

## Research Article

# The Impact of Technological Innovation on Industrial Efficiency and Food Manufacturing Industry

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**Abstract:** There is no denying that China's rapid economic growth is largely relying on high consumption and high emission, shows the character as low efficiency of extensive growth, which will inevitably lead to deep-seated contradictions and problems that restrict economic long-term development. From the perspective of economic growth, the enhancement of technical efficiency can make existing economic resources be fully utilized and reduce the losses caused by low efficiency, while the enhancement of technological progress can make the continuous and stable economic growth possible. In this study, we make an empirical analysis of how technological innovation will impact on industrial efficiency in food manufacturing industry. The result shows that: technological innovation has important influence to the rising of industrial efficiency; it has a strong co integration relationship with industrial efficiency at 5% significance level. Therefore, technological innovation is the fundamental way to solve the problems of environment and resources. At the same time, technological innovation is the Grainger reason to the industrial efficiency in food processing industry.

**Keywords:** Causality test, food manufacturing industry, industrial efficiency, technological innovation

## INTRODUCTION

In 2005 the world economic forum put climate change as one of the third big challenges in the world, G8 summit to climate change as one of the most important issues (Zhang and Dan-Dan, 2012; Zou *et al.*, 2011). At present, the global warming problem which caused by carbon dioxide emissions is causing a lot of attention from international society. In 2006, the British government announced the "Stern review" drafted by Nicholas who is the former world bank chief economist, this report make a quantitative analysis to the economic effects of global warming and point out that the economic costs of climate change is almost same as a world war economic loss. Thus, greenhouse gas emissions is closely related to the level of economic development and the quality of human life (Lai *et al.*, 2012; Yuan *et al.*, 2008), global climate change may also have evolved as a disaster which will affect the whole world.

At present, China's carbon dioxide emissions produced by fossil energy consumption have been ranked second in the world. After 1980's, with the rapid development of Chinese economy, the energy consumption is increasing fast, the total energy consumption grew nearly five times within 30 years in China (Fan and Fan, 2007; Yao *et al.*, 2012). Chinese

energy consumption mainly includes coal, oil, natural gas and other fossil fuel; coal accounting 71.4% of the total energy consumption, oil accounting for 20%, natural gas accounting for 2.4%. While the carbon dioxide emissions produced by fossil energy consumption accounted 75% of China total carbon dioxide emissions. China's carbon dioxide emissions growth rate has been the forefront of the world and growth rapidly in recent years. At present, China's carbon dioxide emissions produced by fossil energy consumption have been ranked second in the world. It is expected that by 2030, China's carbon dioxide emissions is likely more than the United States, ranking first in the world (Bian *et al.*, 2013; Chang, 2010).

Since the 1960's, the population dimensions and economic gross grows continuously, as the earth's natural resources decreased and the human environment deteriorated, environmental problem get more and more attention. Dasgupta and Heal (1979) using CES production functions, they considered the non-renewable resources as raw materials and put them into the production function to study the economic growth. Stiglitz (1974) considering the population growth factors in the new classical economic growth model. Schumpeter (1934) argue that financial intermediary services has crucial effect to economy growth, bank promoting technical innovation by provide funds to the

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most competitive entrepreneurs and finally promote the economic growth. Gurley and Shaw (1955) developed the Schumpeter's point of view; they think that technical innovation is a necessary condition for economic growth. Chevallier (2011) first put forward the causal relationship between R&D investment and economic growth.

After reform and opening up, China's economy has maintained a high-speed average annual growth rate of 9.8%. China's economic growth is impressive, but also aroused questions about sustainability of China's economic growth mode. Such doubts deny the existence of enhance in Chinese economic efficiency and improvement of the quality of economy growth. There is no denying that China's rapid economic growth is largely relying on high investment, high consumption, high emission, low efficiency of extensive growth, which will inevitably lead to deep-seated contradictions and problems which restrict economic long-term development. From the perspective of economic growth, the enhancement of technical efficiency can make existing economic resources be fully utilized and reduce the losses caused by low efficiency, while the enhancement of technological progress can make the continuous and stable economic growth possible (Castellacci, 2008). The industry has been the main force driving China's economic growth, the industrial contribution rate to the economic growth has exceeded 49% by the end of 2013. At present, China is still in the middle stage of industrialization, the transformation and upgrading of the industrial structure is an important part of the transformation of economic development mode. The enhancement of technical efficiency and the acceleration of technological progress, thereby, the growth of total factor productivity is a necessary condition for the transformation and upgrading of industrial structure.

Thus, studying China's industrial efficiency, technological progress and total factor productivity has great significance to the sustained development in China. In this study, we made empirical analysis about how technological innovation will impact on industrial efficiency in food manufacturing industry.

## MATERIALS AND METHODS

**Low-carbon economy growth model:** We analyze a closed economy which has five sectors: the final product sector, human capital sector, R&D sector, intermediate products sector and energy production sector. Economic operating mechanism is that: Human capital sector develop human capital, were used for the final product sector, R&D department and human capital sector; R&D sector use human capital and existing technology to develop new technologies; intermediate products sector use the material capital and technology which provided by R&D departments to product a series of durable intermediate products; energy production departments engaged in product renewable energy; the final product sector use human

capital, intermediate products and renewable energy sources to produce the final product. The final product sector produces the final product and exhaust carbon dioxide emissions at the same time. According to the meaning of low carbon economy growth, it requires non-renewable energy growth rate was negative, while the carbon dioxide emissions growth rate is also negative. Because we should gradually reduce the non-renewable energy consumption during the production process, otherwise it cannot solve the carbon dioxide emissions problem fundamentally, also cannot achieve a low carbon economy growth.

**Various departments' production function:** We presume the final product production function D-S function and introduce the non-renewable energy as a factor into the production function, therefore, the production function of final product sector is:

$$Y = H_r^{a_1} \int_0^A X_i^{a_2} di E^{a_3} \quad (1)$$

In formula 1,  $0 < a_1 < 1$ ;  $0 < a_2 < 1$ ;  $0 < a_3 < 1$  and  $a_1 + a_2 + a_3 = 1$ . This means that the production function has constant returns to scale.  $H_r$  represent human capital which has been put into final product sector,  $Y$  represent per capita output,  $A$  is the type number of intermediate products, represent the stock of technical knowledge. We presume  $A$  is continuous;  $X_i$  is the quantity of intermediate product  $i$ ;  $E$  is non-renewable energy that put into final production department.

Human capital mainly depends on the production efficiency of human capital and input quantity. Assume that the technology in R&D sector is non-exclusive; so, technology innovation mainly depends on the Department's human capital investment and the existing technical stock.  $A$  represent the technical stock in economy;  $\delta A$  represent possibility of technological innovation, the greater the  $\delta A$  is the higher the possibility of technological innovation;  $H$  represent the human capital investment. In the intermediate products sector, once the new varieties of products or design was invented by the R&D department, one unit of the intermediate product  $X_i$  ( $i \in [0, A]$ ) just consumed 1 units of material capital  $K$ , therefore, the capital amount can be expressed as:

$$K = \int_0^A X_i di \quad (2)$$

According to the final product sector production function, the entire intermediate product  $X_i$  is asymmetrical and the input requirement is same. For  $\forall i \in [0, A]$ , we can get  $X_i = X = K/A$ . Put this into the final product production function, we can get:

$$Y = H_Y^{a_1} A x^{a_2} E^{a_3} = H_Y^{a_1} A^{1-a_2} K^{a_2} E^{a_3} \quad (3)$$

We presume there is no capital depreciation, therefore, the increase of capital stock value equals to the total output subtracts consumption. We assume S is the stock of non-renewable; E is energy into flow the final product production process. We assume existing energy are non-renewable, the initial stock of energy is S<sub>0</sub> and then the stock of energy is:

$$S = S_0 - \int_0^t E(v)dv \quad (4)$$

Assumed representative consumer has a standard fixed elastic utility function in the infinite domain:

$$U(C) = \int_0^\infty \frac{c^{1-\sigma} - 1}{1-\sigma} L e^{-\alpha} d_1 = \int_0^\infty \frac{c^{1-\sigma} - 1}{1-\sigma} e^{-\alpha} di \quad (5)$$

The c = C/L represent per capita consumption, L represent the total population, as we assume the total population is 1, thus, the per capita consumption are equal to total consumption. σ is marginal utility elasticity, ρ is the consumer's time preference. According to input and output of the final product department, human capital development of human capital department, technology research and development of the R&D department, production of product department and non-renewable energy consumption, Social dynamic optimization mathematical expression can be shown as:

$$\max U(C) = \max \int_0^\infty \frac{C^{1-\sigma} - 1}{1-\sigma} e^{-\alpha} d_1 \quad (6)$$

We use Hamilton function to calculate the value of this dynamic optimization model, the equation is:

$$H_c = \frac{C^{1-\sigma} - 1}{1-\sigma} + \lambda_1 [H_r A^{a_1} K^{a_2} E^{a_3} - C] + \lambda_2 [\delta_H (H - H_r - H_A)] + \lambda_3 (\delta_A H_A) + \lambda_4 (-E) \quad (7)$$

On the balanced growth path, each variable growth rates were constant. According to relationship of consumption, investment and output, we can know that the economic variables Y, C, K have the same growth rate and gr, gc, gx are the same constant. According to the above formula, then the only transversality condition is:

$$(1 - \sigma)g_r - \rho < 0 \quad (8)$$

According to the substance of low carbon economy growth, the necessary condition to achieve a low carbon economy growth is: gr>0, gE<0, it means the per capita output increases ceaselessly, the consumption of non-renewable energy sources ceaselessly reduce. To achieve this conditions need δH, δA sufficiently large;

ρ sufficiently small and σ≥1. Therefore, once the economy has enough human capital accumulation efficiency and technical efficiency, it will resulting in higher efficiency of technological innovation and can reduced consumption of non-renewable energy sources, achieve the low-carbon economy growth.

## RESULTS AND DISCUSSION

**ADF unit root test:** The unit root test was first put forward by David Dickey and Wayne Fuller, so it is also called DF test. DF test is a basic method in stationary test, if we have a model as:

$$Y_t = \rho Y_{t-1} + \mu_t \quad (9)$$

DF test is the significance test to the coefficient. If ρ<1, when T→∞, ρ T→0, that means the impulse will be reduced when the time is increased. However, if ρ≥1, the impulse will not be reduced with the time, so that this time-series data is not stable. The basic DF test model can be written as:

$$Y_t = \beta_1 + \beta_2 t + (1 + \delta) Y_{t-1} + \mu_t \quad (10)$$

If we add the lagged variable of ΔY<sub>t</sub> in formula 10, then it will be called the augmented Dickey-Fuller test, so that ADF test model can be written as:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^m \Delta Y_{t-i} + \varepsilon_t \quad (11)$$

Data stable is the premise of establishing VAR model, an augmented Dickey-Fuller test (ADF) is a test for a unit root in a time series sample.

We make the empirical test of the relationship between the technological innovation and the industrial efficiency in food manufacturing industry. I use the annual data of R&D investment (RD) to represent the technological innovation; and use Food Industry Productivity (FIP) in food manufacturing industry to represent the industrial efficiency, sample data from the years 1990-2012, data from China Statistical Yearbook. In order to solve the nonlinear problem, I take natural logarithms of RD and FIP, as LnRD and LnFIP. In this study, I use the ADF unit root test method to test the smoothness of each variable; the result is shown as Table 1.

**Test result:** In order to study the cointegration relation between LnRD and LnFIP, I made a Johansen Cointegration Test, the result stated in Table 2. According to the results from Table 2, we can get that LnRD and LnFIP has a strong co integration relationship at 5% significance level. According to the test results from Table 2, we get that there exist

Table 1: Augmented Dickey-Fuller test (ADF)

| Variables               | LnRD    | LnFIP   | d.LnRD  | d.LnFIP |
|-------------------------|---------|---------|---------|---------|
| ADF Test statistic      | -1.5724 | 0.5316  | -5.2736 | -2.8923 |
| Inspection type (c,t,k) | (c,0,0) | (c,0,0) | (c,0,1) | (c,0,1) |
| 10% Critical value      | -2.6299 | -2.6251 | -2.6299 | -2.6326 |
| Stationary or not       | No      | No      | Yes     | Yes     |

Table 2: The co-integration test between lnDK and lnE

| Eigen value | Trace test | 5% critical value | Hypothesized No of CE(s) |
|-------------|------------|-------------------|--------------------------|
| 0.3115      | 0.3912     | 19.6344           | None                     |
| 0.2629      | 0.0075     | 8.8097            | At most 1*               |

Table 3: Granger causality test

| The null hypothesis                 | Lag | F-statistic | p-value | Receive H0 or not |
|-------------------------------------|-----|-------------|---------|-------------------|
| ΔLnRD does not Granger cause ΔLnFIP | 2   | 0.0287      | 0.8799  | Reject            |
| ΔLnFIP does not Granger cause ΔLnRD | 2   | 0.8616      | 0.0846  | Accept            |
| ΔLnRD does not Granger cause ΔLnFIP | 3   | 0.0169      | 0.9718  | Reject            |
| ΔLnFIP does not Granger cause ΔLnRD | 3   | 0.4380      | 0.0929  | Accept            |

normalized co-integrating equations between LnRD and LnFIP. Also we the VAR model can be shown as:

$$LnFIP = -0.587 + 0.629LnRD + 0.117LnRD + 1.766LnFIP - 0.771LnFIP \quad (12)$$

From the VAR model, it shows that, the cointegration relation between LnRD and LnFIP is positive, that means technological innovation will cause the rising of industrial efficiency in food manufacturing industry.

**Granger causality test:** The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another, A time series X is said to Granger-cause Y if it can be shown, usually through a series of t-tests and F-tests on lagged values of X (and with lagged values of Y also included), that those X values provide statistically significant information about future values of Y, we assume a VAR model as:

$$y_t = \sum_{i=1}^k a_i y_{t-i} + \sum_{i=1}^k \beta_i x_{t-i} + u_t \quad (13)$$

So the null hypothesis will be:

$$H_0 : \beta_1 = \beta_2 = \dots = \beta_k = 0 \quad (14)$$

If all the parameter estimates of x are not significant, then the null hypothesis will not be rejected. In other words, if there is any parameter estimate of x significant, that means x is the granger reason to y. This test can be shown by F statistics:

$$F = \frac{(SSE_r - SSE_u)/k}{SSE_u/(T - kN)} \quad (15)$$

In this formula, SSE<sub>r</sub> represents the residual sum of squares when null hypotheses was passed and SSE<sub>u</sub> represents the residual sum of squares when null

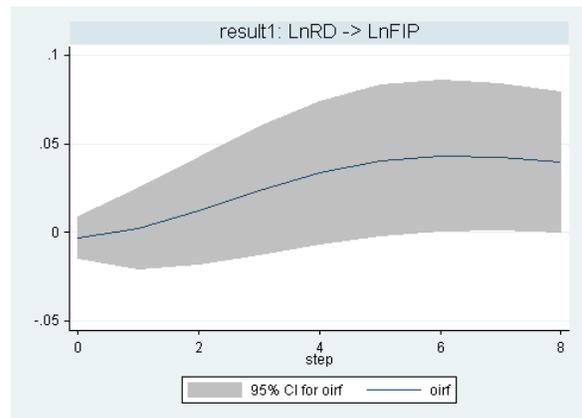


Fig. 1: Impulse-response analysis for LnRD to LnFIP

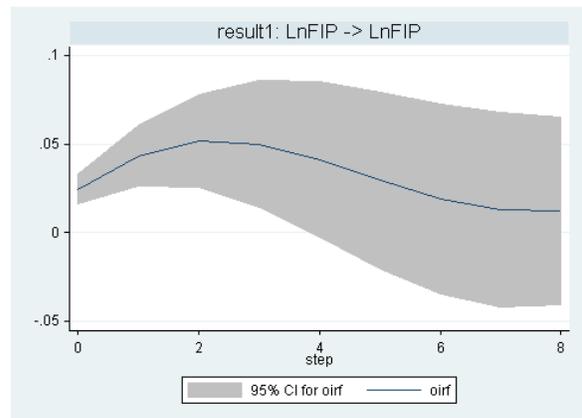


Fig. 2: Impulse-response analysis for LnFIP to LnFIP

hypotheses was not passed, k represents the lag length, N represents the number of variables. In order to examine causal relationship between LnRD and LnFIP, we performed the Granger causality test for the model and the results are shown in Table 3.

According to the test results, technological innovation is Grainger reason to industrial efficiency in food processing industry. In fact, the rising of industrial efficiency is also the reason for the technological

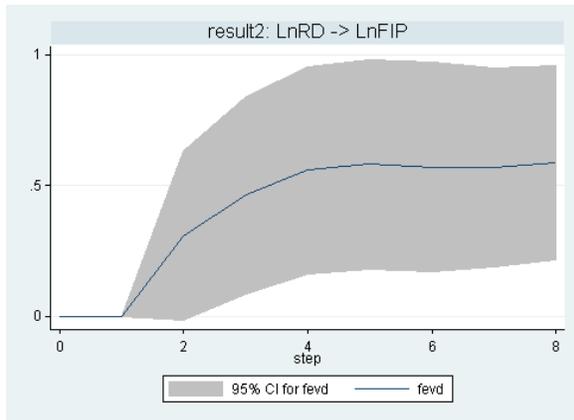


Fig. 3: Cholesky variance decomposition for LnRD to LnFIP

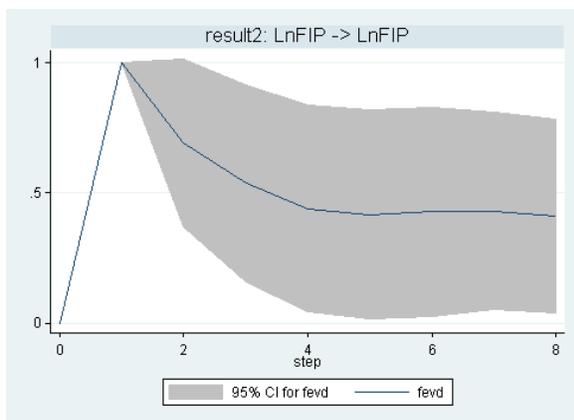


Fig. 4: Cholesky variance decomposition for LnFIP to LnFIP

innovation, so it can prove that the food processing industry will also be influenced by the R&D investment.

**Impulse-response analysis and cholesky variance decomposition:** According to the results above, we can get that there exist a long-term equilibrium relationship between R&D investment and food industry productivity, also the VAR model is stable. In order to analyze the VAR model, we use Impulse-response function, the results is shown in Fig. 1 and 2. Figure 1 is the impulse-response analysis for LnRD to LnFIP and Fig. 2 is the impulse-response analysis for LnFIP to LnFIP.

From Fig. 1, we can get that when LnRD received one unit impact, it will lead LnFIP increase currently, LnFIP at  $t = 1$  period is 0.0024 and then increased to 0.0121 at  $t = 2$  period. LnFIP will reach the max at  $t = 5$  period and begin to be stable then. It illustrates there is long-term effect between R&D investment and food industry productivity. From Fig. 2, we can get that when LnFIP received one unit impact, it will lead LnFIP increase currently, LnFIP will reach the max as 0.0515 at  $t = 2$  period and then decrease to 0.019.

Finally, it will return to the basic situation at  $t = 8$  period. According to the impulse analysis results, we can get that R&D investment will have significant influence to food industry productivity, it will promote the rising of productivity; at the same time, we can get that industrial productivity has continuous effect and tends to be stable in the long time.

Then, we make cholesky variance decomposition to the VAR model, the results is shown in Fig. 3 and 4. The cholesky variance decomposition also shows the same result, the contribution degree of LnRD to LnFIP is gradually increased. From Fig. 3, we find the contribution degree of LnRD to LnFIP at  $t = 1$  period is 0 and then increase to 30.81% at step 2, the contribution degree rapid growth to 55.90% after step 4. This means that R&D investment has obvious interpretative strength to industrial efficiency in the long-term. From the Fig. 4, we can find that LnFIP has a stable contribution degree to itself; the contribution degree of LnFIP to LnFIP is reached 100% at step 1 and then decrease to 69.18% at step 2. This proves that the industry productivity has a certain expansion to itself. The result of variance decomposition means that both R&D investment and food industry productivity has adequate contribution degree to the rising of productivity and can be used to explain the increase of productivity.

## CONCLUSION

In this study, the result shows that: R&D investment has the important influence to the rising of industrial efficiency; at the same time, technological innovation is the Grainger reason to industrial efficiency in food processing industry.

First of all, by using the endogenous economic growth model to analyze the low-carbon economic growth, from the results we can get that: if the technical innovation has a sufficiently high efficiency, economy can overcome the constraint of non-renewable energy consumption, achieve low-carbon economy growth. There need to explain that through the analysis of the model we can get that technology innovation can promote low-carbon economic growth and the low-carbon economy growth is a necessary condition to the low carbon economy development. Therefore, technological innovation is the fundamental way to solve the problems of environment and resources and also the essence to develop low-carbon economy.

Then we make empirical analysis of how technological innovation will impact on industrial efficiency in food manufacturing industry. The result shows that: the cointegration relation between LnRD and LnFIP is positive, that means technological innovation will cause the rising of industrial efficiency in food manufacturing industry.

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