	-0.3264*	0.1912	1			
wages	0.8607*	0.8453*	0.9447*	0.8853*	0.7026*	0.0451	-0.5740*	1		
arearev	0.8781*	0.8534*	0.9346*	0.9140*	0.7279*	0.0506	-0.6345*	0.9589*	1	
edufee	0.9629*	0.9233*	0.8636*	0.9413*	0.8901*	0.5477*	-0.3504*	0.8337*	0.8111*	1

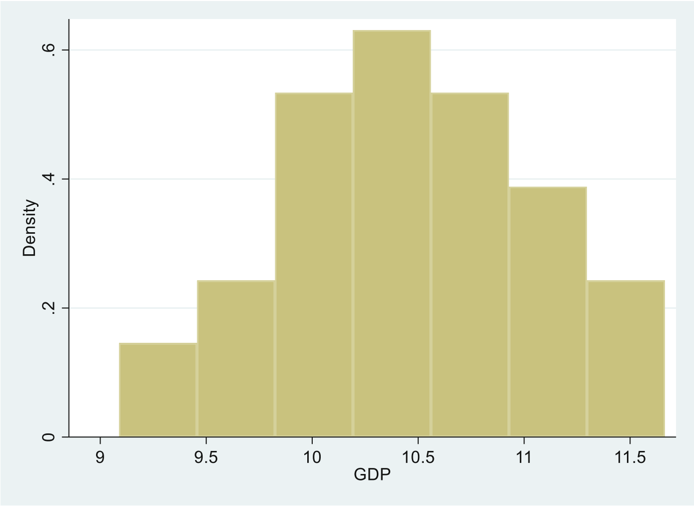

Fig. 1. Statistical histogram of GDP

Figure 1 and Fig. 2 respectively show the statistical histograms between the level of economic development (GDP) and various technological innovation indicators (patent authorizations, invention authorizations, scientific research people, and R&D funding), in order to better describe the probability distribution of each variable. These variables essentially follow the assumption of normal distribution, as shown by the histogram.

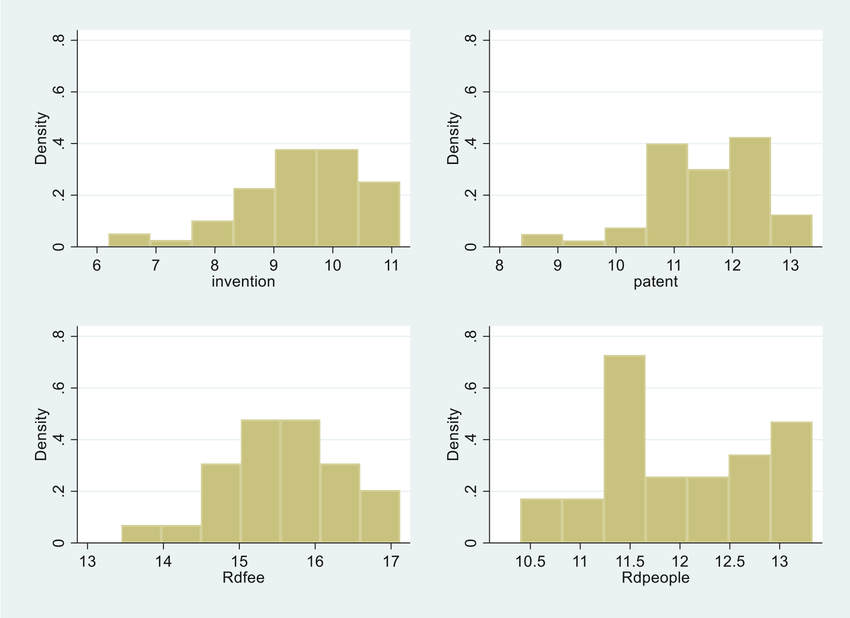

Fig. 2. Statistical histogram of the technical innovation index

3 Method

In this paper, we will first use the principal component analysis method to reduce the dimensions of various indicators of technological innovation and form a technological innovation index to measure the technological innovation capabilities of each province. Then use OLS regression and quantile regression to test the impact of technological innovation on GDP.

3.1 Principal Component Analysis

In order to determine the capacity for technological innovation, this paper uses principal component analysis (PCA) [10, 11]. The principal component analysis is a powerful tool for solving a wide range of issues, including those in population statistics, quantitative geography, molecular dynamics simulation, mathematical modeling, etc. It is a widely used method for examining many variables. Principal component analysis (PCA) is a widely used analytical method that serves as the foundation for mathematics. Through PCA, the dimension of the data can be reduced without altering its characteristics.

Principal component analysis may be used to control the risk of interest rate derivative portfolios directly in quantitative finance. Trading multiple swap instruments aim to simplify them to 3 or 4 main components, which define the direction of interest rates on a macro level and are often a function of 30–500 other market quotable swap products. Risks can be assessed and understood in ways that go beyond what is possible by just considering risks as a whole in terms of individual 30–500 buckets. This is done by converting risks to be represented as those to factor loadings (or multipliers).

PCA has been used in a similar way to analyze portfolio risk and risk-return for equities portfolios. Application of allocation methods to "primary portfolios" rather than the underlying equities is done to lower portfolio risk. Using the principal component analysis, which is used for multi-indicator comprehensive evaluations [12], the significant influences between each assessment indicator can be eliminated. Mathematical transformations during the analysis process have produced the amount of information and the number of system impacts. The PCA looks like that though.

$X = (X_1, X_2, X_3, ..., X_n)^{'}$ is N-dimensional random vector, and its linear changes are as follows.

$$\begin{aligned} PC_1 &= a_1^{'}X = a_{11}X_1 + a_{21}X_2 + a_{31}X_3 + ... + a_{n1}X_n \\ PC_2 &= a_2^{'}X = a_{12}X_1 + a_{22}X_2 + a_{32}X_3 + ... + a_{n2}X_n \\ PC_3 &= a_3^{'}X = a_{13}X_1 + a_{23}X_2 + a_{33}X_3 + ... + a_{n3}X_n \\ &\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ PC_n &= a_n^{'}X = a_{1n}X_1 + a_{2n}X_2 + a_{3n}X_3 + ... + a_{nn}X_n \end{aligned} \tag{1}$$

The STATA program is used in this article in order to address the PCA issue. By making mathematical adjustments to the original N variable, it would construct a new variable (first main component) that, to some extent, reflects the information of the original variable. We can introduce the second main components after introducing the first main ingredients, which cannot replace the majority of the original variables, and so forth. According to the main component's cumulative contribution rate, the number of main components is determined. The primary component's cumulative contribution rate is as follows.

$$AC = \sum_{k=1}^{m} \lambda k / \sum_{i=1}^{n} \lambda_i \tag{2}$$

In this formula: λ is the characteristic value of each main component; k is the selected number in component; i is all the main components.

PCA analysis is the technique of analyzing numerous classes of tangible or intangible items based on how closely their quality features to match. Finally, the cluster analysis aggregates in accordance with numerous detailed properties of the category, completing the clustering analysis process. The technological innovation (f1) element would then be available. The potential to innovate in technology is mostly represented by the f1 according to the characteristics of these data. In other words, there is a lot of potential for technical innovation.

3.2 OLS Regression for Panel Data

A mathematical optimization strategy is the method of least squares, commonly known as the method of least squares [13, 14]. By reducing the sum of squared errors, it determines the function that fits the data the best. The sum of squares of the errors between the obtained data and the actual data can be reduced by employing the least square approach to quickly retrieve the unknown data. Numerous disciplines, including finance, economics, and marketing, employ the OLS model. The OLS model is frequently used to analyze how the epidemic affects the economy. When OLS is applied to regression with panel data, the influence of time and area fixed effects are also considered. At this time, OLS regression is also called a fixed effect model.

In this article, we consider technological innovation as the dependent variable and GDP as the independent variable for measuring the economic development level of different areas in Yangtze River Delta region. We also set the number of local household registration population, population growth rate, local annual wage level, government fiscal revenue of the year, and education expenditure as control variables as the control variable. Thus, we obtain the following regression model to investigate the impact of technological innovation on the GDP based on the Chinese condition.

$$GDP = \beta_0 + \beta_1 \times f_1 + \sum_{i=1}^{n} \gamma_i \times control_i + Area_i + Year_i + \varepsilon_i \tag{3}$$

3.3 Quantile Regression Method

The quantile regression model is basically expanded by the quantile regression model [15, 16]. Unlike least squares regression, which can only estimate parameters at a certain quantile point, quantile regression can estimate parameters at any quantile point. Compared to conventional least squares estimators, outliers have a substantially smaller impact on the assumptions about the distribution of the error component. As a result, quantile regression's estimation findings are more reliable, and it also makes it simple to cope with sample heterogeneity across areas and degrees of economic development. The association between a group of predictor (independent) variables and particular percentiles (or "quantiles") of a target (dependent) variable, most frequently the median, is modeled using quantile regression. Compared to Ordinary Least Squares regression, it offers two significant advantages:

(i) There are no presumptions made by quantile regression on the distribution of the target variable.
(ii) Outlying observations tend to have less of an impact when using quantile regression.

Research in fields including ecology, healthcare, and financial economics frequently uses quantile regression [16]. When there is no association or only a weak relationship between the means of two variables, quantile regression has been developed and used in ecology as a tool to find more relevant prediction relationships. The complexity of interactions between many elements that result in data with the unequal variation of one variable for distinct ranges of another variable has been credited as the reason for the necessity and success of quantile regression in ecology. The quantile regression is as follows.

$$Q_{yi}(\tau|\alpha_i, \xi_t, f_{it}) = \alpha_i + \beta_1 \times f_1 + \sum_{i=1}^{n} \gamma_i \times control_i + Area_i + Year_i + \xi_t \tag{4}$$

In this model, we evaluate the economic development levels of several areas in the Yangtze River Delta region using GDP as the independent variable and technological innovation as the dependent variable. Additionally, we used local yearly salary levels, population growth rates, local household registration rates, annual government fiscal receipts, and education spending as control variables. This model would help us to evaluate the impact of technological innovation on GDP under different conditions.

4 Results Analysis

4.1 Results of PCA

The technical innovation is calculated in the paper using PCA. Based on the table of the characteristic value, contribution rate, and accumulation contribution rate, the article discovers that for the major component, the first factor's eigenvalue to the fourth factor's eigenvalue is more than 1, and the other is lower than 1. Besides, the first factor's proportion is 0.9137, which contains lots of information of different technological innovation indexes. As a consequence, we gather 1 components of technical innovation. The gravel produces the same result (Fig. 3). The article makes predictions about the variables using Stata software (Table 3).

We can further evaluate the effectiveness of the primary component using the Bartlett and KMO test. When either the KMO value or the P-Value is less than 0.05, the result is regarded as credible. The table shows that f1's KMO is 0.6756. The Bartlett test shows that Chi-square is 368.132 and the p-value is 0. Thus, the accuracy of the PCA result is displayed in this analysis's result.

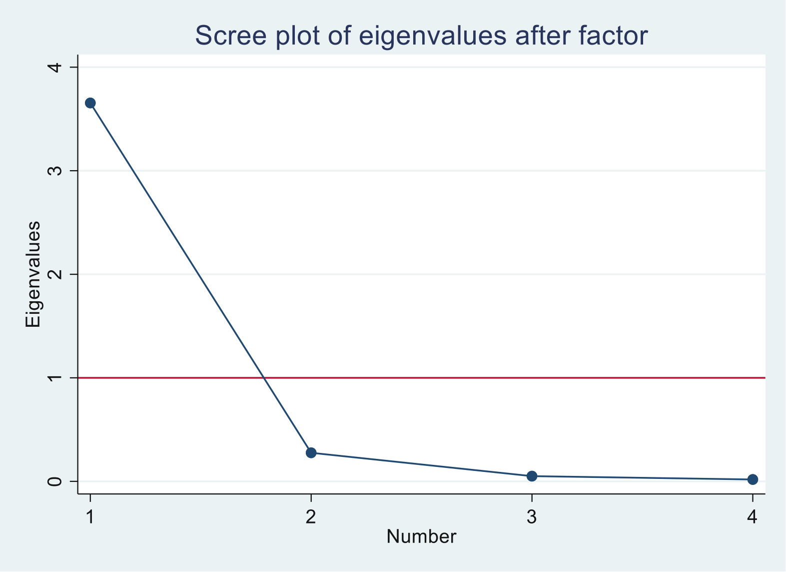

Fig. 3. Gravel of different main components

Table 3. The characteristic value, contribution rate and accumulation contribution rate of the main component

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.65468	3.37851	0.9137	0.9137
Factor2	0.27617	0.2254	0.069	0.9827
Factor3	0.05077	0.0324	0.0127	0.9954
Factor4	0.01838	.	0.0046	1
LR test: independent vs. saturated: chi2(6) = 375.10 Prob > chi2 = 0.0000				

4.2 Regression Analysis

Table 4 counts the regression results of OLS and the quantile regression results of different quantile points (10% level, 25% level, 50% level, 75% level, and 90% level). Quantile movement from small to large corresponds to the rise in GDP from low to high. We can observe the effect of technological innovation on GDP by comparing the degree of local scientific and technological innovation.

Through OLS and quantile regression results, we found that technological innovation has a positive impact on economic development. From the results of OLS, we know that the coefficient of technological innovation is 0.21, which has a significant impact on economic development and is acceptable at the 99% significance level. At the same time, the results of quantile regression also show that technological innovation has a positive effect on economic development, especially when the level of economic development is low, and the promotion effect of technological innovation is stronger. The impact coefficient of technological innovation on GDP in the 10% quantile regression is 0.285. In the 25% quantile regression, the impact of technological innovation on GDP is 0.235. In the regression results, we also control for time and region effects.

We further investigate the effects of other control variables on GDP in light of the OLS regression results. According to this study, the GDP is significantly impacted negatively by both the population growth rate and the population size, which will cause the GDP to fall. The level of local wages and tax income has a stimulating effect on GDP growth. Furthermore, the growth in education spending has a weakening impact on GDP.

In accordance with quantile regression, Fig. 4 depicts the various impact coefficients of various variables on GDP at various GDP quantiles. We plot it from low to high quantile points and use the quantile points to show the trend of each variable's effect coefficient on GDP. We found that as the quantile increases, the effect of technological innovation on GDP growth decreases, but when GDP is at a high level, the effect of technological innovation on GDP rebounds, further enhancing the development of GDP.

Table 4. OLS and Quantile regression results

	OLS	Q10	Q25	Q50	Q75	Q90
	GDP	GDP	GDP	GDP	GDP	GDP
f1	.21***	.285***	.235***	.194***	.142*	.213***
	(.024)	(.023)	(.051)	(.05)	(.074)	(.068)
peoplegrowth	-.016***	-.026***	-.034***	-.035***	-.026**	-.038***
	(.004)	(.003)	(.007)	(.007)	(.01)	(.009)
people	-.437***	.457***	.405***	.431***	.432***	.232**
	(.09)	(.029)	(.065)	(.064)	(.095)	(.088)
wages	.11***	.085**	.113	.134*	.131	.028
	(.029)	(.034)	(.076)	(.075)	(.112)	(.103)
arearev	.09**	.29***	.247***	.301***	.384***	.129
	(.04)	(.037)	(.082)	(.081)	(.12)	(.11)
edufee	-.135**	-.104**	.042	.061	.093	.452***
	(.063)	(.049)	(.11)	(.108)	(.161)	(.148)
Area	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
_cons	12.911***	2.459***	1.094	-.534	-2.472	-1.231
	(1.311)	(.813)	(1.809)	(1.781)	(2.652)	(2.441)
Pseudo R^2	0.9994	0.9243	0.9115	0.9106	0.9050	0.8994

Standard errors are in parentheses
*** $p < .01$, ** $p < .05$, * $p < .1$

GDP is significantly impacted negatively by population growth, and when GDP quantiles rise, this impact first gets stronger before weakening. The population growth rate has a negative impact on GDP which is more pronounced below the middle GDP level. When GDP is at a high level, population growth will further lead to a decline in GDP, and a reversal effect appears. Population affects GDP growth in quantile regression. Additionally, the impact of this expansion is diminished at high GDP levels, which is consistent with the law of diminishing marginal effect.

Local wage effects on GDP have a positive marketing effect at the low quantile, which can raise GDP output. As the quantile rises, this effect is amplified even more. However, when the quantile is especially high, the rise in local wages actually causes a decline in GDP output. The explanation is that residents will favor leisure more and be more inclined to take a break when GDP is high, people's living standards are good, and earnings are sufficient. Because it is not labor, an increase in wages will drive up costs and lower GDP.

The increase in local fiscal revenue has a positive effect on GDP at the low quantiles and can increase GDP output. This effect is further amplified as the quantile increases. However, when the quantile of GDP is particularly high, the increase in fiscal revenue

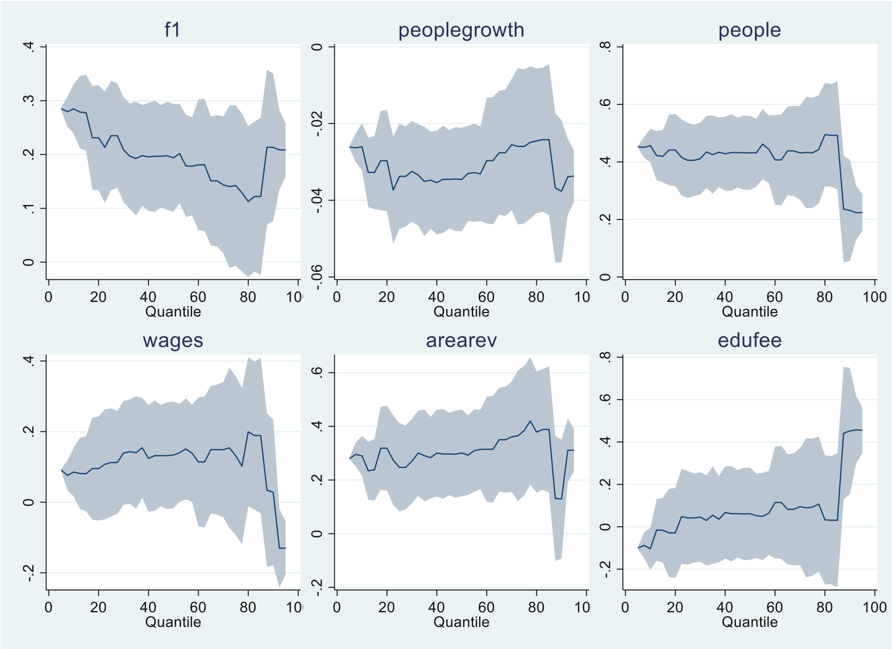

Fig. 4. Quantile regression results for a different level of coefficient trend

actually leads to a decrease in GDP output. The reason is that when the GDP is high, the government's fiscal revenue is relatively rich, and the further increase in fiscal revenue comes from the increase in taxation, which pushes up costs and lowers GDP.

Expenditure on education presents a very interesting phenomenon. When the level of GDP is low, the impact of education expenditure on GDP is negative. An increase in education spending will lead to a decline in GDP. But when the GDP level is at a relatively high level, the increase in education expenditure will further promote the increase in GDP, which shows that education can only play a greater role when the economic level is high. And there is a certain critical value for this change. When GDP does not meet such a critical condition, the effect is not significant.

In conclusion, we discovered that technical innovation has a beneficial impact on GDP and that this positive impact gradually diminishes as GDP levels rise. However, once the GDP level reaches a certain point, the impact of technological advancement will further accelerate GDP growth and produce the Matthew effect. In addition, we further examine the population, population growth rate, education expenditure, and local finance to explore their impact on different levels of GDP. In order to ensure that the results are more accurate, we further conducted stability tests, including PSM regression and group regression.

5 Robustness Test

In order to examine the effects of a public policy, economists frequently create "treatment groups" and "control groups" to compare the effects of different policies. The baseline conditions of the treatment group and the control group are typically not identical in non-randomized observational studies, and this creates an issue with selection bias. In Propensity Score Matching (PSM), information from a multidimensional vector is compressed into one dimension using a propensity score function, and matching is then carried out using the propensity score. The problem of selection bias of the treatment effect can be solved by making the individuals in the treatment group and the individuals in the control group as similar as possible under the supplied observable characteristic variables.

The PSM approach makes two assumptions. (1) The premise of common support. Matching requires that the two subsamples of the treatment group and the control group overlap. It guarantees that the proportion of propensity score values in the treatment group and the control group are equal. 2) The assumption of balancing. There is no difference between the treatment group and the control group prior to the treatment because it is randomized, and the impact shown in the treatment group is solely attributable to the treatment.

The steps below are typically followed when using PSM.

(1) Select covariates to minimize the impact of the various impacts of dependent variables.
(2) Probit or logit models can be used to estimate the propensity score;
(3) Determine whether the parallel hypothesis is true: after matching, bring the means of the treatment and control groups for the independent variable closer to maintain data balance;
(4) Based on the propensity score, pair up members of the treatment group and members of the control group; matching techniques include nearest neighbor, radius, kernel, etc.;
(5) Determine the ATT using the matched.

Therefore, we use PSM to further test the impact of technological innovation and other control variables on different levels of GDP and compare the OLS estimation results with reference objects. Table 5 shows the results of OLS and Quantile regression based on PSM. After passing through the PSM, we discovered that the effect of technical innovation on GDP is still consistent with the earlier findings. Technology innovation continues to contribute to GDP growth. We found that technical innovation has a favorable influence on GDP, but that as GDP levels climb, this positive impact eventually decreases. However, at a certain point, the Matthew effect will further increase GDP growth due to the impact of technological advancement. In order to further identify their effects on various GDP levels, we also examine the impact of population, population growth rate, education spending, and local government revenue on GDP with a different conditions.

Table 5. OLS and Quantile regression results based on PSM

	OLS	Q10	Q25	Q50	Q75	Q90
	GDP	GDP	GDP	GDP	GDP	GDP
f1	.193***	.244**	.052	.142	.17***	.23***
	(.038)	(.109)	(.132)	(.103)	(.053)	(.083)
peoplegrowth	-.015**	-.013	-.024*	-.021***	-.029***	-.028***
	(.006)	(.017)	(.012)	(.006)	(.002)	(.004)
people	-.544***	.481***	.364***	.617***	.635***	.709***
	(.18)	(.094)	(.122)	(.114)	(.041)	(.078)
wages	.094***	.01	.056	.239***	.274***	.321***
	(.028)	(.061)	(.099)	(.075)	(.037)	(.056)
arearev	.126***	.719***	.357**	.435***	.376***	.403***
	(.041)	(.055)	(.163)	(.072)	(.033)	(.102)
edufee	-.168	.679***	.399*	.348**	.375***	.364***
	(.11)	(.215)	(.215)	(.136)	(.056)	(.074)
Area	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
_cons	13.726***	-17.537***	-5.879	-10.083***	-9.891***	-11.203***
	(1.362)	(2.861)	(4.892)	(2.979)	(1.21)	(1.719)
Pseudo R^2	0.9993	0.8818	0.8677	0.8815	0.8976	0.8911

Standard errors are in parentheses
**** $p < .01$, ** $p < .05$, * $p < .1$*

By using the matching resampling method, PSM attempts to minimize the deviation of the observation data as much as possible from the random experimental data, but it also has the following weaknesses: PSM often needs a substantial sample size to achieve high-quality matching. PSM needs a higher common support range between the propensity scores of the treatment group and the control group; otherwise, more observations will be lost, making the remaining samples unrepresentative. PSM can only reduce the impact of observable variables; if there is a selection of unobservables, "hidden bias" will still exist. Then, we conduct a group regression using the data after 2008. The results are shown in Table 6. The result is consistent with our former analysis. The dependability and stability of our model's findings are further demonstrated by the two stability tests of PSM and group regression.

Table 6. OLS and Quantile regression results based on group regression

	OLS	Q10	Q25	Q50	Q75	Q90
	GDP	GDP	GDP	GDP	GDP	GDP
f1	.208***	.287***	.182***	.181***	.16**	.205***
	(.024)	(.024)	(.06)	(.05)	(.074)	(.052)
peoplegrowth	-.015***	-.026***	-.034***	-.031***	-.022**	-.002
	(.004)	(.003)	(.008)	(.006)	(.009)	(.007)
people	-.504***	.456***	.403***	.408***	.395***	.34***
	(.142)	(.031)	(.079)	(.065)	(.096)	(.068)
wages	.11***	.083**	.096	.111	.122	.118
	(.031)	(.035)	(.09)	(.074)	(.11)	(.078)
arearev	.099**	.292***	.289***	.315***	.364***	.334***
	(.042)	(.036)	(.092)	(.076)	(.112)	(.079)
edufee	-.133*	-.105**	.124	.129	.128	.158
	(.067)	(.048)	(.122)	(.1)	(.148)	(.105)
Area	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
_cons	13.246***	2.475***	-.84	-1.522	-2.324	-1.824
	(1.405)	(.804)	(2.051)	(1.694)	(2.499)	(1.768)
Pseudo R^2	0.9993	0.9187	0.9086	0.9120	0.9100	0.9062

Standard errors are in parentheses
*** $p < .01$, ** $p < .05$, * $p < .1$

6 Discussion

According to previous studies, the Yangtze River Delta region's GDP is positively impacted by technological innovation. Additionally, it investigates the extent of the impact of technical innovation at various GDP levels. Now we shall further connect the actual to the present discussion and suggestion.

The globe is currently seeing significant changes that haven't occurred in a century, and this period of upheaval and change is here to stay. In terms of China, it has started a new road toward fully constructing a robust and modern communist nation. In light of this domestic and international context, it is important to accurately understand the general trend of the global industrial and technological revolution, be skilled at creating new opportunities in emergency situations, and be able to open new games in shifting circumstances in order to support the integrated high-quality development of the Yangtze River Delta.

Looking back the history of revolution may have some enlightenment. The industrial revolution in the 1760s, the electrical and chemical industrial revolutions in the late 19th and early 20th centuries, and the atomic energy, computer, and material revolutions in the middle of the 20th century are the four major technological revolutions and industrial transformations that have most significantly impacted human society to date. Since the turn of the century, there have been revolutions in technology, other fields, information technology, and the Internet. There will soon be another wave of technological advancement and industrial change. This is built on the preceding four industrial revolutions and scientific and technical revolutions. The world's scientific and technical innovation has advanced as a result of economic globalization, a significant reorientation of the industrial structure and economic center of gravity, as well as the quickening accumulation and flattening of information throughout human society. Up until the industrial transformation reached a plateau and descended into a deep valley, it underwent a methodical, all-encompassing, and disruptive significant technological revolution. Technological innovation would increase the speed of China's economic development. The question of how to implement scientific and technical innovation to further development must be answered.

In addition to promoting the integration of the three industries and altering the structure of the traditional three, two, and primary industries, intelligent, digital, green, and low-carbon development and transformation also significantly alter people's production, office, communication, and consumption patterns. The old economy is being destroyed, dismantled, reorganized, and rebuilt by the economy. The service sector will make up a larger percentage of the three industries, industrial development will become more service-oriented, and the primary and secondary industries' service links and service value ratios will continue to rise. The integration of production, manufacturing, and services is encouraged by digitalization, green and low-carbon transformation, and an increase in the share of R&D, financing, management, sales, and maintenance, among other factors.

Natural resources and nonrenewable energy sources are becoming increasingly scarce and crucial to the growth and development of human civilization. Economic growth that depends on extensive input and use of natural resources must stop. Maximum resource conservation, intense resource utilization, the creation of endless new energy sources, and the evolution of industrial structures must all be supported by economic growth. Green and low-carbon development and transformation must be realized in all production, manufacturing, and service links. Natural resources per person in China are far lower than the global average. Promoting intensive and economic development as well as green and low-carbon transformation is essential for achieving modernization on all fronts. Thus, it would be suggested that the following ways would help Chinses technological innovation to speed up the economy.

First of all, we must give full play to the strategic advantages of the Yangtze River Delta under the new situation, and clearly see the changes in the world, the needs of the country, and the strengths of the Yangtze River Delta. In the face of a new round of technological revolution and industrial transformation, the Yangtze River Delta should become a growth pole that drives the strong and active development of China's economy, leading the promotion of high-quality development of China's economy. This is mainly because the Yangtze River Delta region has the following benefits. The first is a strong economy. Important critical regions must take the lead in order to achieve balanced and coordinated economic development in major countries. 3.7% of the nation's land area is made up of the Yangtze River Delta, as is almost 20% of its resident population, nearly a quarter of its GDP, and a third of its fiscal revenue. Over 114,000 yuan, or 1.64 times the national average, is the GDP per person. Eight of the top 11 cities nationally were located in cities with a median income of over $20,000.

Secondly, it is necessary to accelerate the construction of a new development pattern supported by the integrated development of the Yangtze River Delta. In the new situation and new stage, to give full play to the comprehensive advantages of the Yangtze River Delta, it is necessary to accelerate the construction of a new development pattern around the national strategy and enhance the important function of the Yangtze River Delta region to lead and drive my country's economic double cycle. We should promote the Yangtze River Delta's institutional opening-up and take the helm in my nation's high-level opening-up. It is vital to compel deep institutional innovation through institutional opening up and to promote reform through opening up in order to support the reciprocal promotion of domestic and international dual cycles. Building an open platform for cooperation and sharing, strengthening the establishment of the free trade zone system in the Yangtze River Delta provinces and cities, enhancing the institutional opening of the Shanghai Pilot Free Trade Zone and the Lingang New Area, and exploring the development of a digital integration interim and ex-post supervision and government service system are all necessary.

7 Conclusion

In March 2020, the Ministry of Science and Technology and the Ministry of Finance issued the "Overall Plan for Promoting the Construction of a National Technological Innovation Center", proposing a national strategy focusing on the integration of the Yangtze River Delta, laying out and building a comprehensive national technological innovation center, in order to enhance the overall development capability and coordination of the region Innovation capability provides comprehensive and leading support. According to the opinion of the Ministry of Science and Technology, the Yangtze River Delta National Technology Innovation Center will be jointly established by Shanghai Municipality and the three provinces of Jiangsu, Zhejiang, and Anhui. This reflects the importance of technological innovation to the economy.

In order to explore the impact of scientific and technological innovation on the development of GDP, this paper first uses the principal component analysis method to reduce the dimension according to the number of patents, the number of inventions, the number of scientific and technological innovation personnel and the cost of scientific and technological research and development, and constructs a technological innovation index to measure Shanghai in the Yangtze River Delta region. City, Jiangsu Province, Zhejiang Province, and Anhui Province's scientific and technological innovation level. Then we established an OLS model and a quantile regression model considering time and regional fixed effects to test the impact of technological innovation on GDP. we also local yearly salary levels, population growth rates, local household registration rates, annual government fiscal receipts, and education spending as control variables. We further prove the reliability of our model results through stability testing methods such as PSM regression and group regression.

We also propose some suggestions to help accelerate the technological innovation level in the Yangtze River Delta. It is necessary to accelerate the construction of a new development pattern supported by the integrated development of the Yangtze River Delta. We should give full play to the strategic advantages of the Yangtze River Delta under the new situation, and clearly see the changes in the world, the needs of the country, and the strengths of the Yangtze River Delta.

There are still some deficiencies in this paper. It does not consider the impact of some omitted variables and does not build a theoretical model to identify the theoretical framework of technological innovation on GDP growth. In the future, we will further consider more control variables to further test the impact of technological innovation on GDP.

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