Financial innovation system reform in Chinese banking: the impact on bank profitability

Bingbing Shen[1] and *Zhenpeng* Xu[2*]

[1]Novosibirsk State University, 2, Pirogov str., 630090 Novosibirsk, Russian Federation
[2]Belgorod State Technological University named after V. G. Shukhov, 46, Kostukova str., 308012 Belgorod, Russia

Abstract. China's innovation capacity has been growing rapidly in recent years, but the country still needs to improve its national innovation system and form a financial services system that is compatible with the full life cycle of science and innovation companies. Looking back at China's history of financial development, the choice and feedback of commercial banks on regulatory policy has been an important factor influencing regulatory policy. With China's financial market gradually opening up to the outside world and an influx of foreign commercial banks, Chinese commercial banks are facing increasing competitive pressure. Improving the profitability of Chinese commercial banks to enhance their competitiveness has become a key to financial innovation and reform in the Chinese banking sector. Therefore, this study investigates the profitability and profit efficiency levels of Chinese banking industry over the period 2012-2020 using stochastic frontier approach. The empirical analysis leads to the following conclusions: The result is that national joint-stock commercial banks and city commercial banks, which have been given more management freedom, are trying to adapt to the dynamically changing environment and show an increase in efficiency. State-owned commercial banks maintain high levels of efficiency, but are more conservative to change. Agricultural commercial banks, for the most part, are showing efficiency gains, with no strong deterioration shown. Keywords: national innovation system, banking system, profitability, central bank, return on assets

1 Introduction

Establishing a national science and technology innovation system in a socialist market economy is impossible without financial support from the financial sector, so commercial banks, which dominate the financial sector, should be an important part of the science and technology innovation system. However, both theorists and practitioners pay much attention to the creation of new financial sectors, that is, institutions and venture capital systems, and their importance for the science and technology innovation system, and rarely talk about the status and role of commercial banks in the science and technology innovation system [1].

The global financial crisis of 2007-2009 and the subsequent period of low interest rates have renewed the interest of policy makers in the relationship between bank profitability and

* Corresponding author: xuzhenpeng@yandex.ru

financial stability. Profits tend to provide a buffer against negative shocks. While the level of bank profitability is important for financial stability, the source of bank profits is also important. In the low interest rate environment following the global financial crisis, banks have diversified their activities by seeking sources of noninterest income. It is important to consider the profitability of a bank on a risk-adjusted basis. A bank's very high profitability may reflect a very high degree of risk, which could threaten financial stability. Bank profitability can also affect the transmission of monetary policy by influencing the willingness or ability of banks to lend.

In line with China's policies and regulations for establishing a science and technology innovation system, and given the reality of the gap between China's economy and the world's economic development, we believe that China's science and technology innovation system consists of two aspects.

The science and technology innovation system of small and medium companies, this system refers to small and medium-sized scientific and technological companies as the main body, research institutions and research results or research results obtained by researchers themselves through the operation and development of the company so that they can be transformed into real productive innovative institutions [2]. This is an important aspect of the science and technology innovation system. The system in China is in its infancy and needs the support of the whole society. A realistic model for this system is the National High-Tech Development Zone or the S&T Industrial Park. The science and technology innovation system plays a key role in transforming research results into real products and is of particular importance in raising the status and level of China's national economy in the world economy. Small and medium-sized enterprises need the support of rural commercial banks and urban commercial banks for their S&T innovation systems.

Science and technology innovation system of large enterprises or groups of enterprises This refers to innovation institutions with large enterprises or groups of enterprises using high and new technologies to transform and improve traditional industries and help upgrade traditional industries; research and development of new products; breakthroughs in key technologies in the industries where the enterprises are located as the core. In the face of the new situation, it is difficult for Chinese enterprises, especially large enterprises or groups of companies, to compete internationally if they are still satisfied with the status quo, i.e., slow development of new products, low product quality, high energy consumption, and low efficiency and have not mastered key technologies to develop their industries, etc. To improve its international competitiveness [3], it must constantly engage in technological innovation. This system has a definite social, economic and technological foundation in China, but it is weak and there is a real urgency and importance to strengthen and promote the development of this system. The science and technology innovation system of large enterprises or groups of companies is supported by state-owned commercial banks and national joint-stock commercial banks.

2 Materials and methods

Initially, boundary methods were based on a theory that tries to explain the relationship of output (profit) to costs [4]. Banks were assumed to operate in perfect output-cost markets and input prices were defined as exogenous. Competition leads to equalisation of prices for inputs and outputs. Banks produce products of equal quality. In 1977 Aigner, Lovell, Schmidt and Meeusen, Vanden Broeck discovered the stochastic frontier approach. Regarding the effect of capital restrictions on the profitability of commercial banks, one viewpoint is that capital restrictions will have a positive effect on the profitability of banks [5]. Separate aspects of the evaluation of the profitability of banking activity in different directions are described in scientific researches of the following scientific publications [6] studied bank efficiency by

the stochastic frontier approach (SFA) [7], Staub, R.B. [8]. The works of the mentioned economists due to the different direction of research contain fragmentary analysis of commercial bank profitability, there is no complex approach to bank profitability estimation that would contain a conceptual system and the development of a bank profitability indicators system under the conditions of interbank competition.

The SFA model estimates technical efficiency of technological solutions by decomposing the error term [9]. The error term is divided into two parts: one part is used for random error and the other part is used for technical inefficiency, including technical inefficiency refers to uncontrollable factors such as statistical errors, etc. The stochastic frontier model combines an efficiency term u with an error term v. The basic model (perhaps after a logarithmic transformation) looks as follows:

$$y^k = f(x^k; \beta) + v^k - u^k \tag{1}$$

$$v^k \sim N(0, \sigma_V^2), u^k \sim N_+(0, \sigma_u^2), k = 1,2,3 \cdots K \tag{2}$$

The term v takes into account the randomness of the production process and possible measurement errors in costs and output, while the term u accounts for the inefficiency of the enterprise. We assume that v and u are independent. If u=0, the efficiency of the firm is 100%, if u> 0, the efficiency is low. N+ stands for a semi-normal distribution, i.e., a truncated normal distribution where the truncation point is 0 and the distribution is concentrated in the half-interval [0, ∞].

The biggest advantage of stochastic frontier approach is boundary analysis. Stochastic frontier approach is a parametric method based on the output frontier, and the technically unacceptable elements are part of the factors that differ from the output frontier caused by some artificially controlled factors. Consequently, under the influence of random influencing factors, the boundary is not fixed, so that the actual values of low technical efficiency deviate from the boundary. The problem that the stochastic frontier approach must solve is to measure technical efficiency (TE).

In economics, technical efficiency refers to the ability of output to increase or decrease output at a given cost [10]. The efficiency of a particular firm in both additive and multiplicative models depend on u. In the multiplicative model, efficiency depends only on u, while in the additive model efficiency also depends on the maximum expected output, i.e., the output determined from the estimated function. Thus, the efficiency of a particular firm is determined by the expression:

$$TE_{add}^k(x^k, y^k) = \frac{f(x^k, \hat{\beta}) - \hat{u}^k}{f(x^k, \hat{\beta})} = 1 - \frac{\hat{u}^k}{f(x^k, \hat{\beta})} \tag{3}$$

$$TE^k = TE_{mult}^k(x^k, y^k) = \exp(-\hat{u}^k) \tag{4}$$

where technical efficiency TE without a lower index refers to a multiplicative model.

In China, the banking system is segmented [11]. Each segment solves a certain range of tasks, which allows the country to function [12]. There are two stakeholders: ~~the~~ People's Bank of China and commercial bank owners [13]. We plan to do an analysis of the profitability of the Chinese banking sector. It is important for ~~the~~ People's Bank of China to ensure that the commercial banks that are part of the banking system are profitable. This will allow them to function normally, to remain interesting to their owners. For commercial banks operating in a market environment, it is important to provide their owners with acceptable profitability. Taking into account that different in size banks have different capabilities in the use of banking technology, the efficiency analysis should be conducted by type of bank and in a

time perspective: State-owned commercial banks (SO), national joint-stock commercial banks (NJ), foreign commercial banks (FB), rural commercial banks (RB), city commercial banks (CB). An analysis of profitability efficiency by bank type reveals a declining trend in banks' profitability, which is generally associated with declining interest rates and spreads in the banking sector and the slowdown of very high economic growth, typical of developing countries and the transition to growth corresponding to developed countries. The input and output parameters are an important element in the construction of the production function. The sample used for the calculations includes data from 240 Chinese banks - all credit institutions at the end of 2020. The data are obtained from the Orbis database for the period 2012-2020 and the values are presented in thousands of US dollars, we have chosen annual data. We proposed a set of parameters that, in contrast to previous studies.

Model specification of the profitability function

$$\ln\left(\frac{\text{Profit}}{w_3}\right) = \beta_0 + \sum_{j=1}^{3}\beta_j \cdot \ln\left(y_j\right) + \sum_{n=1}^{3}\gamma_n \cdot \ln\left(\frac{w_n}{w_3}\right) + \frac{1}{2}\left[\sum_{i=1}^{3}\sum_{j=1}^{3}\varphi_{ij} \cdot \ln(y_i) \cdot \ln\left(y_j\right)\right] + \frac{1}{2}\left[\sum_{m=1}^{2}\sum_{n=1}^{2}\mu_{mn} \cdot \ln\left(\frac{w_m}{w_3}\right) \cdot \ln\left(\frac{w_n}{w_3}\right)\right] + \left[\sum_{i=1}^{3}\sum_{n=1}^{2}\alpha_{in} \cdot \ln(y_i) \cdot \ln\left(\frac{w_n}{w_3}\right)\right] + u + v \quad (5)$$

here y_j is the j-th result (output); w_n is the cost of the n-th entry; β, γ and α are parameters to be estimated; u defines resource inefficiency; v is a random error. Regarding profits, let us transform the profit equation (8) by adding the absolute value of the minimum profit plus one to the actual values. This ensures that ln(Profit) has a value greater than 0.

y1 - loans. Statistics for this variable are derived from the total amount of loans of Chinese banks in their annual reports published by Orbis.

y2 - other operating assets. Statistics for this variable are obtained from income securities and other types of investments and other income-generating assets published by Orbis.

y3 - non-interest income mainly includes fee and commission income, investment income, foreign exchange income and other income published by Orbis.

The resources described in the model are represented by three types of prices:

w1 is the price for the use of fixed assets: overheads divided by net fixed assets;

w2 is the price for using borrowed capital for interest operations: interest costs divided by the borrowed capital;

w3 is the price for the use of borrowed capital for the provision of commission services: non-interest expenses divided by borrowed capital.

Table 1. Characteristics of the sample.

	Units of measure	**Mean value**	**Standard deviation**	**Maximum value**	**Minimum value**
y1	billion dollars	79.365	283.069	2775.303	0.001
y2	billion dollars	1.021	3.428	25.140	0.000
y3	billion dollars	56.683	170.387	1620.405	0.006
w1	ratio	4.404	8.997	124.837	0.257
w2	ratio	0.018	0.011	0.178	0.003
w3	ratio	0.023	0.007	0.079	0.001

It should be noted that there is a significant difference between the minimum and maximum sample values, highlighting the differences in the size of banks in the Chinese banking sector. The standard deviation of the indicator is also important: the variance of the data is

due to the diversity of banks rather than outliers in individual observations. The stochastic frontier approach itself allows for different scales of facilities in panel data.

3 Results and discussion

The return on capital indicator takes into account the level of financial leverage and characterises the profitability of bank owners, reflecting the level and interest in business development. The central bank is interested in creating such conditions so that the banking sector is attractive to investors. Figure 1 shows the dynamics of ROE over the monitored period. It can be noted that foreign commercial banks show ROE levels in the range of 3%. Chinese banks are showing a decline in ROE, which, as noted above, has been influenced by the general decline in interest rates in the economy. Equity banks show the highest ROE, which appears to be due to better management of the capital structure. This indicates the success of the measures to introduce market mechanisms in the banking sector. Rural banks show good adaptation to market conditions. They manage to compensate for lower returns on assets and show weak ROA decline. Urban banks are showing similar ROA and ROE dynamics. Apparently, they are not able to improve management efficiency yet.

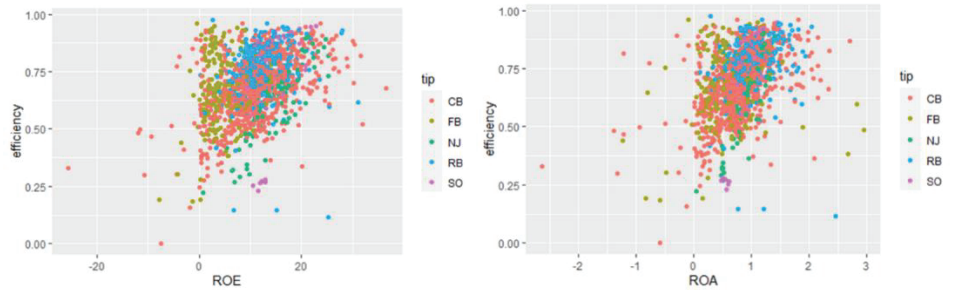

Fig. 1. Functional relationship between technical efficiency and return on assets of Chinese commercial banks (left) and the relationship between technical efficiency and return on e uity of Chinese commercial banks.

The obtained vector of technical efficiency consists of numbers, each in the range 0 to 1, showing the normalised distance from the upper limit of what is possible. The first question we plan to answer is to illustrate the functional relationship between technical efficiency and profitability. We can show this graphically. As can be seen, we can argue that the X-efficiency factor has a positive effect on the profitability of banks. This means that the management of credit institutions and the actions of government agencies have a positive impact on banking activities.

The next question is related to the assessment of the stability of the influence of the X-efficiency factors. We will also use a graphical illustration for this purpose.

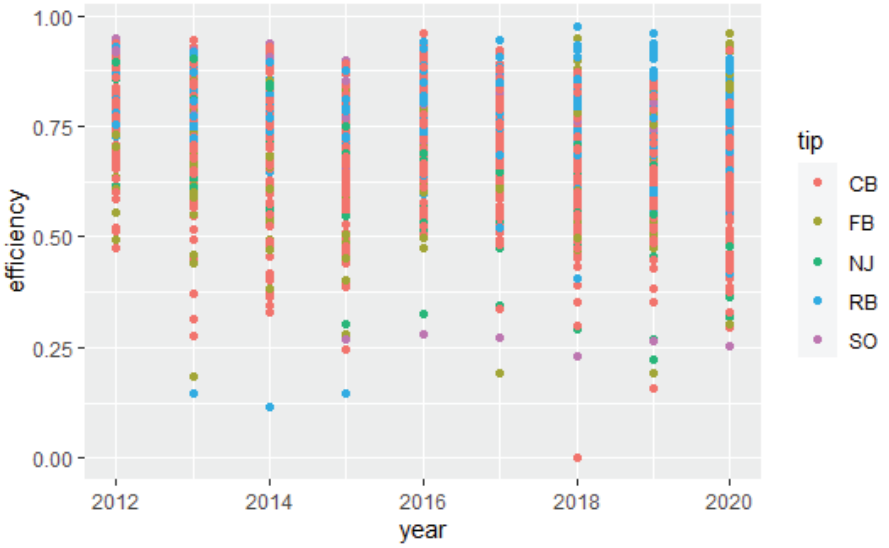

Fig. 2. Stability of influence of X-efficiency factors of Chinese commercial banks.

The graph shows that over the period, a number of banks exhibit a decline in the influence of the X-efficiency factor. This may be a consequence of the deregulation envisaged by the Chinese reforms during this period. At the same time, there is reason to believe that this effect is controllable and does not exhibit stochasticity.

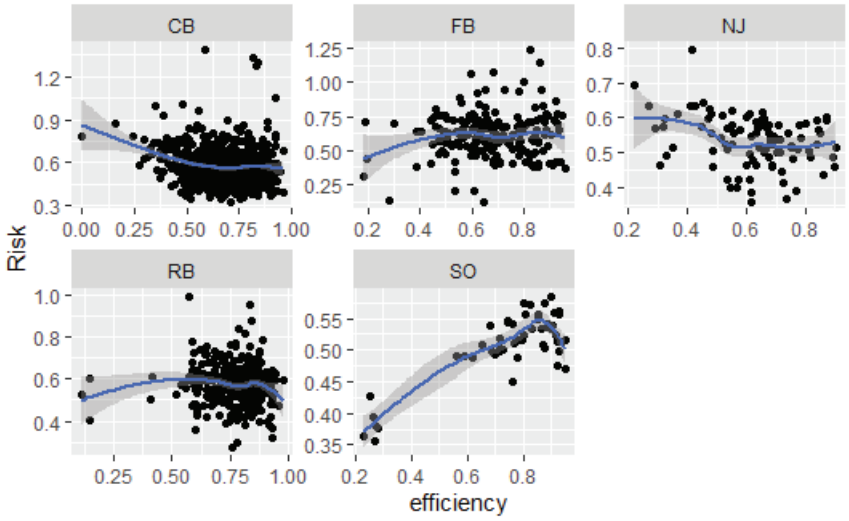

Fig. 3. The relationship between profit efficiency and risk in banks.

The profit efficiency of state-owned commercial banks is directly proportional to their risk, and profits will inevitably flow to where there is capital concentration. The capital market is characterised by concentration of profits, so the entry of commercial banks into the capital market is an inevitable result of their economic interests.

Most significant for the Chinese banking system is the classification of banks. For the PRC banking system, as already mentioned, segmentation is important.

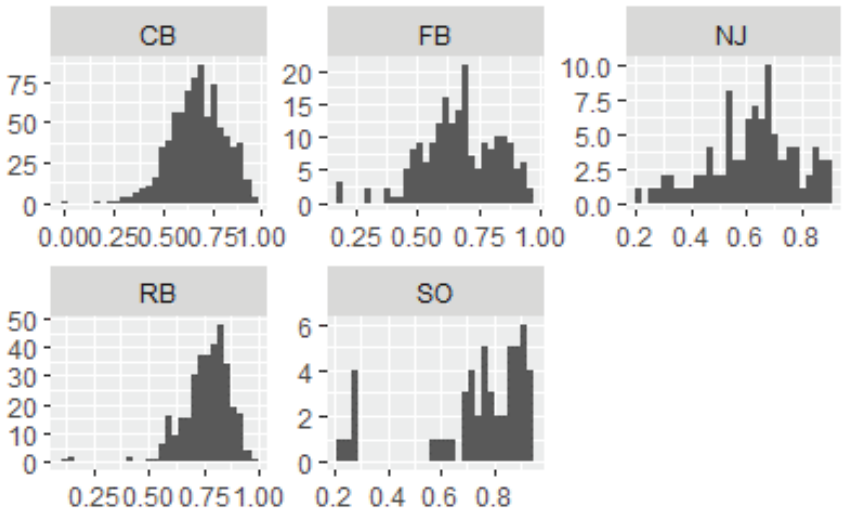

Fig. 4. Classification-based efficiency distribution of 240 commercial banks in China.

The distribution of efficiency, as shown in the figure, is similar to a normal distribution density with a rightward slope for city commercial banks (CBs). Overall, the group contains banks with different levels of technical efficiency. Noteworthy are the poly banks, here the impact of X-efficiency on profit is close to maximum. This confirms the close link between the activities of these banks and the solution of government tasks and the closest relationship between the government and the management of these banks. Foreign commercial banks (FBs) confirm once again the conclusions that we obtain. In this case, we see little influence from external and internal influences.

We believe that the stochastic frontier approach to assessing the profitability of commercial banks not only assesses the bank's ability to generate profits relative to the leading banks in the industry, but also takes into account the specific circumstances of the technology used and the market environment. At the micro level, there has been a marked improvement in the performance of rural commercial banks. Rural areas are receiving strong support from the Chinese government to help them develop. The banks have been a key factor in the financial transformation of this support, providing concessional loans for such schemes. Since the reform, the efficiency gap with other banks has narrowed considerably. This demonstrates the effectiveness of rural commercial bank reforms. National joint-stock commercial banks focus on different sectors of the economy, which to a certain extent affects their profitability by linking them to the development of these sectors. The infrastructure of Chinese cities is probably one of the most developed in the world. Chinese cities have a large concentration of manufacturing, logistics and financial institutions, all of which are growing. City dwellers are financially literate and can respond to new banking products. This has driven urban banks to improve their customer service, which has had an impact on efficiency.

The X-factors have influenced profitability differently in different time periods. The above chart does not show the distribution of technical efficiency indicators within a single year. In order to do so, we have constructed a series of graphs in the form of a bar chart.

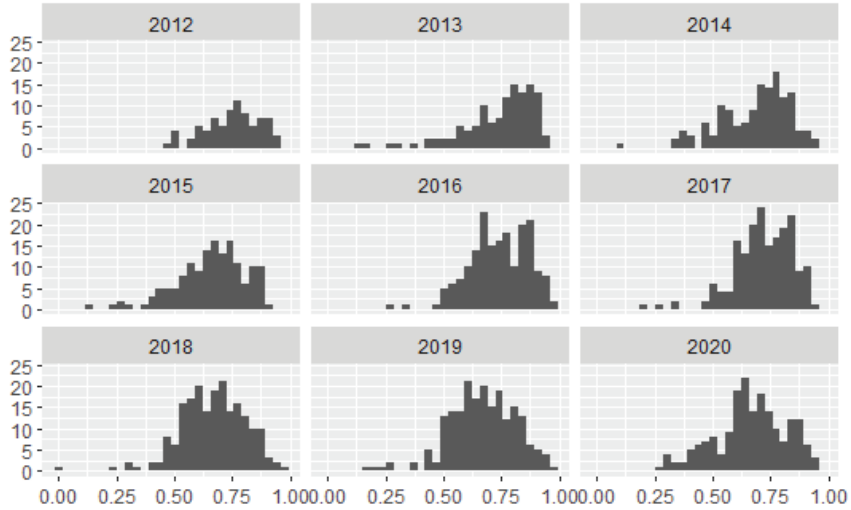

Fig. 5. Histogram of distribution of technical efficiency indicators within one year from 2012 to 2020 240 commercial banks in China.

As the figure illustrates, until 2014 there was an increase in technical efficiency across a larger set of banks and the density shifted significantly to the right. After this period, we see a "dilution" of technical efficiency. At the same time, there is an increase in differentiation between the individual groups in 2015-2017, which will decline thereafter. This, in our view, may indicate an adaptation of the banking system to the new conditions.

Considering that banks of different sizes have different capabilities in the use of banking technologies, it is worth analysing efficiency by groups of banks

4 Conclusions

The rationale for regular monitoring of the banking system, including profitability, as it should be an incentive for bank managers and owners to get serious about this business. This is in line with the Chinese model of regulating dynamic economic management processes with clearly defined strategic goals in the public interest. It is important to strike the right balance between market incentives and government expediency.

Stochastic frontier approach allows to obtain objective evaluation of situation of commercial banks profitability and influence on it of behavioral, management and other factors, which are difficult to be evaluated by other methods. For China, where the level of regulation is quite high, the assessment of such factors is very important.

The result is that national joint-stock commercial banks and city commercial banks, which have gained greater management freedom, are struggling to adapt to a dynamically changing environment and are demonstrating increased efficiency. State-owned commercial banks maintain high levels of efficiency, but are more conservative to change. Agricultural commercial banks for the most part show efficiency gains, with no strong deterioration shown.

Medium and small banks are more agile in using more profitable technologies, according to global practise. Larger banks are more cautious about embracing innovation, as wrong decisions on their scale can lead to losses.

References

1. C.C. Lee, M.F. Hsieh, Journal of International Money and Finance **32(1)**, 251–281 (2013)
2. W. Huang, Y. Wu, L. Deng, Pacific Basin Finance Journal **70**, 1–15 (2021)
3. J. Cornaggia et al, Journal of Financial Economics **115**, 189–209 (2015)
4. Aigner, Journal of Econometrics **6(1)**, 21–37 (1977)
5. N.B. Allen, Journal of Money, Credit and Banking **27(2)**, 432–456 (1995)
6. A. Pavlos, M.U. Karakaplan, L. Kutlu, Journal of Productivity Analysis **10**, 1–16 (2019)
7. Filipa Da Silva Fernandes, C. Stasinakis, V. Bardarova, Expert Systems with Applications **96**, 284–301 (2018)
8. R.B. Staub, G.S. Souza, B.M. Tabak, European Journal of Operational Research **202(1)**, 204–213 (2010)
9. L. Drake, M.J.B. Hall, R. Simper, Journal of Banking and Finance **30(5)**, 1443–1466 (2006)
10. Yong Zha, Nannan Liang, Maoguo Wu, Yiwen Bian, Omega (United Kingdom) **60**, 60–72 (2016)
11. F. Mergaerts, Journal of Financial Stability **22**, 57–75 (2016)
12. Xiaoqing (Maggie) Fu,Shelagh Heffernan, China Economic Review **18(1)**, 35–53 (2007)
13. Chengming Li, Si He, Yuan Tian, Shiqi Sun, Lu Ning, Journal of Innovation and Knowledge **7.3**, 1-13 (2022)