Evaluation of technological progress and technical efficiency based on sequential data development analysis and Malmquist index decomposition

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ABSTRACT. *This paper attempts to disclose the dynamic evolution features and industrial heterogeneity of growth drivers of the total factor productivity (TFP) in Taiwan's service industry. As a result, the sequential data development analysis (DEA)-Malmquist index model was adopted to compute the TFP and its components of service industry in Taiwan. The results show that the TFP growth, which is obviously dominated by technological progress, has entered a downward spiral, featuring significant industrial heterogeneous. This conclusion was proved valid through robustness analysis. On this basis, it is concluded that Taiwan should promote new technology efficiency and pursue the coordinated development of the service industry, in addition to enhancing the research and development of new technologies.*

RÉSUMÉ. *Cet article tente de révéler les caractéristiques d'évolution dynamique et l'hétérogénéité industrielle des moteurs de croissance de la productivité totale des facteurs (TFP) dans le secteur des services à Taiwan. En conséquence, l'analyse du développement de données séquentielles (DEA)- modèle d'indice de Malmquist a été adopté pour calculer la TFP et ses composantes de l'industrie des services à Taiwan. Les résultats montrent que la croissance de la PTF, qui est évidemment dominée par le progrès technologique, est entrée dans une spirale descendante caractérisée par une hétérogénéité industrielle significative. Cette conclusion a été prouvée par une analyse valable de robustesse. Sur cette base, il est conclu que Taiwan devrait promouvoir l'efficacité des nouvelles technologies et poursuivre le développement coordonné du secteur des services, en plus d'améliorer la recherche et le développement de nouvelles technologies, en plus d'améliorer la recherche et le développement de nouvelles technologies.*

KEYWORDS: *total factor productivity, sequential DEA-Malmquist productivity index model, technological progress, technical efficiency.*

MOTS-CLÉS: *productivité totale des facteurs, DEA séquentiel- modèle d'indice de productivité de Malmquist, progrès technologique, efficacité technique.*

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1. Introduction

At the commencement of the 21st century, Taiwan’s service industry began to enter a period of slower development as the results of population and resident's income growth slowdown, and the large-scale relocation of service enterprises. How to reshape the leading role of the development of service industry to Taiwan's economic development, was became increasingly interested by both Taiwanese and mainland scholars. Lin (2011) argued that manufacturing service is a new growth area for the future development of Taiwan’s service industry. Qian (2013) pointed out that technological innovation and the internationalization of the service industry represent breakthroughs in terms of promoting the development of Taiwan’s service industry. Yan (2014) reported that the promotion of “service technology” and the development of “cooperation between different industries” are important ways to accelerate the development of Taiwan’s service industry. Chen and Zeng (2014) pointed out that increasing investment in science and technology in the service industry, paying attention to developing innovation capability within the service trade industry, and strengthening the degree of internationalization and high-level human resource cultivation are the keys to accelerating the development of Taiwan’s service industry and enhancing its international competitiveness.

The previous studies suggest that there were several areas that need to be addressed to accelerate the transformation of growth mode in Taiwan's service industry, which was currently in the doldrums. The core of changing the growth mode is to improve the growth quality of service industry, let the development of service industry turn from mainly depending on factors inputting to the improvement of technological progress and efficiency. What is the result of the transformation of growth mode in Taiwan's service industry? At present, few literatures have discussed this issue in depth, and it the main issue of the article. The article used the sequential DEA-Malmquist index model to calculate the TFP and its decomposition of Taiwan's service industry. Basing on this, the article deeply analyzed the dynamic evolution characteristics and growth drivers industry heterogeneity of TFP in Taiwan's service industry, with a view to making a comprehensive and objective evaluation of the transformation of growth mode, then pointing out the main breakthrough direction of transformation of growth mode. The following research contents were: research method and data, development changes of TFP and industry heterogeneity of TFP development, and conclusion and implications.

2. Research method and data

2.1. Research method

The Malmquist productivity index was introduced by Caves *et al*. based on the Malmquist quantitative index and Shepherd’s distance function (Caves *et al*., 1982). Then, a DEA (Charnes *et al*., 1978)-Malmquist productivity index model was derived. The DEA-Malmquist productivity index has several advantages over other

TFP measures including: (1) there is no need to designate the specific form of the function, which avoids errors that can occur during function setting; and (2) it takes into consideration the non-efficiency factor during production, which avoids deviations caused by the distribution of the non-efficiency factor. Therefore, the DEA-Malmquist productivity index is the method that is most commonly used to measure TFP. Yuan *et al*. pointed out that because of the "rigid" form of production organization in the manufacturing industry and the more "flexible" form in the service industry, it is debatable whether it is reasonable to fit the production process in the service industry with a fixed production function. However, using the DEA method can avoid the discussion of function setting (Yuan *et al*., 2009). Therefore, the DEA method is more suitable for TFP measurement in the service industry. The DEA method usually uses current input-output data to construct the optimal production frontier in the current period, but technical regression may occur during the process of dynamic analysis. However, the sequential DEA method determines the optimal production frontier in the current period using both current and previous input and output data, which not only avoids the technical regress problem, but also eliminates the impact of short-term output on the production frontier. Thus, the sequential DEA method is used to construct the optimal production frontier.

It is assumed that time t(t=1, …, T) in each stage, in industry k(k=1, …, K), if n(n=1, …, N) inputs $x_{k,n}^t$ are used, then m(m=1, …, M) outputs $y_{k,m}^t$ will be obtained, in which X^t and Y^t respectively represent the input and output vectors of the service industry. Under the conditions of constant scales and rewards and of that the input factors are controlled, the following reference equations can be used for evaluation of technological application in the service industry:

$$\overline{P}^t = (y : y \leq \lambda \overline{Y}^t, x \geq \lambda \overline{X}^t, \lambda \geq 0) \tag{1}$$

Where

$$\overline{X}^t = (\cdots, X^{t_0}, \cdots, X^{t-1}, X^t) = (\overline{X}^{t-1}, X^t)$$

$$\overline{Y}^t = (\cdots, Y^{t_0}, \cdots, Y^{t-1}, Y^t) = (\overline{Y}^{t-1}, Y^t)$$

λ is the weight of observed values of the cross-section, and t_0 is the observed value of the first input-output technique in the first stage. Because input-output information cannot be obtained prior to t_0, the reference technique is defined as follows:

$$\begin{aligned} &\overline{P}^t(x|\overline{X}^{t_0} = X^{t_0}, \overline{Y}^{t_0} = Y^{t_0}) \\ &= \left\{y : y \leq \lambda \cdot (Y^{t_0}, Y^{t_0+1}, \cdots, Y^t), x \geq \lambda \cdot (X^{t_0}, X^{t_0+1}, \cdots, X^t), \lambda \geq 0\right\} \end{aligned} \tag{2}$$

The output-based distance function is:

$$D_o^t(x^t, y^t) = \inf \left\{\theta : (x^t, y^t/\theta) \in \overline{P}^t\right\} \tag{3}$$

The above equation can be solved by the following linear programming equation:

$$\inf_{\theta,\lambda\geq 0}\theta \quad s.t.\ \lambda\cdot(Y^{t_0},Y^{t_0+1},\cdots,Y^{t})\geq y/\theta$$
$$\lambda\cdot(X^{t_0},X^{t_0+1},\cdots,X^{t})\leq x \tag{4}$$

To avoid variations caused by random period selection, Fare *et al.* proposed the use of the geometric mean value of two Malmquist indices to measure the TFP growth rate and its decomposition. Following this idea, the sequential Malmquist index can be expressed as follows:

$$M_0(y^{t+1},x^{t+1},y^{t},x^{t})=[\frac{D_0^{t}(x^{t+1},y^{t+1})}{D_0^{t}(x^{t},y^{t})}\times\frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t+1}(x^{t},y^{t})}]^{\frac{1}{2}} \tag{5}$$

The Malmquist index that is obtained using this method can be further decomposed into:

$$\begin{aligned}M_0(y^{t+1},x^{t+1},y^{t},x^{t})&=\frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t}(x^{t},y^{t})}\times[\frac{D_0^{t}(x^{t+1},y^{t+1})}{D_1^{t+1}(x^{t+1},y^{t+1})}\times\frac{D_0^{t}(x^{t},y^{t})}{D_0^{t+1}(x^{t},y^{t})}]^{\frac{1}{2}}\\&=EC\times TC\end{aligned} \tag{6}$$

Where *EC* refers to the technological efficiency improvement index under the condition of constant scale and rewards. It mainly measures the catch-up effect of the subdivisions of the service industry. An *EC* value greater than 1 indicates improvement in technical efficiency, while a value of less than 1 suggests reduced technical efficiency, and a value equal to 1 denotes constant technical efficiency. *TC* refers to the technological progress index that measures the growth effect of the technical frontier from t to $t+1$. A *TC* value greater than (less than) 1 indicates technological progress (regression) and a value equal to 1 indicates that there has been no technological progress. Similarly, a Malmquist index value equal to 1 indicates constant productivity, while a value greater than (less than) 1 suggests an increase (decrease) in the growth rate. Under the condition of a production frontier with changeable scale and rewards, the EC index can be further decomposed into pure technical efficiency change (PEC) and scale efficiency change (SEC).

2.2. Variable selection and data processing

2.2.1. Data sources

Since 1997, Taiwan has revised its industry standard once every five years, the most recent revision being the ninth edition in 2012. After comparing the criteria in the eighth and ninth editions, it was found that both amendments were consistent with the criteria for the division of the service industry, i.e., they both divided the service industry into 13 subdivisions.

In addition, in accordance with the eighth edition of the industry standard, the Directorate General of Budget, Accounting and Statistics of Taiwan analyzed the employment data in each subdivision of the service industry. Taking into account the availability of data, we selected data from the period 2001 to 2014. Unless otherwise stated, the data used in this article are from the Directorate General of Budget, Accounting and Statistics of Taiwan. The value of outputs from the service industry and the input value of fixed assets are based on data for 2011, and the actual value was expressed as the relative value relative to the corresponding price index.

2.2.2. Selection and processing of output variables

There is currently no uniform academic standard regarding the selection of output variables in the service industry. For example, Mahadevan, Wang and Hu, and Zhai *et al*. use added value to represent the output variables, while other scholars such as Yuan *et al*. use gross domestic product. Taking into account the availability of data, we used subdivisions of service industry's gross domestic product as the output variable.

2.2.3. Choice of input variables

Capital and labor are the core elements of the service industry, and these are the only input variables that are considered in the model.

(1) Labor input. The amount of labor input includes both the quantity and quality of the labor force, but in our study, construction of the labor variable depends on the availability of data. In addition, as society has developed, the level of education of the labor force has continuously increased, and thus the quality of labor continues to improve. However, scientific and technological progress have reduced both labor hours and intensity, meaning that the quantity and quality of the labor input counteract each other to a certain degree. Therefore, Yuan *et al*. reported that the number of labor workers was used to approximately substitute the labor input, which can not cause too much error. Based on this consideration, we used the number of labor workers as a proxy variable of labor input. The number of labor workers in each subdivision of service industry was expressed as the mean number of employees in this year and the last year.

(2) Capital investment. Capital investment is usually represented by material capital stock. Because the official statistics for material capital stock in each subdivision of Taiwan’s service industry were unavailable, we referred to the processing methods used in most of the existing studies and used the perpetual inventory method to calculate capital investment according to capital formation and annual investment data for fixed assets in each subdivision. The details of the calculations are as follows:

$$K_{it} = I_{it} + (1-\delta_{it})K_{it-1} = \sum_{j=1}^{t} I_{ij}(1-\delta_{it})^{t-j} + (1-\delta_{it})^{t} K_{i0} \quad (7)$$

where K_{it} represents the capital stock of industry i in year t, K_{i0} represents base-year capital stock, and I_{it} and δ_{it} represent the amount of investment and the capital depreciation rate, respectively, of industry *i* in year *t*. Base-year capital stock was evaluated using the steady-state approach proposed by Harberger (1978) as follows:

$$K_{it-1} = I_{it} / (g_{it} + \delta_{it}) \tag{8}$$

where g_{it} represents the actual growth rate of fixed asset investment in subdivision i in year t. To eliminate the impact of short-term economic fluctuations, the mean growth rate of output during the period studied was substituted for g_{it}. In this study, we used the mean growth rate of actual output in each subdivision as a substitute for g_{it}. There is no consensus regarding the choice of depreciation rate δ_{it} in existing studies. Industry heterogeneity means that different subdivisions have different depreciation rates, but because of the scarcity of relevant statistical data and because there is no good solutions proposed to determine the difference in depreciation rate between different subdivisions. Therefore, following the processing method used in the majority of studies, we set the capital depreciation rate for each subdivision of Taiwan's service industry at 4%.

3. Development changes of TFP and industry heterogeneity of TFP development

Based on the above discussion on DEA input and output variables and the processing methods used in most of the existing studies, the output-led estimation method was used. The results are shown in Table 1. It can be seen that overall, the average annual TFP growth rate in Taiwan's service industry was only 1.7%, which was significantly lower than the average annual growth rate of 4.2% on the mainland. The average annual growth rate of technical efficiency was only 0.2%, and that of technological progress was 1.5%, suggesting that the growth of TFP in Taiwan's service industry obviously benefitted from technological progress. In addition, progressively reduced pure technical efficiency is a main reason of poor improvement in technical efficiency. Table 1 shows the changes over time of the various elements of TFP in Taiwan's service industry.

Table 1. Malmquist index values for Taiwan's service industry

Year	Technological progress	Technical efficiency	PEC	SEC	TFP index
2001/2002	1.003	1.020	1.033	0.987	1.023
2002/2003	1.015	0.992	0.997	0.995	1.008
2003/2004	1.032	0.987	1.003	0.985	1.019
2004/2005	1.028	0.988	0.990	0.999	1.016
2005/2006	1.030	1.009	0.992	1.017	1.039

2006/2007	1.046	0.989	0.980	1.009	1.034
2007/2008	0.982	1.016	1.005	1.011	0.998
2008/2009	0.968	1.030	1.008	1.022	0.997
2009/2010	1.044	1	0.989	1.011	1.044
2010/2011	1.015	1.002	0.986	1.016	1.018
2011/2012	0.995	1.011	0.995	1.016	1.006
2012/2013	1.014	1	0.991	1.009	1.014
2013/2014	1.032	0.979	0.974	1.005	1.010
Mean value	1.015	1.002	0.995	1.006	1.017

Note: Each annual index is expressed as the geometric mean value for the service industry. The mean value in the period 2001-2014 is calculated based on the geometric mean value in each year

3.1. Changes in TFP over time and its decomposition

3.1.1. Changes in TFP

Overall, TFP increased in each studied year, with the exception of the period 2008 and 2009. But TFP increase reached a peak level and then declined. First, from 2002 to 2007, the TFP growth rate increased from 0.8% to 3.4%. The main reasons for the continual increase in the TFP growth rate during this period are as follows: (1) after Taiwan's acceptance into the World Trade Organization in 2002, the substantial elimination of trade barriers provided new opportunities for Taiwan's service industry; (2) the intensified market competition forced the Taiwanese authorities to deepen the reform of the service industry, and encouraging reform strategies benefit development of Taiwan's service industry; (3) the 2008 global financial crisis and the European debt crisis impacted heavily on economic development worldwide, and Taiwan's export-oriented economic development faced significant challenges, such that in 2009, the annual GDP growth rate in Taiwan was –1.81%, which was the first year of negative growth during the period studied. Thus, there was negative TFP growth in 2008 and 2009, leading to a decline in the TFP growth rate in Taiwan's service industry. To promote the recovery and development of Taiwan's economy and the transformation of Taiwan's service industry to cope with the increasingly fierce international competition, the Taiwanese authorities began to plan for the future development of the service industry. In 2009, Taiwan launched the "Service Industry Development Program," which focused on the development of emerging service industries including tourism, culture, and technical services. As a result of this policy, the TFP growth rate in 2010 was 4.4%, which was the maximum value observed during the period studied. However, the continuing stagnation of global economic development meant that this was only a flash in the pan, and the growth rate of TFP began to decline year by year (Song, 2018). In 2012, a program of upgrades including characterization of traditional industries, service-providing manufacturing industry, technological innovation and internationalization of service industry was proposed, but had no obviously beneficial effect on growth in Taiwan's service industry. The three-year moving average of the TFP growth rate confirms this finding (see Figure 1). It can be seen from Figure 1 that the three-year moving average of the TFP growth rate continued to decline from 2.27% in 2012 to 1% in 2014, which was the lowest value during the period studied. In addition, although the average contribution of TFP growth to service industry growth was 57.85% until 2008, it decreased to 53.88% after 2008.

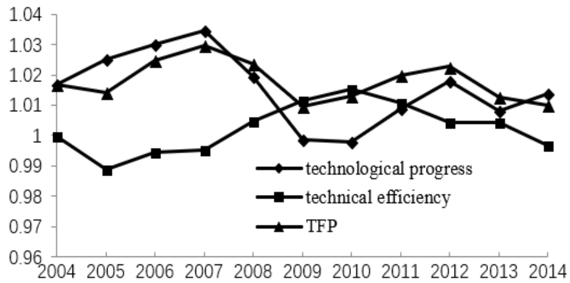

Figure 1. Three-year moving averages for TFP, technological progress, and technical efficiency

3.1.2. Changes in technical efficiency and technological progress

First, technological progress and technical efficiency grew in opposite directions, i.e. the correlation coefficient for technological progress and technical efficiency was –0.80. During the period studied, the average annual growth rate of technological progress was 1.5% while that of technical efficiency was 0.02%. Thus, the growth of TFP in Taiwan's service industry was obviously led by technological progress. Second, regarding time, the growth rate of technological progress rose from 0.3% in 2001 to 4.6% in 2007, which was the maximum value during the period studied. This rapid development in technological progress possibly occurred because of the introduction of policies promoting the development of the service industry and a favorable international economic development environment. According to IMF statistics, the period 2001–2007 was the strongest growth period in terms of GDP since the 1970s, although technical efficiency experienced negative growth during most of this period. However, because the growth rate of technological progress was significantly higher than that of technical efficiency, the growth rate of TFP remained positive during this period. In 2008 and 2009, the growth rate of technological progress declined significantly to –1.8% and –4.2%, respectively. Thus, TFP experienced negative growth in these two years as a result of the decline in technological progress. From 2012 to 2014, although the growth rate of technological progress constantly increased, the growth rate of technical efficiency remained in decline. The decline in the growth rate of technical efficiency was greater than the rise in the growth rate of technological progress, resulting in a decline in the growth rate of TFP. The slow growth in terms of technological progress and the continued lack of improvement in technical efficiency in recent years has resulted in slow progress in the transformation and upgrading of Taiwan's service industry.

3.1.3. Changes of technical efficiency

As noted earlier, PEC and SEC are subdivisions of technical efficiency. During the period studied, the average annual growth rate of PEC was –0.5% and that of SEC was 0.6%. It can be seen that the improvement in the technical efficiency of Taiwan's service industry during the period studied is related to economic scale.

The reasons for the continuous improvement in SEC in Taiwan's service industry include: (1) the rapid development of modern information technology and its wide application in the service industry make certain services separable in "time and space" and improve the tradability of the service industry, similar to the development of scaled tangible economics; and (2) under the international development strategy pursued by the Taiwanese authorities, Taiwan's service industry will provide more opportunities for economic cooperation with countries outside Taiwan. According to statistics from the Taiwan Ministry of Economic Affairs Investment Review Committee, the average annual growth rate of foreign investment in Taiwan's service industry was more than 17% during the period studied. With the rapid expansion of investment by Taiwanese authorities in countries outside Taiwan, reducing production costs can enhance the scale efficiency. In addition, continuous reduction in PEC leads to poor improvement in technical application. From the point of view of time, the growth rate of PEC during the period 2001–2003 was higher than that of SEC, but since 2004, the growth rate of PFC has been lower than that of SEC until now.

The continued reduction of PEC suggests that technical innovation and application cannot increase the production efficiency of service industry in Taiwan.

3.2. Industry heterogeneity of TFP development

As can be seen from Table 2, growth in TFP remained positive in all service industry subdivisions with the exception of real estate and residential services, and health care and social work services, with growth rates of 0–4.6% evident. The greatest TFP growth occurred in other service industries, while the TFP in professional, scientific, and technical service industries did not improve during the period studied. In addition, the driving force behind TFP growth was not consistent in terms of technological progress and efficiency. There was obvious industry heterogeneity, which is discussed as follows.

First, it can be seen from Table 2 that the driving force behind TFP growth in the subdivisions of wholesale and retail trade, transportation and warehousing, support services, education services, finance and insurance, and professional, scientific, and technical services is technological progress. Among these subdivisions, the average technical efficiency value was 1 in wholesale and retail trade and the finance and insurance industry, i.e. TFP growth was predominantly led by PEC. The growth rate of technical efficiency was low in transportation and warehousing and support services, and thus the growth of TFP in these two subdivisions can be considered to be driven by technological progress. In addition, technical efficiency continued to deteriorate in the subdivisions of professional, scientific, and technical services, educational services, and public administration and defense during the period studied, partially offsetting the positive effect of technological progress on TFP growth, rendering TFP growth in these three subdivisions significantly lower than that in other subdivisions. Moreover, in the real estate and residential services subdivision, technical efficiency was not increased during the period studied, but annual growth rate of technological progress was–0.9%. These findings suggest that the negative growth of TFP in the real estate and residential services subdivision was caused by the decline in technological progress.

Second, TFP growth in the accommodation and catering industry and other service industries was largely the result of growth in technical efficiency. Annual growth in technical efficiency was 1.10% in the accommodation and catering industry, but this was partially offset by the negative growth in technological progress. The annual growth rate of technical efficiency in other service industries was 3.9%, the highest among all subdivisions. The growth rate of technological progress in this subdivision was very low, and its contribution to TFP growth was only 15.22%. Therefore, similar to other subdivisions TFP growth was led by technical efficiency. In addition, the growth rate of technological progress in the health care and social services subdivision was very high, although the negative growth of technical efficiency completely offset the positive growth in technological progress, which led to negative growth in TFP. Therefore, it can be seen that the negative growth in the health care and social services subdivision was caused by the decline in technical efficiency.

Third, in subdivisions where technological progress and efficiency were the driving forces, the annual growth rate of TFP in the information and communication industry was 4.2%, which was the second highest growth rate behind that of other service industries. The growth rate of technological progress was 2.2% and that of technical efficiency was 2%. Thus, the contribution of these two elements to the growth rate of TFP was basically the same. The growth rate of TFP in the information and communication industry showed obvious characteristics of being driven by both elements. In addition, although the growth rate of technical efficiency was lower than that of technological progress in the arts, entertainment and leisure services subdivision, the average annual growth rate of TFP reached 1%, and was clearly driven by growth in both technological progress and technical efficiency.

Table 2. Malmquist productivity index and its components in relation to Taiwan's service industry

Year	Subdivision	Technological progress	Technical efficiency	Pure technical efficiency	Scale efficiency	TFP index
2001-2014	Wholesale and retail trade	1.010	1	1	1	1.010
	Transportation and warehousing	1.022	1.005	1.003	1.002	1.028
	Accommodation and catering	0.998	1.011	0.976	1.035	1.008
	Information and communication	1.022	1.02	1.021	1	1.042
	Finance and insurance	1.023	1	1	1	1.023
	Real estate and residential service	0.991	1	1	1	0.991
	Professional, scientific and technical service	1.022	0.978	0.974	1.004	1
	Support service	1.022	1.004	0.993	1.011	1.027
	Public administration and defense; mandatory social security	1.02	0.992	0.974	1.019	1.012
	Education services	1.022	0.991	0.991	1	1.013
	Health care and social work services	1.022	0.972	0.969	1.003	0.993
	Arts, entertainment and leisure services	1.023	1.010	1	1.01	1.033
	Other services	1.007	1.039	1.040	0.999	1.046
Note: The index for each industry is the geometric mean for the year in question.						

3.3. Robustness analysis

To examine the robustness of the results, a robustness analysis was performed by changing the capital depreciation rate and base-year capital stock in accordance with the method used by Wang and Hu. The results of the robustness analysis are shown in Table 3. Method 1 and method 2 indicate that base-year capital stock was evaluated using the methods of Harberger and Kohli (1978), respectively. First, we examined the sensitivity of the results to a change in the depreciation rate. Using method 1, depreciation rates of 4%, 7%, and 9.6% corresponded to TFP growth rates of 1.7%, 2.3%, and 2.3%, respectively. These differences did not affect our conclusion, i.e., that TFP displayed positive growth during the period studied. Similarly, using method 2, a change in the depreciation rate did not affect our conclusion. Next, we investigated the sensitivity of the results to changes in base-year capital stock. Table 3 shows that the use of either method 1 or method 2 to estimate base-year capital stock in terms of either TFP, technological progress, or technical efficiency had no influence on our conclusion. Therefore, generally speaking, our conclusion is robust.

Table 3. Robustness analysis

Depreciation rate	Method	Technological progress	Technical efficiency	Pure technical efficiency	Scale efficiency	TFP index
4.0%	1	1.015	1.002	0.995	1.006	1.017
	2	1.022	1.001	0.997	1.004	1.023
7.0%	1	1.022	1.001	0.996	1.005	1.023
	2	1.022	1.001	0.996	1.005	1.023
9.6%	1	1.021	1.002	0.996	1.006	1.023
	2	1.021	1.002	0.996	1.006	1.023

4. Conclusion and implications

A DEA-Malmquist productivity index model was used to analyze the changes over time and industry heterogeneity of TFP in Taiwan’s service industry during the period from 2001 to 2014 based on panel data for various subdivisions of the industry. The main conclusions are as follows.

The transformation of Taiwan’s service industry is facing difficulties. First, from the viewpoint of a three-year moving average, by 2014, TFP growth in Taiwan’s service industry was at its lowest point in the period studied. The contribution of TFP to output in the service industry had also continually declined over the period studied. Second, from the viewpoint of the driving force behind TFP growth, although both technological progress and technical efficiency exhibited positive average annual growth rates during the period studied, the growth that was achieved was largely the result of technological progress, while the decline in technical efficiency was the main reason for the low level of growth in Taiwan's service industry.

The driving force behind the growth of Taiwan's service industry displays industry heterogeneity. Specifically, growth in the wholesale and retail trade industry and the transportation and warehousing industry was driven by technological progress, while growth in the accommodation and catering industry was driven by improvements in technical efficiency. Growth in the information and communication industry and the arts, entertainment, and leisure services industry was driven by improvements in both technological progress and technical efficiency.

To accelerate the growth of Taiwan's service industry, we should strengthen the development of new techniques aimed at improving efficiency. First, we should attach great importance to enhancing employees' skills and knowledge and their ability to master new techniques. Second, we should fully engage various service trade associations to accelerate the dissemination of new techniques. In addition, we should pay attention to the industry heterogeneity in relation to the driving force behind growth and develop a feasible industry development strategy in accordance with the development characteristics of the service industry to promote the coordinated development of all subdivisions. For example, as for the service industry driven by technological progress, under the coordination of the service industry association, the government administration authorities should build a new technology service sharing platform to promote the dissemination of new technology. As for the service industry driven by technological efficiency, the government administration authorities should provide tax deduction and innovation award policies to encourage the enterprises to increase investment in science and technology and develop innovation capability in service trade industry.

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