Aquatic Product Processing Industry’s Total Factor Productivity and Influencing Factors in China

CHEN, Tinggui
College of Economics and Management, Shanghai Ocean University | Laboratory of Environmental Economics, Division of Agricultural and Resource Economics, Departmentof Agricultural and Resource Economics, Faculty of Agriculture, Kyushu University

LIN, Gan
College of Economics and Management, Shanghai Ocean University | Laboratory of Environmental Economics, Division of Agricultural and Resource Economics, Departmentof Agricultural and Resource Economics, Faculty of Agriculture, Kyushu University

TAKAHASHI, Yoshifumi
Faculty of Agriculture, Kyushu University | Laboratory of Environmental Economics, Division of Agricultural and Resource Economics, Departmentof Agricultural and Resource Economics, Faculty of Agriculture, Kyushu University

YABE, Mitsuyasu
Laboratory of Environmental Economics, Department of Agricultural and Resource Economics, Faculty of Agriculture, Kyushu University

https://doi.org/10.5109/1955665

出版情報：九州大学大学院農学研究院紀要. 63 (2), pp.423-431, 2018-09-01. Faculty of Agriculture, Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **63** (2), 423–431 (2018)

Aquatic Product Processing Industry's Total Factor Productivity and Influencing Factors in China

Tinggui CHEN[1], Gan LIN[1], Yoshifumi TAKAHASHI[2] and Mitsuyasu YABE[2]*

Laboratory of Environmental Economics, Division of Agricultural and Resource Economics,
Departmentof Agricultural and Resource Economics, Faculty of Agriculture,
Kyushu University, Fukuoka 812–8581, Japan
(*Received May 1, 2018 and accepted May 8, 2018*)

This paper studies the TFP (total factor productivity) of China's aquatic product processing industry, which is estimated and decomposed by using OP (Olley and Pakes) method based on Chinese Industrial Enterprises Database from 2005 to 2013. Then this paper discusses the characteristics of TFP from the microscopic point of view, and finally analyzes the factors that affect the change of TFP. The results indicate that: (1) The TFP differs remarkably as the sub–sectors, regions and ownership of firms vary: the TFPs of aquatic product frozen processing and aquatic feed manufacturing are the highest, the productivity of firms in inland areas is higher than those in coastal areas and the productivity of private firms is the highest, followed by foreign–funded firms and state–owned firms. (2) Growth within firms contributes the most to the TFP growth, and resource allocation is inefficient among firms. (3) Labor productivity, firm size, export, FDI (foreign direct investment) and R&D can effectively promote the improvement of TFP in the aquatic product processing industry, and capital intensity and financing constraints will inhibit the industry from improving its TFP.

Key words: Aquatic product processing industry, Chinese Industrial Enterprises Database, Influencing factor, Total Factor Productivity

INTRODUCTION

China is a major country in fishery. According to the China Fishery Statistical Yearbook 2017, the entire fishery economics output value reached 2,366.229 billion yuan (calculated at current prices) in 2016, of which the fishery output was 1200.291 billion yuan. In 2016, the total output of aquatic products in China was 69,012,500 tons and increased by 3.01% over the same period of last year. The per capita of aquatic products was 49.91 kg and increased by 2.40% over the same period of last year. With the development of fisheries, the aquatic product processing industry has also made great strides. In 2016, the processing capacity of aquatic products in China increased by 1.38% compared with that in the same period of last year. The total amount of processed aquatic products reached 21,654,407 tons and increased by 3.50% over the same period of last year. The aquatic product processing industry is an important part of China's food processing industry, occupying an important position in the national economy and people's livelihood. As the aquaculture industry is booming, aquatic products, as the main source of human intake of protein, provide raw materials for the food industry, pharmaceutical industry and feed industry. As an important link to improve the economic performance and added value of aquatic products, the aquatic product processing industry is not only an effective aid to develop fishery modernization in China, but also the key to promote the industrial added value.

Although China's aquatic product processing industry has made great progress over the years, there are still some shortcomings restricting its development. One of the major problems is that the processing capacity is still weak. In 2016, the total aquatic products processing output accounted for only 31.38% of the total output of aquatic products, down from 34.80% in 2015. In addition, most of the equipment of aquatic product processing firms in China still lags behind the world's advanced level. As a result, the aquatic product processing firms in China are still exporting raw materials and semi–finished products, which lacks international competitiveness. The level of total factor productivity (TFP) is possibly one of the key factors that restrict the development of aquatic product processing industry in China.

TFP is often referred to as the rate of technological progress. It is used to measure the role of pure technological progress in production in the neoclassical economic growth theory. Robert Merton Solow proposed the aggregate production function with constant returns to scale and formed what is commonly referred to as the meaning of total factor productivity in the article "Technical change and aggregate production function" published in 1957. He indicates that the residual value obtained by deducting the growth of input factors in output growth can be regarded as the result of technological progress, that is, the total factor productivity. The increase in productivity mainly comes from improvements in education, knowledge, technical training, specialization, organizational management, production innovation and so on. The backward technology leads to insufficient vitality in the aquatic product processing industry. China is constantly encouraging firms to engage in innovation,

[1] College of Economics and Management, Shanghai Ocean University, P. R. China
[2] Faculty of Agriculture, Kyushu University
* Corresponding author (E–mail: yabe@agr.kyushu–u.ac.jp)

and TFP is also the key to the healthy development of aquatic product processing industry. This paper next explores the TFP of China's aquatic product processing industry, such as the characteristics of TFP, and how the relevant factors affect the TFP of aquatic product processing industry.

There are two types of research in the field of aquatic product processing industry. The first category is the study of China's aquatic product processing industry. Zhao and Yang (2010) analyze the market structure of China's aquatic product processing industry based on the SCP (Structure–Conduct–Performance) model from the aspects of market concentration, product differentiation, barriers to entry and exit, and concluded that government should adjust the structure to improve the economic performance of the aquatic product processing industry as a first priority. Ju and Qin (2013) point out that in recent years, the processing level of aquatic product in China has been greatly improved. The layout of firms is becoming more reasonable and the product variety is constantly increasing. However, there are also problems such as low technological level, weak innovation capability and low comprehensive utilization rate. Yang *et al*. (2016) also find that China's aquatic product processing industry has witnessed a rapid growth in a decade and achieved good results. However, the processing rate in China is still below the world average; the regional structure is irrational; and processing of freshwater products is weak.

The second category of previous studies is about China's food processing industry productivity research. Yang *et al*. (2012) study the changes of TFP in the food processing industry in Jilin Province from 2006 to 2010 and find that the TFP of the food processing industry increased rapidly with large differences among sub–industries. Liu and He (2009) also study the same issue and found that the technical efficiency is steadily increasing, but there is still a technical efficiency loss.

The above studies share one thing in common: the data used are all macro data of the industry. However, Ye and Huang (2016) use the micro data of China's Industrial Enterprises Database from 1999 to 2011 to examine the dynamic changes of TFP on China's agro–food processing industry and find that the aggregate productivity of agro–food processing industry is growing at an average rate of 8.88%.

Many studies have conducted extensive research on the aquatic product processing industry, but they all examined the development of the industry at a macro level and do not address the issue of productivity. Some scholars have made relevant research on the productivity of the food processing industry, but seldom specifically studied the productivity of China's aquatic product processing industry. This article is dedicated to contributing in this field. This paper will study the following parts: (a) the factor contribution rate and TFP of China's aquatic product processing industry by sorting out the China Industrial Enterprises Database from 2005 to 2013. (b) the TFP of aquatic product processing firms in different regions, different sub–industries and different ownership types. (c) the contribution of different types of firms to TFP change of China's aquatic product processing industry through the decomposition of TFP. (d) what factors will affect the change of TFP on aquatic product processing industry in China and their impacts.

METHODOLOGY OF TFP MEASUREMENT

Many studies adopt different methods to calculate firm' s TFP, including traditional OLS estimation, Fixed Effect estimation, Stochastic Frontier Analysis (Aigner *et al*., 1977; Liu and Li, 2008), DEA method (Mukherjee *et al*., 2001; Peng *et al*., 2013), OP method (Olley and Pakes, 1996) and LP method (Levinsohn and Petrin, 2003). At present, the most common methods for estimating micro–data are the OP method and the LP method. The LP method requires the value of intermediate inputs but this indicator is missing in CIED, and the OP method can well solve the problems of the selectivity bias and the simultaneity bias that the traditional OLS estimation has (Olley and Pakes, 1996). Therefore, this paper uses the OP method to measure the TFP of China's aquatic product processing industry.

The form of the production function must be determined firstly to estimate the TFP. In this study, the Cobb–Douglas production function adopted in most literatures is used as the basis for the calculation of TFP, namely:

$$Y_{it} = AK_{it}{}^{\alpha} L_{it}{}^{\beta} \tag{1}$$

Take a logarithm of Eq. (1),

$$y_{it} = \alpha \cdot k_{it} + \beta \cdot l_{it} + u_{it} \tag{2}$$

Where u_{it} represents the logarithmic form of TFP. The absolute level of TFP is calculated as follows:

$$TFP_{it} = \ln Y_{it} - \alpha \ln K_{it} - \beta \ln L_{it} \tag{3}$$

The gross industrial output value of firms is applied as the proxy variable of output (Y_{it}), capital stock as the proxy variable of capital (K_{it}), and the practitioners of firms as the proxy variables of labor (L_{it}). Then this paper calculates the TFP of China's aquatic product processing industry according to the main ideas and contexts of Olley and Pakes (1996), Lu and Lian (2012) and Zhang *et al*. (2009). There are two benefits: (a) The firm is affected by their observable efficiency in the process of deciding the input of production factors, that is, the observable part of the residual item u_{it} is related to the input of production factors during the current period (simultaneity bias). OP method to solve the problem of simultaneity bias is to build an investment function as a proxy for observable efficiency impact, that is, firms will make an investment decision based on the current observable efficiency. (b) Another problem is the selectivity bias. CIED contains the data of above–scaled non–state–owned firms. Non–state–owned enterprises below the scale are excluded from CIED. However, it tends to be easier for those with lager capital stock to face productivity shock; they are therefore easier to stay in the database. As a consequence, the lack of data may be due to non–random factors, the capital stock will be associated with the residual term, resulting in a bias. The OP method solves the problem of selection bias by constructing a survival probability function to estimate the exit and entry of firms. The above process mainly consists of three steps.

In the first step, Olley and Pakes think that part of the residual item u_{it} in Eq. (2) is observable by firms, this part is assumed to be g_{it}, then $u_{it} = g_{it} + e_{it}$, where e_{it} is truly unobservable technical shocks, that is, the total factor productivity. If we directly perform a regression on Eq. (3), it will cause the residual item to be related to the regression term and thus be biased. In order to solve the problem of simultaneity deviation, Olley and Pakes assume that firms decide the investment situation according to the current productivity situation, that is, use the current investment of the firm as the proxy variable of the unobservable technical shocks. Olley and Pakes first established a relationship between capital stock and current investment based on the perpetual inventory method:

$$K_{i,t+1} = I_{i,t} + (1-\delta)\, K_{i,t} \tag{4}$$

Where K represents the capital stock of the firm, I represents the current investment and δ represents the depreciation rate. Next, we construct the relationship between investment and the level of productivity that can be observed by the firm, if the firm is expected to have a higher productivity level in the future, it will choose to increase the current investment, the specific investment function is as follows:

$$i_{i,t} = i_t\,(g_{i,t}, k_{i,t}) \tag{5}$$

Then find the inverse function of Eq. (5) as follows:

$$g_{i,t} = g_t\,(i_{i,t}, k_{i,t}) \tag{6}$$

Substituting Eq. (6) into Eq. (2):

$$y_{it} = \alpha \cdot k_{it} + \beta \cdot l_{it} + g_t\,(i_{i,t}, k_{i,t}) + e_{it} \tag{7}$$

In the second step, $\alpha \cdot k_{it} + g_t\,(i_{i,t}, k_{i,t})$ of the eq. (7) can be defined as the contribution of capital to the output and used ω_{it} instead, followed by the specific form set, and Olley and Pakes's approach is to construct a fourth order polynomial that contains the firm's capital stock and investment, and then estimate them to obtain unbiased estimates of labor input, which is a non–parametric estimation, and then solve the problem of simultaneous deviations.

In the third step, Olley and Pakes use a survival probability function to estimate the entry of firms and the exit of firms in order to solve the problem of sample selectivity bias. The Probit model is estimated as follows:

$$\Pr(\chi_{it} = 1 | J_{i,t-1}) = \Pr(\chi_{it} = 1 | g_{i,t-1}, \widehat{g_{it}}(k_{i,t+1}))$$
$$= \phi(i_{i,t-1}, k_{i,t-1}) \tag{8}$$

χ_{it} =1 represents the firm will continue to operate, χ_{it} =0 represents the firm will exit the market. And whether the firm exits depends on the technical threshold g. If the actual productivity is higher than the threshold, the firm will continue to operate. If the actual productivity is lower than the threshold, the firm will exit the market; $J_{i,t-1}$ represents the information set that the firm can observe in the period t–1. Substituting the Probit model fit value estimated from Eq. (8) into Eq. (7):

$$y_{it} - \hat{\beta} \cdot l_{it} = \alpha \cdot k_{it} + z_t\,(\phi_{t-1} - \alpha \cdot k_{i,t-1}, Pr_{i,t-1}) + \mu_{it} + e_{it} \tag{9}$$

$Pr_{i,t-1}$ represents the survival probability of the firm, which is estimated by Eq. (8); z_t can be represented by a high–order polynomial including ϕ_{t-1}, $k_{i,t-1}$ and $Pr_{i,t-1}$. Olley and Pakes control the sample selection bias and obtain a consistent estimate of capital investment by estimating Eq. (9).

In terms of the realization of the specific regression process, this paper refers to Lu and Lian (2012) estimating the following equation:

$$\ln Y_{it} = \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_A\, age_{it}$$
$$+ \sum_m \delta_m\, year_m + \sum_n \lambda_n\, reg_n + \sum_k \eta_k\, ind_k + \varepsilon_{it} \tag{10}$$

The regression uses the OP semi–parametric three–step regression method, with the state variables being $\ln K_{it}$ and firm age (age_{it}). The free variables are $\ln L_{it}$, regional dummy variable (reg_n) and 4–digit code industry dummy variable (ind_k). The control variable is time trend variable ($year_m$). The proxy variable is the investment variable ($\ln I_{it}$). The exit variable is *exit* according to whether the firm is out of data. ε_{it} is the random disturbance. The estimated β_K and β_L can be obtained by regression of Eq. (10). Then the total factor productivity at the firm level can be estimated based on Eq. (3).

DATA

The data used in this paper is derived from China Industrial Enterprise Database (CIED): 2005–2013, which is maintained by the China National Bureau of Statistics, including all state–owned enterprises and above–scale (enterprise annual sales above 5 million RMB (1RMB=$0.1579, 2018/4/30) and 20 million RMB since 2011) non–state–owned enterprises. The object of this study is the aquatic product processing industry, which corresponds to the database of frozen processing of aquatic product (4–digit industry code: 1361), dry salting processing of surimi product and aquatic product (1362), aquatic feed manufacturing (1363), other aquatic product processing (1369) and aquatic product canning (1452), including a total of 17,570 observations. According to the firm code after matching (Brandt *et al*., 2012), there are 4687 firms in the data.

Nie *et al*. (2012) point out that some serious problems exist in CIED such as confusion of sample matching, abnormal size and vague definition of variables, obvious error of measurement. In order to make the result more reasonable, we exclude the samples from CIED according to Xie *et al*. (2008) and Yang (2015): (a) if industrial output value, total assets, capital stock and product sales and other key variables are missing, zero and negative. (b) if the number of employees in a firm is less than 8. (c) if the year which the firm was created in is before 1950. (d) if paid–in capital of a firm is greater than 0. In addition, this study deflates nominal variables such as industrial output value and capital stock, in which the industrial output value is deflated by the Producer Price Index (2005) and the capital stock is deflated by the Price Indices of Investment in Fixed Assets (2005). Perpetual inventory method is used to estimate investment. The formula is as follows, investment in fixed assets = current capital stock – (1 – depreciation rate) * Lagged capital stock, where the depreciation rate is 15% referring to Zhang *et al*. (2009).

After the above process, the description of the main variables is shown in Table 1.

Due to the particularities of the aquatic product processing industry, the size of firms in different regions may be different. It is found that there is a lack of data

Table 1. Statistical description of the main variables

Variable	Definition	Observations	Mean	Standard deviation
ln*Yit*	Industrial output value (thousand yuan)	17,122	10.94	1.34
ln*Kit*	Capital stock (thousand yuan)	17,122	8.73	1.60
ln*Lit*	Practitioners of firms (number of employees)	17,122	4.93	1.16
ln*Iit*	Investment (thousand yuan)	9,234	7.55	1.97
ageit	Firm age (year)	17,122	9.47	6.53

Table 2. Industrial output value of sub–regional aquatic product processing

Region	ln*Y*	Region	ln*Y*	Region	ln*Y*
Liaoning	10.97	Hainan	10.98	Yunnan	10.40
Hebei	10.52	Beijing	9.60	Shaanxi	10.01
Tianjin	10.13	Jilin	10.51	Gansu	8.84
Shandong	11.55	Heilongjiang	9.73	Xinjiang	9.91
Jiangsu	10.48	Anhui	10.65	Inner Mongolia	9.39
Zhejiang	10.52	Jiangxi	11.28	Guangxi	10.86
Shanghai	10.27	Henan	10.57	Sichuan	10.30
Fujian	10.90	Hubei	10.65		
Guangdong	10.90	Hunan	10.59		

on the aquatic product processing in Shanxi, Chongqing, Guizhou, Tibet, Qinghai and Ningxia, indicating that the aquatic product processing industry in these provinces is still underdeveloped. The average industrial output value in other regions is shown in Table 2.

Due to the small number of observations (all below 50) in Beijing, Heilongjiang, Sichuan, Yunnan, Shaanxi, Gansu, Xinjiang and Inner Mongolia, these areas were excluded in the follow–up analysis. The results in Table 2 show that the average size of aquatic product processing firms in Shandong and Jiangxi are largest, and the logarithm of the industrial output value surpassed 11, at 11.55 and 11.28 respectively. In other regions, the log of the industrial output value is between 10 and 11, with a small gap. The areas with the smallest average firm size are Tianjin and Shanghai, at 10.13 and 10.27 respectively.

RESULTS OF TFP MEASUREMENT

Capital and labor contribution rate

The capital and labor contribution rate measure the contribution of the two most important elements of economic growth in the change of TFP. The contribution rate of capital β_K and the contribution rate of labor β_L in the aquatic product processing industry are estimated by Eq. (9), as shown in Table 3.

Table 3. Factor contribution rate in aquatic product processing

Contribution rate	OLS	FE	OP
β_K	0.23***	0.14***	0.32***
β_L	0.52***	0.25***	0.46***

Note: *, **, *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

It can be seen from the factor contribution rates calculated by the OP method in Table 3 that the contribution of labor to output in China's aquatic product processing industry is significantly higher than that of capital. This is in line with the characteristics of the food industry, indicating that China's aquatic product processing industry is labor–intensive. This was also confirmed by the results calculated by OLS and FE (fixed effect). In addition, the labor contribution rate of the aquatic products processing industry calculated by the OP method is 0.46; the capital contribution rate is 0.32; and the sum of the labor contribution rate and the capital contribution rate is less than 1. This shows that China's aquatic products processing industry is decreasing returns to scale, with the possible reason as the lack of coordination of the various elements in the production process and the inefficiency of firm's operation.

TFP of heterogeneous aquatic product processing

Then the TFP of aquatic product processing firms in different regions, different sub–industries and different ownership types is studied. Regarding the comparison of firm's TFP with different ownership types, this paper processes as follows: (1) To avoid the difference of scale standard, this paper compared the difference between the above–scale state–owned and non–state–owned firms of the data. (2) The non–state–owned firms are divided into private firms and foreign–funded firms. According to Nie *et al*. (2012), this paper defines the state–owned firm as that whose state–owned capital accounts for more than 50% of the total and the foreign–funded firm as that whose foreign investment (including Hong Kong, Macao and Taiwan businessmen) accounts for more than 25% of the total. Then this paper calculates the TFP according to Eq. (3) and carries out the weighted average at the firm level, with the weight of the real gross industrial output (this weight is used in the TFP levels calculated in the following text). In addition, this paper also calculates the annual average growth rate of TFP, labor productivity and capital productivity, with the results shown in Table 4. Labor productivity and capital productivity are average value weighted by real gross industrial output. The formula for calculating labor productivity is $\ln Y/L$, for calculating capital productivity is $\ln Y/K$.

As can be seen from Table 4, the TFP levels of the five sub–industries are between 6 and 7. The TFP levels of frozen processing of aquatic product (FPAP) and aquatic feed manufacturing (AFM) are the highest, with both as 6.76. The TFP of aquatic product canning (APC) is 6.00, which is the lowest. In terms of TFP growth rate, the average annual growth rate of dry salting processing of surimi product and aquatic product (DSPS) and aquatic feed manufacturing with high TFP is relatively low at 2.45% and 2.43%, respectively. Yet the annual average growth rate of aquatic product canning with the lowest TFP is more than 3%, ranking second place. The highest growth rate was for other aquatic product processing (OAPP), reaching 4.45%. In terms of factor productivity, the capital and labor productivity of aquatic product frozen processing and aquatic feed manufacturing are the highest in the aquatic product processing industry, while the capital of aquatic product canning has the lowest factor productivity, indicating that the TFP of China's aquatic product processing industry is positively related to capital and labor productivity.

In different regions, the aquatic product processing industry shows obvious regional differences. The regions with higher TFP levels are Shandong and Jiangxi, with a value as 6.88 and 6.78 respectively, while Liaoning and Fujian also performed well with productiv-

Table 4. TFP and factor productivity of heterogeneous aquatic product processing

		TFP	Annual growth rate (%)	Labor productivity	Capital productivity
Sub–industries	FPAP	6.76	2.81	6.69	2.64
	DSPS	6.57	2.45	6.57	2.59
	AFM	6.76	2.43	7.02	2.69
	OAPP	6.53	4.45	6.69	2.51
	APC	6.34	3.24	6.25	2.42
Regions	Liaoning	6.76	4.10	6.70	2.78
	Hebei	6.27	1.23	6.18	2.92
	Tianjin	6.16	2.00	6.16	2.70
	Shandong	6.88	3.62	6.81	2.58
	Jiangsu	6.64	1.78	6.67	2.89
	Zhejiang	6.44	0.68	6.54	2.41
	Shanghai	6.17	–0.63	6.50	2.12
	Fujian	6.72	2.49	6.63	2.95
	Guangdong	6.45	3.21	6.44	2.48
	Guangxi	6.38	0.91	6.39	2.28
	Hainan	5.92	1.14	5.90	1.85
	Jilin	6.61	5.57	6.35	3.55
	Anhui	6.27	2.54	6.45	2.19
	Jiangxi	6.78	3.47	6.71	2.81
	Henan	6.40	4.47	6.79	2.25
	Hubei	6.66	8.63	6.52	2.47
	Hunan	6.48	1.27	6.60	2.18
Ownership types	State–owned	6.07	–0.93	6.01	1.91
	Foreign–funded	6.63	2.15	6.59	2.55
	Private	6.75	3.00	6.71	2.65

ity exceeding 6.70. This is closely related to the fact that these regions attach great importance to the aquatic product processing industry. The government departments have implemented relevant policies to encourage investment promotion and technological upgrading. The TFP in Tianjin, Shanghai and Hainan are relatively low, with TFP in Hainan being the lowest among all regions. This shows that in the aquatic product processing industry, the regions where the firms with a larger scale have higher TFP. In terms of TFP growth, the growth rate in Hubei far exceeds that of other regions, reaching 8.63%, showing a strong catch–up momentum. Liaoning, Jilin and Henan are the second echelon, with the average annual growth rates being more than 4%. TFP growth of Shanghai, showing the lowest growth rate, was –0.63%, indicating that the TFP of Shanghai's aquatic product processing industry declined in 2005–2013. Capital and labor productivity in different regions also show similarities to the pattern of TFP.

In terms of ownership types, private firms have the highest total factor productivity of 6.75; foreign–funded firms are the second place and state–owned firms are the lowest. Private firms also have significantly higher TFP growth rate than the other two types of firms, indicating that private firms are constantly attaching importance to technological innovation and management progress and have achieved good results. Capital and labor productivity show the same pattern.

Decomposition of TFP

To investigate the contribution of firm' s entry and exit to TFP, the Dynamic Olley–Pakes Productivity Decomposition (DOPD) developed by Melitz and Polanec (2015) was referred to, for decomposing TFP of aquatic product processing firms. The equation is as follows:

$$\Delta \text{TFP} = (TFP_{S2} - TFP_{S1}) + s_{E2}(TFP_{E2} - TFP_{S2}) + s_{X1}(TFP_{S1} - TFP_{X1})$$
$$= \Delta\overline{tfp}_S + \Delta cov_S + s_{E2}(TFP_{E2} - TFP_{S2}) + s_{X1}(TFP_{S1} - TFP_{X1}) \quad (10)$$

In Eq. (10), Melitz and Polanec (2015) consider the TFP changes in 2 phases, and the left–hand side of the equal–sign represents the change of weighted average TFP in 2 phases. TFP_{GT} (G are S, E, X respectively. T are 1, 2.) represents the weighted average TFP of Group G firms over time T. S, E, X groups represent the firm in survival group (survived in 2 phases), entry group (in the second phase but not in the first phase) and exit group (in the first phase but not in the second phase). s_{GT} represents the market share of each group in period T, where the weights are also the real gross industrial output. $\Delta\overline{tfp}_S$ represents the change in arithmetic mean TFP of survivors in two phases; Δcov_S represents the change of the covariance (OP covariance) of the market share and productivity of survival group in two periods; and the calculation formula is $\sum_i (s_{i2} - \bar{s}_2)(tfp_{i2} - \overline{tfp_2}) - \sum_i (s_{i1} - \bar{s}_1)(tfp_{i1} - \overline{tfp_1})$. The first term of second row in Eq. (10) represents the contributions of survival group arithmetic average productivity changes to aggregate productivity changes. The second term represents the contribution of the reallocation of resources and the change of market share among the survival group. The third term represents the contribution of firm's entry. And the last term represents the contribution of firm's exit. Table 5 shows the decomposition result.

As can be seen from Table 5, the contribution of the unweighted average productivity changes to the TFP of aquatic product processing industry in 2005–2013 is 74.56%, which can be explained by the fact that its own productivity–enhancement contributes to the firm when the market share of a firm does not change, that is, its own growth. And this part contributes the most to the growth of TFP of the entire industry. The re–allocation of resources among firms has a negative impact on the growth of TFP with a value of –4.35%. This shows that the re–allocation of resources among aquatic product processing firms is inefficient. In fact, firms with higher TFP need more resources to increase their output and market share, as mentioned above, in the aquatic prod-

Table 5. The result of decomposition

T=1	T=2	Unweighted average productivity change	Re–allocation of resources among firms and changes in market share	Firm's entry	Firm's exit	Aggregation
2005	2006	16.83	–5.27	–2.98	–2.40	6.18
2006	2007	10.08	–4.09	–3.43	1.25	3.81
2007	2008	12.31	–6.48	–3.59	–1.46	0.78
2008	2009	20.35	–8.63	–0.58	0.48	11.62
2009	2010	29.67	37.81	2.21	–5.61	64.08
2010	2011	–27.06	–24.99	–3.57	–5.39	–61.01
2011	2012	14.09	3.42	–2.10	0.01	15.42
2012	2013	–1.71	3.88	–2.58	–1.28	–1.69
Aggregation		74.56	–4.35	–16.62	–14.40	39.19

uct processing industry, the more productive firms are larger in scale. However, the resource flow in the market is inefficient. Firms with low TFP have mastered resources beyond their own needs, and it is very difficult to use resources to enhance their own TFP, resulting in a waste of resources. The entry and exit of firms all have an inhibitory effect on the growth of TFP. This may be because the new entrants have not fully realized their own potentials. Their TFP is not high at the initial stage and they need more time to enhance TFP. And the exit from the market of firms with higher total factor productivity may be related to other factors, thus restraining the growth of TFP.

FACTORS AFFECTING TFP

Finally, factors affecting the TFP of aquatic product processing industry are analyzed in this study. The following regression model is built:

$$\ln TFP = \beta_0 + \beta_1 LP + \beta_2 KLR + \beta_3 SIZE + \beta_4 AGE + \beta_5 FIN + \beta_6 EXP + \beta_7 FDI + \beta_8 RD + \varepsilon \quad (11)$$

In Eq. (11), the left side of the equal sign is the TFP value. LP stands for labor productivity. *KLR* is capital–intensive degree, calculated as ln K / L. *SIZE* is the size of the firm, using the logarithmic form of the firm's real total assets instead. *AGE* is the firm age. *FIN* is financing constraint that uses the ratio of corporate interest expense to fixed assets instead. *EXP* is a dummy variable of export, which is 1 if the firm has export behavior and 0 otherwise. *FDI* is a dummy variable of foreign direct investment; if the firm obtains foreign direct investment, it is 1, while it equals0 otherwise. *RD* is a dummy variable of research and development, equal to 1 if the firm has research and development cost while 0 otherwise. In addition, to avoid the impact of time trends and firm characteristics that do not change over time, this study controls the time variables in the regression and employs regression of individual fixed effect. The regression results are shown in Table 6.

Column (1) in Table 6 shows the regression result without any fixed effects, column (2) shows the regression result that only control the individual fixed effect, column (3) shows the regression resultin when only the year fixed effect is controlled, and column (4) is listed as the regression result in which both the year and individual fixed effects are controlled. In column (1), coefficients of labor productivity, firm size, firm age and export

Table 6. The factors affecting TFP

	(1)	(2)	(3)	(4)
β_1	0.933***	0.930***	0.930***	0.931***
	(0.00101)	(0.00113)	(0.000998)	(0.00111)
β_2	–0.400***	–0.396***	–0.391***	–0.390***
	(0.000857)	(0.000991)	(0.000869)	(0.000983)
β_3	0.135***	0.112***	0.122***	0.0931***
	(0.00106)	(0.00134)	(0.00115)	(0.00148)
β_4	0.00417***	0.00904***	0.000291	–5.71e–07
	(0.000224)	(0.000305)	(0.000247)	(0.000450)
β_5	–0.000572***	–0.00838***	–0.000540***	–0.00773***
	(8.41e–05)	(0.000712)	(8.14e–05)	(0.000681)
β_6	0.00997***	0.00665**	0.0199***	0.0118***
	(0.00241)	(0.00273)	(0.00234)	(0.00262)
β_7	–0.00446*	0.00549*	0.000610	0.00651**
	(0.00268)	(0.00298)	(0.00275)	(0.00307)
β_8	0.00622	0.00268	0.0177***	0.0107**
	(0.00465)	(0.00478)	(0.00457)	(0.00466)
Year fixed effect	NO	NO	YES	YES
Individual fixed effect	NO	YES	NO	YES
Constant	0.389***	0.591***	0.498***	0.795***
	(0.0107)	(0.0132)	(0.0112)	(0.0146)
Observations	16,380	16,380	16,380	16,380
R^2		0.985		0.986
Number of firms	4,474	4,474	4,474	4,474

Note: *, **, *** indicate statistical significance at the 10%, 5% and 1% level, respectively. Standard error in parentheses.

are all significantly positive. The coefficients of capital intensity, financing constraint and foreign direct investment are significantly negative. When the impact of individual characteristics is controlled, the coefficient of foreign direct investment becomes significantly positive while there is no difference in the sign of other coefficients. When the effect of time trend is controlled, the coefficient of R & D becomes significantly positive compared with that of column (1), while the coefficients of firm age and foreign direct investment are no longer significant.

This study will elaborate the result that both the year fixed effect and the individual fixed effect are controlled, as shown in column (4). The coefficient of labor productivity is significantly positive. This shows that the increase of labor productivity can promote the growth of TFP over aquatic product processing industry. The coefficient of capital intensity is significantly negative, suggesting that capital intensity inhibits the growth of TFP over the aquatic products processing industry, which is not in conformity with the general conclusion. The possible explanation is that the re–allocation of resources in the aquatic product processing industry is inefficient and the capital investment has not been clustered into the real needs of firms in order to increase output and TFP, resulting in a waste of capital, which has inhibited the growth of TFP. The coefficient of firm size is significantly positive. This shows that the larger the scale of the firm, the more it can promote the improvement of TFP. The coefficient of financing constraint is significantly negative. Difficulties in financing will directly reduce the funds needed for the development of firms, combat the enthusiasm of firms and restrict the growth of TFP. The coefficients of export, foreign direct investment and R & D are significantly positive. Most of the literature shows that exports can significantly increase the TFP of firms through learning effects and other mechanisms. The same rule exists in the aquatic product processing industry. Foreign direct investment can bring direct capital and technical investment to domestic firms, to promote the improvement of TFP. Firms attaching great importance to R & D will vigorously promote product technology upgrades, which can significantly improve their productivity.

CONCLUSION

This paper compiles the CIED: 2005–2013 and calculates the TFP of China's aquatic product processing industry through the database. And researches on the factor contribution rate of aquatic product frozen processing, dry salting processing of surimi product and aquatic product, aquatic feed manufacturing, aquatic feed manufacturing, other aquatic product processing and aquatic product canning are conducted. Then this paper studies the differences of TFP, TFP growth, capital productivity and labor productivity in different sub–industries, different regions and different ownership types firms in the aquatic product processing industry, and examines the contribution of related factors to the growth of TFP through the decomposition of TFP. Finally, this paper studies the factors that affect the TFP of aquatic product processing industry through regression model. Key findings are concluded as follows.

(a) The aquatic product processing industry is a labor–intensive industry, of which the labor contribution rate is higher than the capital contribution rate, and there is a diminishing return to scale.

(b) The TFP of aquatic product processing industry shows obvious firm heterogeneity. In terms of different sub–sectors, the TFPs of aquatic product frozen processing and aquatic feed manufacturing are the highest, but their TFP growth rate is relatively low, and the TFP of aquatic product canning is the lowest, yet the TFP growth rate is second. The TFP of aquatic product processing industry is directly proportional to the change of capital and labor productivities. In different regions, the areas with the highest TFP are Shandong and Jiangxi, while Tianjin, Shanghai and Hainan are the lowest. In the aspect of TFP growth rate, the growth rate in Hubei Province far exceeds that of other regions, followed by Liaoning, Jilin and Henan, and Shanghai has a negative growth. In terms of ownership types, private firms have the highest TFP, followed by foreign–funded firms and the lowest state–owned firms. These three types of firms also show the same pattern of growth in TFP, capital and labor productivities.

(c) The growth of firm itself contributes the most to the TFP growth of China's aquatic product processing industry, while the re–allocation of resources among aquatic product processing firms lacks efficiency. Improving the efficiency of resource redistribution is the key to enhancing the TFP of aquatic product processing industry. This requires the market to play a right role and the government's correct guidance to give full play to the potential of productivity growth.

(d) Labor productivity, firm size, export, FDI and R & D can effectively promote the improvement of TFP on aquatic product processing industry. Capital intensity and financing constraint will restrain the increase of TFP. Aquatic product processing firms can increase output by boosting labor productivity, expand the scale of firm, and actively communicate with advanced foreign firms, and attach importance to their own R & D.

AUTHOR CONTRIBUTION

T. Chen designed the study. G. Lin analyzed the data and wrote the paper. M. Yabe participated in the design of the study and supervised the work. Y. Takahashi assisted in editing of the manuscript and approved the final version.

ACKNOWLEGEMENTS

Supported by China Agriculture Research System–48

REFERENCES

Aigner, D. J., C. A. K. Lovell, and P. S. Schmidt 1977 Formulation and Estimation of Stochastic Frontier Production. *Journal of Econometrics*, **06**: 21–37

Brandt, L., J. V. Biesebroeck, and Y. F. Zhang 2012 Creative Accounting or Creative Destruction? Firm–level Productivity Growth in Chinese Manufacturing. *Journal of Development Economics*, **97**(2): 339–351

Bureau of Fisheries, Ministry of Agriculture of the People's Republic of China 2017 Fishery Statistical Yearbook. Chinese Agriculture Press, Beijing (China)

Ju, Z. J., L. X. Qin 2013 Research on the Present Situation and the Development Trend of the Aquatic Product Processing Industry in China. *World Agriculture*, **05**: 138–142+156

Levinsohn, J., A. Petrin 2003 Estimating Production Functions Using Inputs to Control for Un–observables. *Review of Economic Studies*, **70**(2): 317–341

Liu, X. X., S. J. Li 2008 Measurement, Comparison and Exogenous Determinants of the Relative Efficiency of China's Manufacturing Enterprises (2000–2004). *China Economic Quarterly*, **07**(3): 843–868

Liu, Z. X., Z. W. He 2009 Technical Efficiency and Changing Tendency of China's Food Processing Industry–Stochastic Frontier Analysis in Different Provinces. *Forum on Science and Technology in China*, **02**: 43–47

Lu, X. D., Y. J. Lian 2012 Estimation of Total Factor Productivity of Industrial Enterprises in China: 1999–2007. *China Economic Quarterly*, **11**(2): 541–558

Melitz, M. J., P. Sašo 2015 Dynamic Olley–Pakes productivity decomposition with entry and exit. *Rand Journal of Economics*, **46**(2): 362–375

Mukherjee, K., S. C. Ray, and S. M. Miller 2001 Productivity Growth in Large US Commercial Banks: The Initial Post–Deregulation Experience. *Journal of Banking & Finance. U. S*, **25**: 913–939

Nie, H. H., T. Jiang, and R. D. Yang 2012 The Status Quo and Potential Problems of China Industrial Enterprise Database. *The Journal of World Economy*, **05**: 142–158

Olley, G. S., A. Pakes 1996 The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, **64**(6): 1263–1297

Peng, L., C. J. Su, L. Sun, P. Li, Y. Fang, W. Liu, and X. L. Wang 2013 Spatial–temporal Evolution Pattern of Agricultural Productivity in Northwestern Sichuan Plateau. *Journal of Mountain Science*, **10**(3): 418–427

Solow, R. M. 1957 Technical change and aggregate production function. *The Review of Economics and Statistics*, **39**(3): 12–320

Xie, Q. L., T. G. Rawski, and Y. F. Zhang 2008 Productivity Growth and Convergence across China's Industrial Economy. *China Economic Quarterly*, **03**: 809–826

Yang, R. D. 2015 Study on the Total Factor Productivity of Chinese Manufacturing Enterprises. *Economic Research Journal*, **02**: 61–74

Yang, X. L., Y. J. Zhang, and L. Wang 2012 Empirical Analysis on the Change of Total Factor Productivity in Food Processing Industry in Jilin Province. *Journal of Agrotechnical Economics*, **12**: 61–67

Yang, Z. Y., S. Li, B. O. Chen, H. Y. Kang and M. H. Huang 2016 China's Aquatic Product Processing Industry: Policy Evolution and Economic Performance. *Trends in Food Science & Technology*, **58**: 149–154

Ye, L. G., J. B. Huang 2016 Total Factor Productivity of Agro–food Processing Enterprises. *Journal of Agro–Forestry Economics and Management*, **15**: 435–445

Zhang, J., Y. Li, and Z. B. Liu 2009 Does export promote the productivity of Chinese enterprises? – Evidence from Manufacturing Industries in China: 1999–2003. *Management World*, **12**: 11–26

Zhao, L., Z. J. Yang 2010 Analysis on Market Structure of China's Aquatic Products Processing Industry Based on the SCP Model. *Chinese Agricultural Science Bulletin*, **26**(11): 386–390