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The Impact of Operational Digitalization and Intangible Asset Investment on Technical Efficiency and Financial Performance of Taiwan's Social Work Industry

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This study establishes a stochastic frontier model and regression equations to assess the impact of operational digitalization and intangible asset investment on technical efficiency and financial performance. Taiwan's census data on the social work industry is utilized to conduct empirical studies. The study's contributions include sustained evidence that (1) operational digitalization and intangible asset investment are positively correlated with technical efficiency and financial performance and, (2) that they influence financial performance through a mediating effect rather than a direct effect. Furthermore, we show that the phenomenon of the information technology productivity paradox does not exist in this industry. Lastly, the study reveals that public social work services, even with greater resources, show poorer financial performance than private organizations.

Keywords: social work industry, operational digitalization, intangible asset, operating performance, stochastic frontier production function
JEL classification: C51, I12, M41

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1 Introduction

Two key demographic data have indicated that the current generation of middle-aged Taiwanese is subject to enormous family support pressure and that social work services have therefore become a strategic necessity for Taiwan's long-term development. The ageing index of Taiwan, a calculation of the ratio of the population aged 65+ over the population aged 15 or younger hit a record high of over 100% in March 2017 according to the Department of Statistics of Taiwan. This means that for the first time Taiwan is populated with a higher percentage of seniors than any other demographic group. Low fertility rates have also caused Taiwan's youth population to shrink by 23.1% in the past ten years. Taiwan's National Development Council estimates that the ageing index will increase to 401% by 2060. Once the current middle-aged population becomes elderly a few decades from now, the rapidly-shrinking, younger demographic groups will inevitably face severe economic and family support problems.

Another demographic datum that requires close observation is the increasing size of the physically and mentally disabled population in Taiwan. The total disabled population increased by 17.1% from 2006 to 2017, according to the Ministry of Health and Welfare of Taiwan. Taiwan's government has been on the alert regarding the above demographic trends. In 2014, the government announced the "368 daycare services project," which aims to establish at least 368 daycare centers within three years. Supporting the project is a raise in hourly wages for nursing aides. Moreover, 100,000 additional qualified social workers are projected to enter the field to help alleviate the industry's current shortage of personnel.

Social workers are defined as people who provide social services or work for private organizations providing help and support for people in need. Table 1 shows the total number of full-time social workers in Taiwan from 2011 to 2015, as well as the social workers' workload in 2016 categorized by senior, young, and disabled nursing care patients. Currently, each social worker must serve an average of 807 senior citizens. This clearly reveals that Taiwan is experiencing a shortage of social workers, especially for senior citizens. With this limited workforce and an increasingly large demand, the industry's need to adopt modern technology and professional training programs is urgent. Therefore, the present study evaluates operational digitalization (OD) and intangible asset investment (IA) with respect to operating/service efficiency and financial performance.

Table 1. Full-time Social Workers in Taiwan from 2011-2016

Year	2011	2012	2013	2014	2015
Workforce	7224	8127	8441	9002	9118
Average workload grouped by service targets in 2016					
			Youth	Senior	Disabled
Service Targets/workforce			224	807	192

Data source: Department of social assistance and social work, Ministry of Health and Welfare.

Current literature features operational digitalization and intangible asset investment as potential methods to evaluate operating efficiencies. Operational digitalization includes software and hardware use to help determine an organization's potential to take advantage of advanced technology. Dong *et al*. (2009) show that firms with stronger information technology resources including backend integration, managerial skills, and partner support – can create value by developing digital integration to improve upstream, downstream, and internal operations. Back-end integration in particular is significantly associated with process-level performance along the supply chain. Sheng and Mykytyn (2002) investigate the relationship between IT investment and firm performance, concluding that the data quality of well-managed IT systems influences a firm's quality of services, products, and operations, which in turn impacts the firm's performance. Mithas *et al*. (2013) suggest that industry factors such as industry turbulence, competition, industry growth, and a firm's degree of involvement in digital business practices have substantial influence on the firm's general IT investment, outsourcing IT investment, and performance. Mas and Seinfeld (2008) examine the effect of health care expenditure on hospitals' adoption of new technology. Empirical results show that (1) managed care that controls health care expenditure leads to long-term reductions in medical costs, and (2) that managed care has a negative effect on the adoption of less profitable technologies. Other recent studies related to operational digitalization and operating performance include Ismail and Mamat (2012), Kohli *et al*. (2012), Mithas *et al*. (2012), Kao (2005), Chang *et al*. (2007), and Lin *et al*. (2008).

Intangible assets such as personnel training and education and research and development expenses are vital in determining service quality. Awano *et al*. (2010)

conducted a survey in the UK to investigate six categories of intangible asset investment including employer-funded training, software, research and development (R&D), reputation and branding, design, and business process improvement. The survey presents these intangible assets' incidence, expenditure levels, and life length. Chueh and Liu (2004) explore hospital characteristics and the relationship between human capital and hospital management's performance. The study concludes that human capital has a considerable impact on hospital performance. Hospital characteristics, however, do not significantly influence hospital performance. Chen *et al*. (2007) adopted a data envelopment analysis to investigate the operating efficiency of military hospitals in Taiwan. Their results show that hospital operations are not fully efficient due to ineffective usage of intellectual capital inputs. For further literature on intangible assets and operating performance, we refer to Van Ark *et al*. (2009), Hao and Jonathan (2011), Haskel (2012), Mention (2012), Wang and Chang (2004), and Yang (2006).

Our present study's contributions to the field are described below. First, our research constructs a Translog stochastic frontier production model to evaluate technical efficiency in the social work services industry. We refer to Coelli (1996) and O'Donell *et al*. (2008) for a detailed review of Translog stochastic frontier models. Research related to operating performance includes, for example, Hughes (2013) and Lin *et al*. (2013). Other literature focuses specifically on nonprofit institutes (see, for instance, Veltri *et al*. (2011) and Sales (2013)). Unlike most literature dealing with technical efficiency, where researchers typically adopt a single variable or conduct a questionnaire-based survey, the present research utilizes census data containing four technology-related variables and online trading volume records to characterize operational digitalization and four variables to assess intangible assets. Second, we examine the operating performance of public and private social work service providers individually and evaluate whether incentive differences exist between these two types of providers. Third, the study also examines whether the information technology productivity paradox exists in Taiwan's social work industry. While some studies in the literature conclude that information technology investment has a positive relationship to returns and productivity, we identified some literature that concluded otherwise; for example, Brynjolfsson (1993), Tang (2005), and Kao (2005). Therefore, this study aims to investigate the relationship between information technology and efficiency in Taiwan's social work industry. Finally, we evaluate the effect of input variables on performance using the conventional method of regression models to assess the direct effect of input variables. However, in addition, we investigate the mediating effect when operational digitalization and intangible asset investment improve an organization's internal management and, in turn, enhance financial performance.

2 Model Specifications

This section is divided into three subsections. Section 2.1 explains model assumptions, efficiency frontier theory, and presents our hypothesis. In section 2.2, a stochastic frontier production function model is constructed to evaluate technical efficiency. In section 2.3, we insert the results of technical efficiency approximations into regression equations to assess the financial effects of operational digitalization and intangible asset investment.

2.1 Assumptions and Hypothesis

The census data in our empirical studies allows us to distinguish public from private social work service providers. Therefore, we are able to examine their technical efficiencies individually and make comparisons. Notations and assumptions regarding these two types of organizations are detailed below.

$\pi(E)$: profit function given E, a certain combination of operational digitalization (OD) and intangible asset investment (IA)

TR: total revenue; MR: marginal revenue

TC: total cost; MC: marginal cost

X_N ; X_P: input levels of organizations; N: public (nonprofit) organizations; P: private organizations

Q_N ; Q_P : output level of public and private organizations

TP: total product of input

We assume that publicly managed organizations devote more efforts towards maximizing service (output) level with an expectation of breaking even. Private organizations, on the other hand, must maximize profits in response to investors. Based on these different operating objectives, the profit function and constraints of public and private organizations are formulated as in Eqs. (1&2). In Eq. (1), we observe that first order condition: $MC>MR$ because public organizations aim at maximizing output Q_N. However, in Eq. (2), the first order condition becomes $MR=MC$ and $MC'> MR'$.

Publicly managed (nonprofit) organizations:

$$\begin{aligned} &Max\ \mathrm{Q_N} = \mathrm{Q_N}(E) \\ &st. \quad \pi(E) = TR(\mathrm{Q_N}(E)) - TC(\mathrm{Q_N}(E)) = 0 \rightarrow TR = TC \\ &\text{First order condition: } \pi'(E) = TR' - TC' < 0 \rightarrow MC > MR \end{aligned} \tag{1}$$

Privately managed organizations:

$$\begin{aligned} &Max\ \pi(E) = TR(\mathrm{Q_N}(E)) - TC(\mathrm{Q_N}(E)) \\ &\text{First order condition: } \pi'(E) = TR' - TC' = 0 \rightarrow M\mathrm{R} = M\mathrm{C} \\ &\text{Second order condition: } \pi''(E) = TR'' - TC'' = 0 \rightarrow M\mathrm{C}' > M\mathrm{R}' \end{aligned} \tag{2}$$

Next, Figure 1 illustrates the interaction between an organization's output and input based on the efficiency frontier theory. For a specific combination of OD and IA levels, we draw profit function $\pi(E)$ as in the upper right corner of Figure 1 and, according to the distinct operating objectives discussed above, we obtain optimum output level, Q_N and Q_P, for public and private organizations, respectively. Observe that $Q_N>Q_P$. Then, the corresponding inputs, X_N and X_p, can be obtained from $TP(E)$ function line on the left. The input level of public organizations X_N is shown to be greater than that of private organizations, $X_N> X_p$. Next, if we assume an increase in the combination of OD and IA levels to, for example, E', is beneficial to an organization's financial performance, then the profit function $\pi(E)$ moves upward to $\pi(E')$ and the output levels of public and private organizations increase to $Q_{N'}$ and $Q_{P'}$, respectively. Note that $Q_{N'}>Q_N$ and $Q_{P'}>Q_P$. However, any movements of input levels X_N and X_P are not definite since they depend on output growth and productivity, which benefit more from increased OD and IA. If output increases more than productivity, then input level increases. That is, $X_{N'}>X_N$ and $X_{P'}>X_P$. If the degree of productivity increase is enough to cover the output growth, then the input level will not change – it might even be reduced. Therefore, input level movement after OD and IA increase is not certain. Nevertheless, the input and output levels of public organizations after increased OD and IA levels are still greater than those of private organizations: $X_{N'} > X_{P'}$ and $Q_{N'} > Q_{P'}$.

The analysis in Figure 1 assumes that both types of organizations are relatively efficient in their operations. However, in practice, organizations might operate inefficiently. Figure 2 illustrates that when public and private organizations are inefficient, with the same inputs X_N and X_P, their outputs become Q'_N, and Q'_P, rather than Q_N and Q_p. Observe that $Q'_N < Q_N$ and $Q'_P < Q_P$. Consequently, technical efficiency equations can be written as follows,

$$TE_N = \frac{OQ'_N}{OQ_N}; \; TE_P = \frac{OQ'_P}{OQ_P} \tag{3}$$

Based on this section's assumptions, we propose four null hypotheses:

H1: Operational digitalization, intangible asset investment, and technical efficiency are irrelevant. (4a)

H2: Operational digitalization, intangible asset investment, and financial performance are irrelevant. (4b)

H3: Public and private organizations are equal in input, output, and operating performance. (4c)

H4: Public and private organizations are equal in operational digitalization and intangible asset investment. (4d)

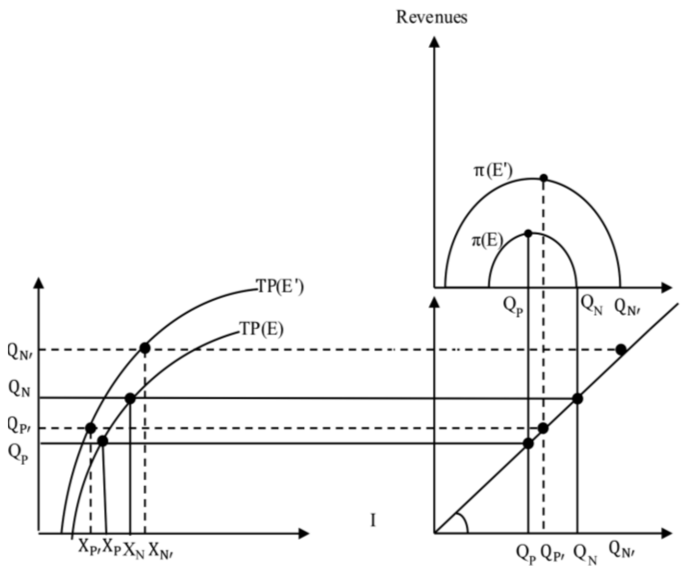

Figure 1. Interaction of Input, Output, and Profit for Public and Private Organizations

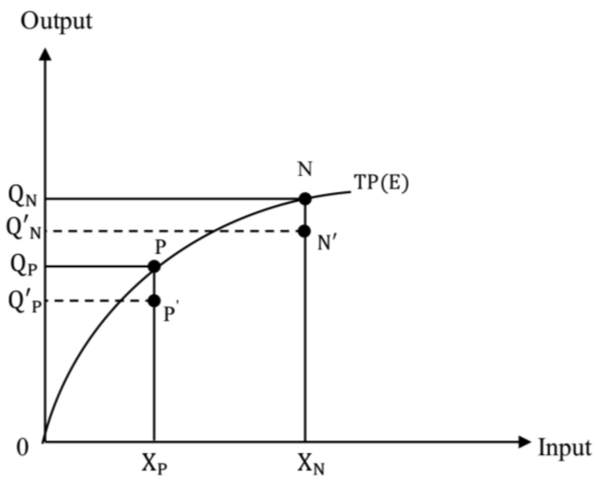

Figure 2. Influence of Inefficiency on Outputs for Public and Private Organizations

2.2 Stochastic Frontier Production Function Model

To evaluate each organization's technical efficiency, a Translog stochastic frontier production function was constructed. For details regarding stochastic frontier production functions, please see Coelli (1996) and O'Donell *et al*. (2008). Q_i is the production output of organization *i*. L_i denotes the total number of employees and K_i represents net fixed assets of organization *i* at the end of the year. Eq. (5a) formulates the stochastic frontier production function. V_i and U_i are error terms. $V_i \sim N(0,\sigma_v^2)$. U_i represents the level of technical inefficiency of organization *i*. U_i is assumed to be a non-negative variable that follows truncated normal distribution. That is, $U_i \sim N^+(\mu(Z),\sigma^2(Z))$ where *Z* is an exogenous variable of U_i. Regression Eq. (5b) assesses the impact of managerial variables available from the census data – including five operational digitalization (OD) variables, five intangible asset (IA) variables, type of organization (*NFP*), service target in the industry (*IND*), and operating scale (*LTA*) – on technical inefficiency U_i. Table 3 provides detailed variable definitions.

$$ln(Q_i) = \beta_0 + \beta_1 ln(L_i) + \beta_2 ln(K_i) + \beta_3 \frac{1}{2}(ln(L_i))^2 + \beta_4 \frac{1}{2}(ln(K_i))^2 + \beta_5 ln(L_i) ln(K_i) + (V_i - U_i) \quad (5a)$$

$$U_i = \delta_0 + \delta_1 OD1_i + \delta_2 OD2_i + \delta_3 OD3_i + \delta_4 OD4_i + \delta_5 OD5_i + \delta_6 IA1_i + \delta_7 IA2_i + \delta_8 IA3_i + \delta_9 IA4_i + \delta_{10} IA5_i + \delta_{11} NFP_i + \delta_{12} IND_i + \delta_{13} LTA_i + \varepsilon_i \quad (5b)$$

We used the maximum likelihood estimate method (MLE) to approximate Eqs. (5a&b). Technical efficiency (*TE*) for each organization can then be obtained by

$$TE_i = e^{-U_i} \leq 1. \quad (6)$$

To validate the stochastic frontier production function model above, two null hypotheses are proposed.

$$H_0 : \gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} = 0 \ or \ \frac{\sigma_u}{\sigma_v} = 0 \ or \ \sigma_u^2 = 0 \quad (7a)$$

$$H_0 : \ LR = -2(LR_{OLS} - LR_{MLE}) \quad (7b)$$

Eq. (7a) is derived according to Eq. (5a). LR_{OLS} and LR_{MLE} in Eq. (7b) stands for the log-likelihood functions of ordinary least squares (OLS) and maximum likelihood estimators (MLE), respectively. If Z-test of Eq. (7a) and χ^2 test of Eq. (7b) are rejected, it can then be concluded that the test organization operates inefficiently.

In addition, based on Eq. (5a), we also calculated the output elasticity of *L* and *K*, denoted as *EOL* and *EOK* as in Eq. (8a & 8b) and returns to scale (*RTS*) of organization *i* in Eq. (8c). *RTS=1* means constant returns to scale. *RTS>1* represents increasing returns to scale.

$$EOL_i = \frac{\partial\, ln\, Q_i}{\partial\, ln\, L_i} = \beta_1 + \beta_3\, ln(L_i) + \beta_5\, ln(K_i) \tag{8a}$$

$$EOK_i = \frac{\partial\, ln\, Q_i}{\partial\, ln\, K_i} = \beta_2 + \beta_4\, ln(K_i) + \beta_5\, ln(L_i) \tag{8b}$$

$$RTS_i = EOL_i + EOK_i \tag{8c}$$

2.3 Financial Performance Models

In this section, we present two financial models. The first model is a regression model aiming to investigate the effect of input variables upon financial performance including profit (PRO), return on assets (ROA), and revenue-cost ratio (RCR). PRO is defined as operating and non-operating revenues minus operating and non-operating expenses. In our empirical studies, information on revenues and expenses was predefined and taken directly from Taiwan’s Industry, Commerce, and Service Census Database. We used ROA to evaluate a particular service provider’s level of efficiency in using its assets. RCR evaluates operating efficiency by comparing costs as a proportion of total revenue. That is, RCR is able to show the level of resources required to generate revenue. It also enables us to compare incentive differences between public and private organizations. The second model aims to further understand the main driving force behind financial performance and whether operational digitalization and intangible asset investment have a direct impact on financial performance or whether they improve managerial efficiency and then indirectly improve financial performance.

Technical inefficiency U_i from the stochastic frontier production function model in Eq. (5b) serves as the mediating variable. We added two additional variables (*CITY* and *HHI*) in the regression model shown in Eqs. (9a-9c). $CITY_i$ denotes the location of organization *i*. $CITY_i=1$ is for organizations located in a municipality and $CITY_i=0$ for organizations located in non-municipality areas. HHI is the Herfindahl-Hirschman Index reflecting the degree of market competition.

$$PRO_i = \alpha_0 + \alpha_1 U_i + \alpha_2 RTS_i + \alpha_3 OD1_i + \alpha_4 OD2_i + \alpha_5 OD3_i + \alpha_6 OD4_i + \alpha_7 OD5_i + \alpha_8 IA1_i + \alpha_9 IA2_i + \alpha_{10} IA3_i + \alpha_{11} IA4_i + \alpha_{12} IA5_i + \alpha_{13} NFP_i + \alpha_{14} IND_i + \alpha_{15} LTA_i + \alpha_{16} CITY_i + \alpha_{17} HHI_i + e_i \quad (9a)$$

$$ROA_i = \theta_0 + \theta_1 U_i + \theta_2 RTS_i + \theta_3 OD1_i + \theta_4 OD2_i + \theta_5 OD3_i + \theta_6 OD4_i + \theta_7 OD5_i + \theta_8 IA1_i + \theta_9 IA2_i + \theta_{10} IA3_i + \theta_{11} IA4_i + \theta_{12} IA5_i + \theta_{13} NFP_i + \theta_{14} IND_i + \theta_{15} LTA_i + \theta_{16} CITY_i + \theta_{17} HHI_i + u_i \quad (9b)$$

$$RCR_i = \gamma_0 + \gamma_1 U_i + \gamma_2 RTS_i + \gamma_3 OD1_i + \gamma_4 OD2_i + \gamma_5 OD3_i + \gamma_6 OD4_i + \gamma_7 OD5_i + \gamma_8 IA1_i + \gamma_9 IA2_i + \gamma_{10} IA3_i + \gamma_{11} IA4_i + \gamma_{12} IA5_i + \gamma_{13} NFP_i + \gamma_{14} IND_i + \gamma_{15} LTA_i + \gamma_{16} CITY_i + \gamma_{17} HHI_i + v_i \quad (9c)$$

To investigate whether OD and IA affect internal management and indirectly influence financial performance, we combined technical inefficiency U_i in Eq. (5b) and parameters estimated in Eqs. (9a-9c) to assess the mediating, direct, and total effects of operational digitalization and intangible asset investment by chain rule as shown in Eqs. (10-12). Total effect is the result of mediating effect plus direct effect.

Mediating effects:

$$\begin{aligned}&\text{On profit (PRO)} = \alpha_1 * \delta_i,\ i=1\sim10\\&\text{On return on assets (ROA)} = \theta_1 * \delta_i,\ i=1\sim10\\&\text{On revenue-cost ratio (RCR)} = \gamma_1 * \delta_i,\ i=1\sim10\end{aligned} \tag{10}$$

Direct effects:

$$\begin{aligned}&\text{On profit (PRO)} = \alpha_j,\ j=3\sim13\\&\text{On return on assets (ROA)} = \theta j,\ j=3\sim13\\&\text{On revenue-cost ratio (RCR)} = \gamma_j,\ j=3\sim13\end{aligned} \tag{11}$$

Total effects:

$$\begin{aligned}&\text{On profit (PRO)} = \alpha_1 * \delta_i + \alpha j,\ i=1\sim10,\ j=3\sim13\\&\text{On return on assets (ROA)} = \theta_1 * \delta_i + \theta j,\ i=1\sim10,\ j=3\sim13\\&\text{On revenue-cost ratio (RCR)} = \gamma_1 * \delta_i + \gamma_j,\ i=1\sim10,\ j=3\sim13\end{aligned} \tag{12}$$

3 Empirical Results

This section presents the results of the stochastic frontier model followed by the results of the financial performance models and then compares the differences between public and private social work service providers.

3.1 Data and Variables

We took our census data of the social work services industry from Taiwan’s Industry, Commerce, and Service Census Database (years 2006 and 2011). After applying the sampling process illustrated in Table 2, we collected 4,101 valid samples from 2006 and 4,086 from 2011. We grouped variables into five panels: stochastic frontier production function; operational digitalization, including four computer and information technology-related variables and online trading volume records; intangible asset investment, composed of research and development expenses, employee training expenses, marketing expenses, and computer software expenses; other control variables; and financial performance as Table 3 shows.

Table 2. Sampling Process

	Sample size	
Year	2006	2011
Original samples	5,794	5,475
Removed samples (missing operational digitalization values)	1,261	865
Removed samples (revenue=0)	1,261	874
Removed samples (operating expenses=0)	1,266	865
Subtotal=	1,266	874
Removed 2.5% extreme values:		
Number of employees	297	351
Yearly wage	114	118
Operating expenses	114	115
Revenues	113	118
Net fixed assets at year end	113	118
Subtotal=	427	515
Valid samples	4,101	4,086

Table 3. Variable Definitions

	Definition	Note
	Panel A：Stochastic frontier production function	
Q	Production	Total value of production (in thousands of NT dollars)
L	Labor	Number of employees
K	Capital	Net fixed assets at year end (in thousands of NT dollars)
TE	Technical efficiency	
U	Technical inefficiency	=- Ln(TE)
EOL	Output elasticity of labor	
EOK	Output elasticity of capital	
RTS	Returns to scale	Sum of EOL+EOK
	Panel B：Operational digitalization (OD)	
OD1	Computers or internet facilities	1: yes; 0: no.
OD2	Information system to aid management	1: yes; 0: no.
OD3	Operating information on the internet	1: yes; 0: no.
OD4	Online purchasing	1: yes; 0: no.
OD5	Value of online purchasing	(in thousands of NT dollars)

Panel C：Intangible assets (IA) (in thousands of NT dollars)		
IA1	R&D expenses	
IA2	Employee training expenses	
IA3	Marketing expenses	
IA4	Software and database expenses	
IA5	Net intangible assets	
Panel D：Other control variables		
NFP	Type of organization	1:public; 0: private
CITY	Municipality	1: municipality; 0: non-municipality
IND	Service category in the industry	1: services for seniors and the disabled; 0: services for young people
LTA	Scale of organization	Natural log of net assets at year end
HHI	Market competition	Herfindahl-Hirschman Index by city
Panel E：Financial performance		
PRO	Profits	NT dollars (in hundred thousands)
ROA	Return on assets	=Profit/total assets
RCR	Revenue-cost ratio	=Revenue/cost

3.2 Results from the Stochastic Frontier Production Model

Table 4 presents the results of the Translog stochastic frontier production function of Eqs. (5a&5b). Regression function parameters in were approximated through the maximum likelihood estimate method (MLE). Technical efficiency is derived from Eq. (6), and returns to scale (RTS) by Eqs. (8a-8c). Panel A of Table 4 shows that values of $\sigma^2, \gamma,$ and LR all suggest that null hypotheses in Eqs. (7a&7b) are rejected. The operating performance of Taiwan's social work industry is revealed as inefficient for both years. Panel C shows the results of the technical inefficiency regression function, Eq. (5b). Five operational digitalization (OD) variables have shown either a significantly negative impact on technical inefficiency or no significant differences at all, indicating that operational digitalization favors technical efficiency. With respect to intangible asset variables, except for the fact that R&D expense (IA1) in 2006 and software and database expense (IA4) in 2011 are positively related to inefficiency, the rest of the IA results show that investment in intangible assets is beneficial to the industry's technical efficiency. In general, OD and IA investments have the capacity to improve technical efficiency.

Moreover, in Panel D average returns to scale (RTS) increased from 0.60 in 2006 to 1.48 in 2011. Average technical efficiency increased from 0.36 in 2006 to

0.86 in 2011, showing that profitability and productivity greatly improved from 2006 to 2011 and that the operating environment for the industry became healthier. To summarize the results from Table 4, operational digitalization and intangible asset investment both proved to improve technical efficiency. Therefore, we can conclude that the information technology productivity paradox phenomenon does not exist in the social work industry in Taiwan. The null hypothesis H1 in Eq. (4a) is then rejected.

Table 4. Results of the Stochastic Frontier Production Function Model

	2006		2011	
Panel A: Tests of hypotheses				
σ^2	0.15	[44.78***]	0.2268	[13.44***]
γ	0.15	[10.16***]	0.0566	[2.01**]
LR_{OLS}	-2380.40		-2665.65	
LR_{MLE}	-1963.65		-2586.62	
LR	{833.48***}		{158.06***}	
Panel B: Production function				
Constant	11.3	(27.63***)	8.1073	(110.20***)
$\ln L$	1.3	(17.15***)	1.1968	(17.45***)
$\ln K$	-0.7[a]	(-10.62***)	-0.387[a]	(-25.86***)
$1/2(\ln L)^2$	0.03	(1.39*)	0.0741	(1.57*)
$1/2(\ln K)^2$	0.08	(11.30***)	0.1226	(84.56***)
$\ln L * \ln K$	-0.08	(-8.08***)	-0.052	(-6.06***)
Panel C: Technical inefficiency regression function				
Constant	3.63	(13.35***)	1.12	(29.98***)
OD1	-0.06	(-2.35**)	-0.22	(-1.33*)
OD2	-0.02	(-0.94)	-0.04	(-0.29)
OD3	-0.02	(-0.16)	-0.01	(-0.15)
OD4	-0.02	(-0.63)	-0.07	(-1.35*)
OD5	-0.00	(-1.33*)	-0.00	(-3.67***)
IA1	0.0003	(12.42***)	-0.00	(-0.03)
IA2	-0.002	(-9.01***)	-0.001	(-2.60***)
IA3	-0.003	(-31.81***)	0.00	(0.66)
IA4	-0.00	(-4.00***)	0.00	(3.21***)
IA5	-0.00	(-0.84)	-0.00	(-3.58***)
NFP	-0.03	(-1.04)	0.07	(1.04)
IND	0.13	(4.87***)	0.28	(6.36***)
LTA	-0.25	(-9.63***)	-0.09	(-10.80***)

Panel D: Productivity	2006				2011			
	Avg.	Max.	Min.	Std.	Avg.	Max.	Min.	Std.
RTS	0.60	0.66	0.47	0.03	1.48	1.88	1.2	0.10
TE	0.36	1.00	0.12	0.1	0.86	1.00	0.49	0.08

( ), [ ], and { } present t value, Z value, and χ^2 value respectively. *, **, and *** denote 10, 5, and 1% level of significance respectively.

[a] The parameter of ln K shows negative, however, the marginal product of capital MPK is greater than 0.

3.3 Results from the Financial Regression Model

Table 5 presents the empirical results based on Eqs. (9a-9c). Findings are summarized as follows. In Panel A, both F and χ^2 values show positive relationships to heteroscedasticity. Therefore, instead of the ordinary least squares method, we adopted White's heteroscedasticity consistent (robust) standard errors approach to calculate t values (as shown in parenthesis in the table). In Panel B, technical inefficiency (U) is shown to be negatively related to all three financial measures – PRO, ROA, and RCR – in both years. In other words, improving technical efficiency is favorable to financial performance. However, the returns to scale (RTS) of 2006 and 2011 have the opposite impact on financial performance. This is because the industry's operating environment shows decreasing returns to scale in 2006, as shown in Panel D of Table 4. The average RTS<1, but this changed to increasing returns to scale in 2011. In Panel E of Table 5, we can observe that public organizations (NFP=1) have a negative relationship to financial performance. Services for seniors and the disabled (IND=1) operate more successfully than services for younger demographics, at least from a financial standpoint. Scale of organization (LTA) appears to have negative impact on financial measures. Municipalities (CITY=1) have better financial performances than non-municipalities. A higher degree of monopoly (HHI) in a city can significantly increase return on assets (ROA); however, it is unfavorable to profit (PRO) and revenue-cost ratios (RCR).

However, the impact of OD and IA variables in Panels C & D of Table 5 are not conclusive. Thus, to further investigate the impact of OD and IA variables on financial measures, we used technical inefficiency U_i as the mediating variable and obtained the mediating, direct, and total effects on profit, return on assets, and revenue-cost ratio according to Eqs. (10-12).

Table 5. Results of the Financial Regression Model

	2006			2011		
Variable	PRO	ROA	RCR	PRO	ROA	RCR
Panel A: Heterogeneity tests and goodness of fit						
F	195.67***	1.95**	11.00***	96.65***	9.79***	4.65***
χ^2	1841.10***	32.94**	179.66***	1175.48***	160.55***	77.89***
$\bar{R}^2$	0.21	0.16	0.20	0.13	0.15	0.26
Panel B: Inefficiency and returns to scale						
Constant	175.27***	395.3***	144.8***	-42.02*	16.03	382.68***
	(5.79)	(5.62)	(5.45)	(-1.45)	(0.29)	(14.36)
U	-44.02***	-56.8***	-40.9***	-56.32**	-127.7***	-78.1***
	(-5.543)	(-3.698)	(-6.02)	(-2.18)	(-3.63)	(-3.89)
RTS	-45.9**	-125***	201.7***	88.02***	276.77***	-253.3***
	(-2.42)	(-5.47)	(13.09)	(3.28)	(4.36)	(-9.30)
Panel C: Operational digitalization variables						
OD1	-3.43***	-3.78**	-3.02***	-10.36**	-26.54***	-13.26***
	(-3.73)	(-2.07)	(-2.58)	(-1.96)	(-3.78)	(-2.42)
OD2	-0.37	1.89*	2.19***	-0.83	1.59	-4.65*
	(-0.56)	(1.48)	(2.42)	(-0.49)	(0.62)	(-1.42)
OD3	0.15	1.11	-4.33***	0.31	2.74*	-1.52**
	(0.28)	(0.99)	(-6.57)	(0.65)	(1.58)	(-1.85)
OD4	-2.85**	-5.07***	-0.69	-1.17	-1.17	-2.31*
	(-2.57)	(-3.09)	(-0.56)	(-0.89)	(-0.46)	(-1.44)
OD5	-0.003*	0.00	-0.001*	0.000	0.000	-0.001
	(-1.48)	(0.09)	(-1.32)	(0.02)	(0.41)	(-0.63)
Panel D: Intangible asset variables						
IA1	-0.08	-0.02	0.01	0.003	0.008	0.001
	(-0.94)	(-0.51)	(0.62)	(1.23)	(1.02)	(0.30)
IA2	0.01	-0.03	-0.12***	0.03	0.00	-0.04***
	(0.39)	(-1.19)	(-4.07)	(0.84)	(0.21)	(-3.44)
IA3	-0.07***	-0.11***	-0.06**	0.00	0.00	0.01**
	(-2.37)	(-2.80)	(-2.09)	(0.41)	(0.39)	(1.65)
IA4	0.006	0.001	0.01***	0.003*	-0.003***	0.001
	(0.36)	(0.14)	(2.82)	(1.60)	(-2.34)	(1.2)
IA5	0.004*	0.003***	0.004***	0.01*	0.01***	-0.006**
	(1.63)	(2.67)	(3.89)	(1.92)	(4.33)	(-2.08)
Panel E: Other control variables						
NFP	-9.7***	-8.2***	-3.19*	-2.99*	-3.86	-29.75***
	(-5.73)	(-4.33)	(-1.45)	(-1.28)	(-1.07)	(-10.42)
IND	6.38**	7.07***	-20.86***	18.70***	28.07***	-21.39***
	(2.02)	(2.38)	(-4.89)	(3.31)	(4.28)	(-4.44)
LTA	-9.29***	-26.1***	-10.41***	-7.05***	-41.1***	15.1***
	(-4.74)	(-5.28)	(-6.2)	(-2.71)	(-7.90)	(6.51)
CITY	1.24*	1.64*	-0.84	1.18**	0.9	3.12***
	(1.46)	(1.58)	(-0.96)	(1.82)	(0.55)	(3.9)
HHI	0.003	0.002**	0.001	-0.001**	0.002***	-0.001**
	(1.2)	(1.74)	(0.25)	(-2.29)	(4.77)	(-1.92)

Note: *, **, & *** indicating 10, 5 & 1% level of significance, respectively. ( ): t value of White's estimator.

The results in Table 6 show that the mediating effect of the sum of all OD variables (ODSUM) and the sum of all IA variables (IASU) are positively related to

PRO, ROA, and RCR in both years. However, the direct effects of most variables are negatively related to financial measures. Therefore, the main driving force behind financial performance is the mediating effect; i.e., financial performance improves as a result of improved management efficiency. The total effect, which is the sum of the mediating effect and the direct effect, depends on the extent of the two opposite influences. Actually, in 2006 only the total effects of ODSUM are negative in three financial measures. In 2011, the total effects of ODSUM are all positive. The different results between 2006 and 2011 can be attributed to the fact that the immediate financial benefits of software or hardware investments are usually not observed in the same year as the investments are made (due to the long-term payback nature of investments). In 2006 and 2011, IASUM have positive total effects on financial performance. Therefore, the null hypothesis H2 in Eq. (4b) is rejected. Operational digitalization, intangible asset investment, and financial performance are related.

Table 6. The Mediating, Direct, and Total Effects of OD and IA Variables

	2006			2011		
	Panel A: Profit					
Variable	Mediating	Direct	Total	Mediating	Direct	Total
OD1	2.75	-3.43	-0.68	12.56	-10.36	2.2
OD2	—	—	—	—	—	—
OD3	—	—	—	—	—	—
OD4	0.85	-2.85	-2	3.72	—	3.72
OD5	0.002	-0.003	-0.001	0.001	—	0.001
ODSUM	3.60	-6.28	-2.68	16.28	-10.36	5.92
IA1	-0.02	—	-0.02	—	—	—
IA2	0.07	—	0.07	0.04	—	0.04
IA3	0.16	—	0.16	—	—	—
IA4	0.005	—	0.005	-0.001	0.003	0.002
IA5	—	0.004	0.004	0.006	0.01	0.02
IASUM	0.22	0.004	0.22	0.05	0.01	0.06
	Panel B: Return on assets					
Variable	Mediating	Direct	Total	Mediating	Direct	Total
OD1	3.55	-3.78	-0.22	28.48	-26.54	1.93
OD2	—	1.89	1.89	—	—	—
OD3	—	—	—	—	2.74	2.74
OD4	1.09	-5.07	-3.97	8.44	—	8.44
OD5	0.002	—	0.002	0.002	—	0.002
ODSUM	4.65	-8.84	-4.19	36.91	-23.81	13.10
IA1	-0.02	—	-0.02	—	—	—
IA2	0.09	—	0.09	0.1	—	0.1
IA3	0.21	-0.11	0.1	—	—	—
IA4	0.00	—	0.00	-0.00	-0.00	-0.01
IA5	—	0.003	0.003	0.02	0.01	0.03
IASUM	0.28	-0.11	0.17	0.11	0.01	0.12

Panel C: Revenue-cost ratio						
Variable	Mediating	Direct	Total	Mediating	Direct	Total
OD1	2.56	-3.02	-0.46	17.41	-13.26	4.16
OD2	—	2.19	2.19	—	-4.65	-4.65
OD3	—	-4.33	-4.33	—	-1.52	-1.52
OD4	0.79	—	0.79	5.16	-2.31	2.84
OD5	0.002	-0.001	0.001	0.001	—	0.001
ODSUM	3.35	-5.17	-1.82	22.57	-21.74	0.83
IA1	-0.01	—	-0.01	—	—	—
IA2	0.06	-0.12	-0.06	0.06	-0.04	0.02
IA3	0.15	-0.06	0.1	—	0.01	0.01
IA4	0.01	0.01	0.02	-0.00	—	-0.00
IA5	—	0.00	0.00	0.01	-0.01	0.00
IASUM	0.20	-0.16	0.05	0.07	0.04	0.03

Note: ODSUM=sum of 5 OD variables and IASUM=sum of 5 IA variables. "-" indicates not significant.

3.4 Comparisons between Public and Private Organizations

This section examines whether organization type has any influence on operating efficiency and financial performance. Panel A in Table 7 demonstrates that the average output, Q, and input variables, labor L and capital K, of public organizations (NFP=1) are higher than those of private organizations. Operational digitalization variables in Panel B are also significantly higher for public organizations, with similar observations applying to intangible asset investment in Panel C. This might be explained because public organizations, supported by government funding, are more willing to allocate resources to information technology and intangible asset investments. Nonetheless, Panel D shows three financial performance measures of public organizations that are lower than those of private organizations. Public organizations strive to maximize output levels while private organizations aim to maximize profitability. Thus, an organization's incentive difference indeed influences operating and financial performance. Therefore, we reject null hypotheses H3 & H4 in Eqs. (4c & 4d).

Table 7. Test of Incentive Differences between Public (NFP=1) and Private (NFP=0) Organizations

	2006			2011		
	Public	Private	t value	Public	Private	t value
Panel A: Average output, input, and technical efficiency						
Q	16616.1	6525.2	-18.1***	12388.1	7202.3	-9.99***
L	24.34	9.44	-24.7***	25	9.62	-24.4***
K	32816.9	17910	-7.72***	34902	18776	-5.29***
U	0.76	1.12	16.65***	0.17	0.15	-2.97***
TE	0.51	0.35	-19.5***	0.85	0.86	2.68***
Panel B: Average operational digitalization						
OD1	0.95	0.87	-3.91***	0.97	0.93	-2.26**
OD2	0.83	0.77	-2.22**	0.97	0.91	-3.23***
OD3	0.45	0.39	-2.03**	0.69	0.66	-0.85
OD4	0.29	0.06	-14.2***	0.35	0.11	-11.1***
OD5	150.81	23.7	-9.12***	485.27	22.64	-18.9***
Panel C: Average intangible asset investment						
IA1	4.28	2.59	-0.45	5.59	7.61	0.38
IA2	40.53	14.54	-9.51***	27.20	24.96	-0.57
IA3	73.02	26.08	-15.1***	32.09	30.24	-0.44
IA4	45.41	19.89	-2.17**	30.69	21.9	-0.28
IA5	264.26	36.96	-10.5***	183.82	24.06	-10.6***
Panel D: Average financial performance						
PRO	8.15	8.34	0.17	7.16	8.98	1.44
ROA	5.27	10.58	2.48***	8.56	18.49	3.02***
RCR	107.7	115.96	6.35***	73.38	113.94	24.27***

Note: *, **, *** indicates 10, 5 and 1% level of significance respectively.

4 Conclusions and Research Constraints

This study's objective is to examine the impact of operational digitalization and intangible asset investment on the social work industry's operating and financial performance in Taiwan. We constructed a Translog stochastic frontier production function model and a financial regression model and followed them with empirical studies. The study's empirical data is from the Industry, Commerce and Service Census Database, including data on 4,061 organizations from 2006 and 4,086 organizations from 2011. The industry's average technical efficiency in 2006 was 0.358 and it rose to 0.864 in 2011, showing an impressive increase in the industry's productivity. However, a 23.6% gap must still be filled before the industry can be considered fully efficient.

This study's major findings are described below. First, operational digitalization can substantially improve operation efficiency. Moreover, the information technology productivity paradox does not exist in Taiwan's social work services field. Thus, we suggest for service providers to devote themselves fully to digitalized business practices to ease social workers' excessive workload. Second, intangible assets have shown positive associations with technical efficiency, especially for employee training programs and marketing expenses. Even though R&D and software and database expenses might cause short-term inefficiency because of their longer payback period, in the long run intangible assets are helpful in enhancing the industry's efficiency. Third, we found that financial performance's main driving force in the social work industry relies on the mediating effect rather than the direct effect. In other words, operational digitalization and intangible asset investment improve financial performance because they help to improve internal management and therefore result in higher operating efficiency and rewarding financial performance. Finally, public service providers have more advantages in terms of labor, capital, and operating scale compared to profit-driven, private service providers. However, public organizations are significantly inferior to private organizations regarding financial performance. This observation suggests that public service providers would benefit by devoting increased capital to information technology, personnel education, and training so that both internal management and financial performance are enhanced. In conclusion, information technology and intangible asset investment are crucial resources for service providers to achieve sustainability and profitability within the industry.

The study's constraints and possible areas for future research are as follows. First, the lack of data on fixed-asset investments for each year, since we only had access to the value of fixed assets at the end of each year. Therefore, we were not able to observe changes in investments. We were also unable to collect a representative variable to quantify service quality, which is an important index for evaluating the industry. Second, in this study we did not investigate the differences between municipality and non-municipality organizations in terms of their input resources, operating efficiency, and financial performance. Therefore, we propose the use of a meta-frontier model to cluster organizations and to estimate group technical efficiency, technical gap ratios, and meta-frontier technical efficiency in the future. For meta-frontier models, we refer readers to O'Donell *et al*. (2008), Huang *et al*. (2014) and Lin *et al*. (2014). Finally, we propose a continuous monitoring of the social work industry particularly after the daycare services project announced by the Taiwanese government is completed and once the latest census data (2017) is made available to the public.

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