Empirical Analysis of R&D Investment, Industrial Structure Transformation and Development of High-tech Industry in Guangdong Province——Based on Time Series Data from 2003-2018

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Abstract. The transition from high-speed growth to high-quality development is the basic strategy for China’s current economic development. The essence of high-quality development lies in releasing the vitality, innovation and competitiveness of the economy. The key lies in technological innovation and technology diffusion. This paper uses the relevant theories and methods of econometrics to conduct an empirical analysis on the relationship between the output value of high-tech industries and R&D investment, industrial structure transformation in Guangdong Province from 2003 to 2018. The results show: When the R&D expenditure (X1) of Guangdong Province changes by 1% in 2003-2018, the output value of high-tech industry (Y) changes by an average of 0.9981%. When the ratio of the output value of the second industry to the output value of the tertiary industry (X2) changes by 1 unit, the output value of the new technology industry (Y) changes by an average of 86.86%. At the same time, it also found some characteristics of the development of manufacturing and service industries in Guangdong Province, which provided a certain idea for Guangdong to cultivate new kinetic energy for economic development and promote high-quality development.

1. Introduction
The 19th National Congress of the Communist Party of China proposed that the Chinese economy should shift from a high-speed growth stage to a high-quality development stage. As the frontier of reform and opening up, Guangdong Province has maintained its number one economic nation for many years. After the signing of CEPA in 2003, the traditional manufacturing advantages of Guangdong Province were more closely integrated with the developed financial and high-end services in Hong Kong and Macao. The speed of industrial transformation and upgrading in Guangdong Province has obviously accelerated, the proportion of medium and high-end manufacturing has been continuously improved, and the industrial structure has gradually moved from industrial economy to service economy[1]. With the official publication of the “Guangdong, Hong Kong and Macao Bay Area” officially written in the central government report, General Secretary Xi Jinping put forward a clear request for “four in the forefront of the country” to Guangdong. Guangdong Province has ushered in a new historical opportunity to further deepen reform, expand opening up, foster new kinetic energy, and continue to promote high-quality development. Especially in the current Sino-US trade friction,
the global political and economic pattern has entered an unprecedented new adjustment period, as the most active region for innovation in China, Guangdong must vigorously enhance the global competitiveness of industrial structure and product quality, and become the regional benchmark for China to promote innovation-driven development. This paper selects the statistical data of Guangdong Province from 2003 to 2018, using the relevant theories and methods of econometrics, empirically analysis the relationship between R&D expenditure, industrial structure transformation and high-tech industry development in Guangdong Province to keep on increase R&D expenditure, further optimize the industrial structure, and provide theoretical support for innovation-driven roads.

2. Empirical analysis

2.1. Selection of variables and setting of models
The development level of high-tech industry in Guangdong Province is represented by the output value of high-tech industry (Y). R&D expenditure (X1) is used as the representative variable of R&D investment, and the ratio of the output value of the secondary industry to the output value of the tertiary industry (X2) is used as the representative variable of industrial structure transformation. According to the empirical principle of data measurement, this paper takes the logarithm of high-tech industry output value (Y) and R&D expenditure (X1). First, it can eliminate the problem of data heteroscedasticity. Second, it can eliminate the influence of dimension to a certain extent. Because the ratio of the output value of the secondary industry to the output value of the tertiary industry (X2) is between 0.7 and 1.6, the range of the variable is small, so no logarithmic change is made. Assuming that linear constraints are met between the output value of high-tech industries and R&D investment, industrial structure transformation in Guangdong Province, the theoretical model is set as:

$$\ln y_t = C + \beta_1 \ln x_{1t} + \beta_2 x_{2t} + \mu_t$$

2.2. Descriptive statistics of major variables
The variables selected in this paper are from the "Guangdong Province Statistical Yearbook" and the "Guangdong Provincial Science and Technology Department Government Information Disclosure Work Annual Report", the data spans from 2003 to 2018. Since the relevant data has not yet been released, the R&D expenditure of 2018 is predicted by exponential smoothing. Using EViews 8.0 metrology software, descriptive statistics for each variable are shown in Table 1:

| Variable | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis | Jarque-Bera | Probability |
|----------|------|--------|---------|---------|-----------|----------|----------|-------------|-------------|
| LnY      | 10.235 | 10.371 | 11.211 | 8.716 | 0.763 | -0.580 | 2.237 | 1.285 | 0.525 |
| LnX1     | 6.658 | 6.823 | 7.759 | 5.191 | 0.891 | -0.316 | 1.685 | 1.418 | 0.491 |
| X2       | 1.017 | 1.066 | 1.162 | 0.771 | 0.134 | -0.660 | 1.990 | 1.844 | 0.397 |

Note: The unit of Y and X1 is 100 million yuan, and X2 is the relative ratio.

2.3. Time series stationarity test (ADF test)
Considering the existence of autocorrelation in the random perturbation terms of most economic data sequences in reality, in order to ensure the validity of the time series stationarity test, this paper uses the extended DF test, namely the ADF test, and the test results are shown in Table 2:

| Variable | Test critical values (1% level) | Test critical values (5% level) | Test critical values (10% level) | T-Statistic | Lag length | Exogenous |
|----------|-------------------------------|-------------------------------|-------------------------------|-------------|------------|-----------|
| LnY      | -3.959148                     | -3.081002                     | -2.681330                     | -5.877244   | 0          | Constant  |
| LnX1     | -3.959148                     | -3.081002                     | -2.681330                     | -2.746955   | 0          | Constant  |
At a 10% significance level, \( \ln Y \sim I(0) \), indicating that \( \ln Y \) is a stationary time series; \( \ln x_1 \sim I(0) \), indicating that \( \ln x_1 \) is a stationary time series; \( x_2 \sim I(0) \), indicating that \( x_2 \) is a stationary time series. It can be seen that both the explanatory variable and the interpreted variable are stationary time series, and there is no unit root.

2.4. *Determine whether there is multicollinearity between model variables*

In this paper, the variance expansion factor method (VIF) is used to judge whether there is multicollinearity between explanatory variables. The test results are shown in Table 3:

| Variable | Coefficient | Uncentered VIF | Centered VIF |
|----------|-------------|----------------|--------------|
| C        | 0.460132    | 678.1840       | NA           |
| \( \ln x_1 \) | 0.002816    | 187.0647       | 3.088811     |
| \( x_2 \)  | 0.123064    | 190.7214       | 3.088811     |

As a rule of thumb, when VIF > 10, there is severe multicollinearity between the explanatory variable and the remaining explanatory variables. It can be seen from the test results that the model does not have a serious multi-collinearity problem. In addition, the problem of multicollinearity can be eliminated to a certain extent by the logarithmic form.

2.5. *Determine whether the model has heteroscedasticity*

This paper uses the ARCH to test whether there is heteroscedasticity in the time series, the test results are shown in Table 4:

| Variable | Coefficient | Std.Error | t-Statistic | Prob.   |
|----------|-------------|-----------|-------------|---------|
| C        | 0.010012    | 0.003760  | 2.662481    | 0.0221  |
| \( \ln y^2 \) | 0.155260    | 0.298607  | 0.519947    | 0.6134  |
| \( \ln y^2 \) | -0.364109   | 0.257797  | -1.412389   | 0.1855  |

It can be seen from the results that the \( P \) value = 0.3207, which is much larger than the significance level of 0.05, so the original hypothesis should not be rejected, indicating that the model does not have heteroscedasticity.

2.6. *Determine whether the model has autocorrelation*

2.6.1. *The DW test method, the test results are shown in Table 5:*

| Variable | Coefficient | Std.Error | t-Statistic | Prob.   |
|----------|-------------|-----------|-------------|---------|
| C        | 3.136038    | 0.678330  | 4.623173    | 0.0005  |
| \( \ln x_1 \) | 0.945328    | 0.053063  | 17.81529    | 0.0000  |
| \( x_2 \)  | 0.791912    | 0.350805  | 2.257415    | 0.0418  |

Durbin–Watson stat 0.620616
By checking the critical value table, the corresponding critical value $d_L=0.98$, $d_U=1.54$ is obtained. It can be seen from $DW=0.620616$ that the DW value falls within $[0, 0.98]$, indicating that the model has positive autocorrelation.

2.6.2. The Breusch-Godfrey test (LM test), the test results are shown in Table 6:

| Breusch-Godfrey Serial Correlation LM Test: |
|-------------------------------------------|
| F-statistic | Prob.F(2,11) | 0.0535 |
| Obs*R-squared | Prob.Chi-square(2) | 0.0368 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares

| Variable | Coefficient | Std.Error | t-Statistic | Prob. |
|----------|-------------|-----------|-------------|-------|
| C        | 0.052912    | 0.583393  | 0.090697    | 0.9294 |
| LnX1     | -0.000181   | 0.044913  | -0.004038   | 0.9969 |
| X2       | -0.047076   | 0.305361  | -0.154166   | 0.8803 |
| RESID(-1) | 0.854730    | 0.310707  | 2.750917    | 0.0189 |
| RESID(-2) | -0.386382   | 0.320067  | -1.207190   | 0.2527 |

The results showed that the $P$ value = 0.0368, which is less than the significance level of 0.05, indicating that the model has autocorrelation. From the auxiliary results, the first-order autoregressive coefficient is significant, and the second-order autoregressive coefficient is not significant, indicating that the model is likely to have first-order autocorrelation.

2.7. Model autocorrelation remedy (Cockron-Ocot iterative method)
Firstly, the first-order autocorrelation is estimated by the Cochran-Ocot iterative method. The results are shown in Table 7:

| Cochrane-Ocot Iterative Estimation Results (1) |
|-----------------------------------------------|
| Dependent Variable: Y                        |
| Method: ARMA Maximum Likelihood(OPG-BHHH)    |

| Variable | Coefficient | Std.Error | t-Statistic | Prob. |
|----------|-------------|-----------|-------------|-------|
| C        | 2.708115    | 0.759971  | 3.563445    | 0.0044 |
| LnX1     | 0.998121    | 0.064399  | 15.49893    | 0.0000 |
| X2       | 0.868617    | 0.437405  | 1.985841    | 0.0725 |
| AR(1)    | 0.714489    | 0.436254  | 1.637779    | 0.1297 |
| SIGMASQ  | 0.004981    | 0.002461  | 2.023817    | 0.0680 |
| R-squared| 0.990878    | Mean dependent var | 10.23568 |
| Adjusted | 0.987560    | S.D. dependent var | 0.763166 |
| R-squared|            |            |             |       |
| S.E.of regression | 0.085118    | Akaike info criterion | -1.794597 |
| Sum squared resid | 0.079696    | Schwarz criterion | -1.553163 |
| Log likelihood | 19.35677    | Hannan-Quinn criter. | -1.782233 |
| F-statistic | 298.7063    | Durbin-Watson stat | 1.114771 |
| Prob(F-statistic) | 0.000000 | | |

Inverted AR Roots .71

$DW=1.1147$, it can be determined that DW is at $[0.98, 1.54]$ where is in the inconclusive area. Secondly, the Cochran-Ocot iterative method is estimated for the first-order autocorrelation again. The results are shown in Table 8:
Table 8. Cochrane-Ocot Iterative Estimation Results (2)

| Variable | Coefficient | Std.Error | t-Statistic | Prob. |
|----------|-------------|-----------|-------------|-------|
| C        | 2.890165    | 0.949809  | 3.042892    | 0.0124|
| LnX1     | 0.981427    | 0.075926  | 12.92605    | 0.0000|
| X2       | 0.799448    | 0.515006  | 1.552309    | 0.1516|
| AR(1)    | 1.192192    | 0.309876  | 3.847322    | 0.0032|
| AR(2)    | -0.595737   | 0.420808  | -1.415699   | 0.1872|
| SIGMASQ  | 0.003352    | 0.002120  | 1.581611    | 0.1448|
| R-squared| 0.993860    |           |             |       |
| Adjusted | 0.990790    | S.D. dependent var |       |
| S.E.of regression | 0.073239 | Akaike info criterion | -2.004340 |
| Sum squared resid | 0.053639 | Schwarz criterion | -1.714619 |
| Log likelihood | 22.03472 | Hannan-Quinn criter. | -1.989504 |
| F-statistic | 323.7447 | Durbin-Watson stat | 2.201485 |
| Prob(F-statistic) | 0.000000 |           |       |

Inverted AR Roots: 0.60+0.49i, 0.60-0.49i

At this time, the first-order autoregressive coefficient is significant, and the second-order autoregressive coefficient is not significant, indicating that the model only needs to perform first-order autocorrelation iteration. So, the regression model estimated by the Cochrane-Ocot iterative method is:

\[
\hat{\ln y} = 2.7081 + 0.9981 \ln x_1 + 0.8686 x_2
\]

\[t = (3.5634) \quad (15.4989) \quad (1.9858)\]

\[R^2 = 0.9909 \quad \bar{R}^2 = 0.9876 \quad F = 298.7063 \quad DW = 1.1148\]

It is verified that \(\ln Y\), \(\ln X_1\) and \(X_2\) in Guangdong Province from 2003-2018 are stable time series. There is no multicollinearity and heteroscedasticity in this model. But there is autocorrelation, AR(1) which is the first-order autocorrelation. The autocorrelation of the model is remedied by the Cochrane-Ocot iterative method. The final estimated model equation is:

\[
\hat{\ln y} = 2.7081 + 0.9981 \ln x_1 + 0.8686 x_2
\]

3. Conclusion and policy implications

3.1. Conclusion

The goodness of fit of the model reached 99.09%, the model was significant, and each explanatory variable passed the t test. Assume that when other explanatory variables remain constant, a conclusion can be drawn:

3.1.1. When the R&D expenditure (X1) of Guangdong Province changes by 1% in 2003-2018, the output value of high-tech industry (Y) changes by an average of 0.9981%, that is, the elasticity of Y to X1 is 0.9981.

It can be seen that Guangdong Province can significantly promote the development of high-tech industries, especially advanced manufacturing by increasing R&D expenditures, which is basically consistent with the development laws of developed economies. It is worth noting that the Guangdong's R&D expenditure as a percentage of GDP(R&D expenditure intensity) was 2.55% in 2017, which is a certain gap compared with 3.8% in the Tokyo Bay Area and 2.9% in the San Francisco Bay Area, and
lower than Beijing's 5%, Shanghai's 3.8%, there is a space for further improvement of R&D expenditure intensity in the future.

3.1.2. When the ratio of the output value of the second industry to the output value of the tertiary industry (X2) changes by 1 unit, the output value of the new technology industry (Y) changes by an average of 86.86%, that is, the absolute change of the unit of X2 causes the relative change of Y to be 86.86%.

The ratio of the output value of the secondary industry to the output value of the tertiary industry is used to indicate the trend of industrial structure transformation, and the ratio is reduced, which means that the economy is changing to the direction of service, and the industrial structure is transformed and upgraded. From the results of the model, Y is positively correlated with X2, that is, the larger X2, the larger Y. The reason may be that the manufacturing industry is a traditional advantageous industry in Guangdong Province, and the combination of new technologies, new knowledge with manufacturing industries is more fully manifested, as the proportion of advanced manufacturing and high-tech manufacturing industries continues to rise. The development of modern service industry in Guangdong Province started later than the manufacturing industry. Although the supporting role of the producer service industry is strengthening, the further integration of scientific and technological innovation achievements with service industry requires a process, which is not achieved overnight. The experience of industrial upgrading in developed countries also shows that the output value of technology-intensive manufacturing will grow rapidly after capital-intensive manufacturing reaches a certain scale[2].

3.2. Policy implications

The above discusses the relationship between R&D investment, industrial structure transformation and high-tech industry development in Guangdong Province. The empirical analysis results have direct policy implications for Guangdong’s economy from high-speed growth to high-quality development.

3.2.1. Unswervingly increase investment in R&D

Guangdong Province should continuously improve its independent innovation capability and strive to become a world-class high-tech industry and high-end production service industry cluster. It is necessary to continue to increase R&D investment. High-quality development requires economic transformation and improve power, quality and efficiency that promote economic transformation and upgrade on the "new track". The key point is technological innovation.

3.2.2. Vigorously develop high-end service industry

Guangdong Province should continue to rely on the unique advantages of relying on Hong Kong and Macao to support the development of high-end service industries such as finance, commercial services, warehousing and logistics, information services, continuously optimize the internal structure of the service industry, and increase the added value of high-end service industry to the added value of the service industry to make the high-end service industry a strong support for high-quality economic development.

3.2.3. Play the linkage effect between modern service industry and high-end manufacturing industry, and help Guangdong's industrial transformation and upgrading

Guangdong Province should focus on cultural creativity, tourism services and shipping logistics, strengthen cross-border cooperation between Guangdong, Hong Kong and Macao, actively promote the development of new formats and new business models related to the Internet, build a collaborative innovation system for service industry and manufacturing industry, increase the supply of technology service products, such as electronic payment and new retail, improve the output value of high-tech service products and open up new space for economic growth.
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