Journal of the Korea Industrial Information Systems Research Vol. 20 No.4, Aug. 2015 :25-37
http://dx.doi.org./10.9723/jksiis.2015.20.4.025 ISSN:1229-3741

Empirical Analysis on the Industrial Productivity in the Electricity·Gas·Water Service Sector

Yan Hua Zhu[1)], Joo Hoon Kang[2)*], and Sehoon Park[3)]

Abstract The early studies indicated that the firm with monopoly power is likely to engage in X-inefficiency such as a managerial slack. The reflection of the X-inefficiency theory has led to the issue that the public sector may be more inefficient than the private sector. In Korea like other many countries the electricity·gas·water service which can be considered as natural monopoly have been provided mostly by the public sector. In order to provide the empirical evidence to the argument that the public sector may be more inefficient than the private sector this paper estimated the four types of Solow residual which is called the total factor productivity in the electricity·gas·water service industry with the associated empirical model and compared its productivity with one in the manufacturing industry. The empirical results do not support the argument that the public sector may be more inefficient or less productive than the private sector.

Key Words : X-inefficiency, electricity·gas·water service, total factor productivity, Solow residual

I. Introduction

The early studies(Leibenstein(1966)[1]; Machlup (1967)[2]) suggested that the firm with monopoly power is likely to engage in X-inefficiency such as a managerial slack. The reflection of the X-inefficiency theory has led to the issue that the public sector may be more inefficient than the private sector. The reason is that in many countries the public sector encompasses many industries that are "natural monopolies".

The natural monopoly industries such as railroad, electricity, water supply, and telecommunications, etc. cannot be competitive and nationalized or regulated due to the existence of large economies of scale.

In Korea like other many countries the electricity · gas · water service which can be considered as natural monopoly have been provided mostly by the public sector which can be central or local government.

The electricity·gas·water industry has remarkably grown during the last four decade as the Korean economy has accomplished high rates of economic growth. Table 1 demonstrates the growth pattern for laborer, capital stock, and output in the electricity·gas·water industry over the period 1975-2010.

* Corresponding Author : jhkang@cku.ac.kr
Manuscript received June 28, 2015 / accepted July 31, 2015
1) Department of Economics, Yan Bian University, First Author
2) Department of Economics, Catholic Kwandong University, Corresponding Author
3) Department of Economics, Catholic Kwandong University, Co-Author

The number of labor has steadily increased from 15,091 in 1975 to 56,537 in 2010. On the other hand capital stock and industrial output has remarkably grown from 179 billion won and 316 billion Won in 1975 to 16,905 billion Won and 66,497 billion Won respectively. Despite the remarkable changes in laborer and capital stock, there has been little empirical research to elucidate the industrial characteristics such as industrial productivity and markup. Many empirical studies(Bae et.al.(2014)[3]; Zhu et.al.(2013, 2014)[4-5]) focused mainly on the investigation for the industry-specific characteristics in the manufacturing industries although Park et. al.(2014)[6] examined the industrial productivity in medical service industry.

This paper is to provide the indirect evidence to the argument that the public sector may be less efficient than the private sector. If the industrial efficiency is assumed to result in industrial productivity the argument would be that the public sector may be less productive than the private sector. Hence it is desirable to evaluate the industrial efficiency for the electricity·gas ·water industry by estimating the industrial productivity. To compare the public sector with private sector, we use the manufacturing industry as a yardstick since manufacturing industry is the prototype for the private sector consisted of profit maximizing firms. In order to prove the suggestion that the electricity·gas·water industry may be less productive than the manufacturing industry, this paper is to estimate the Solow residual which is called the total factor productivity in the electricity ·gas·water industry and to compare its productivity with one in the manufacturing industry.

The cyclicality of productivity has been one of the essential issues in macro- economics and industrial economics. Since Solow(1957)[7] developed the dominant approach to the measurement of productivity growth, Solow's approach, which assumes the perfect competition, the constant returns to scale, and the full use of input factor has been modified particularly in Hall(1990)[8] and Basu(1996)[9]. Their researches take account of market power, returns to scale, and variable factor utilization.

This paper has two purposes. First, the paper is to set up the empirical model based

Table 1 Growth in Electricity·Gas·Water service industry during 1975-2010

Year	Labor (person)	Capital stock (billion Won)	Output (billion Won)
1975	15,091	179	316
1985	24,061	1,617	4,107
1995	44,431	8,325	14,082
2005	52,142	10,780	43,865
2010	56,537	16,905	66,497

Sources: Statistics Korea, Kosis, Service Industry, The Bank of Korea, National Accounting on Hall(1990)[8] and Basu(1996)[9] models, to estimate 4 types of Solow residuals in the electricity·gas·water industry over the period 1975:1-2010:4, and to analyze the properties of measured productivity, comparing with the manufacturing industry. Second, the paper is to provide the indirect evidence to the proposition that the electricity·gas·water industry may be less productive than manufacturing industry.

This paper consists of four sections. Section 1 is the introduction. Section 2 specifies the empirical models for measuring 4 types of Solow residuals. In section 3 empirical results and comparative analysis are presented. Concluding remarks are offered in Section 4.

2. The Empirical Setup

2.1 Cost-based Solow residual

In order to derive the estimation model we assume the general production function as follows.1)

$$Q_t = Z_t F(K_t, L_t, DM_t, FM_t) \quad (1)$$

where Q_t, Z_t, K_t, L_t, DM_t and FM_t represent, respectively, real output, Hicks-neutral technological coefficient, real value of capital stock, labor hours, domestic and foreign intermediate inputs and t denotes time.2)

Taking a log of Eq.(1) and differentiating with respect to time t, we have

$$\frac{dQ_t/dt}{Q_t} = \frac{dZ_t/dt}{Z_t} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial K_t}\frac{\partial K_t}{\partial t} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial L_t}\frac{\partial L_t}{\partial t} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial DM_t}\frac{\partial DM_t}{\partial t} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial FM_t}\frac{\partial FM_t}{\partial t} \quad (2)$$

where we assume that $Z_t \geq 0$ and $F(\cdot) = F(K_t, L_t, DM_t, FM_t)$. For simplicity of exposition we drop the subscript t and let $\partial X/\partial t$ denote $\dot{X}$. Then Eq.(2) can be written as follows.

$$\frac{\dot{Q}}{Q} = \frac{\dot{Z}}{Z} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial K}\dot{K} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial L}\dot{L} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial DM}\dot{DM} + \frac{1}{F(\cdot)}\frac{\partial F(\cdot)}{\partial FM}\dot{FM} \quad (3)$$

Multiplying respectively each term in the right hand side of Eq.(3) by L/L, K/K, DM/DM and FM/FM, Eq.(3) becomes;

$$\frac{\dot{Q}}{Q} = \frac{\dot{Z}}{Z} + Z\frac{\partial F}{\partial K}\frac{K}{Q}\frac{\dot{K}}{K} + Z\frac{\partial F}{\partial L}\frac{L}{Q}\frac{\dot{L}}{L} + Z\frac{\partial F}{\partial DM}\frac{DM}{Q}\frac{\dot{DM}}{DM} + Z\frac{\partial F}{\partial FM}\frac{FM}{Q}\frac{\dot{FM}}{FM} \quad (4)$$

where $Z\cdot\partial F/\partial L$, $Z\cdot\partial F/\partial K$, $Z\cdot\partial F/\partial DM$, and $Z\cdot\partial F/\partial FM$ represent the marginal productivities of input factors respectively. With the cost minimization we can derive revenue-based factor shares from the marginal productivities of input factors.3)

1) Our model is based on the previous studies: Hall(1990)[8], Basu(1996)[9], and Park and Zhu (2011)[10].

2) The production function includes foreign intermediate goods as an argument for open economy model. See Batini et. al.(2005)[11], Rumler(2005)[12], Leith and Mally(2007)[13], Kang and Jeong(2001)[14], and Kang and Park (2011)[15].

3) The cost minimization problem is written as Minimize $TC = P_K K + P_L L + P_D DM + P_F FM$ subject to $Q^* = Z_t \cdot F(K_t, L_t, DM_t, FM_t)$

$$\frac{\dot{Q}}{Q} = \frac{\dot{Z}}{Z} + \frac{P_K}{P_Q}\frac{K}{Q}\frac{\dot{K}}{K} + \frac{P_L}{P_Q}\frac{L}{Q}\frac{\dot{L}}{L} + \frac{P_D}{P_Q}\frac{DM}{Q}\frac{\dot{DM}}{DM} + \frac{P_F}{P_Q}\frac{FM}{Q}\frac{\dot{FM}}{FM} \tag{5}$$

where P_K, P_L, P_D and P_F are the input price of capital, labor, domestic and foreign intermediate goods. Rearranging Eq.(5) in terms of first order difference forms gives the original Solow residual equation,

$$\Delta z_t^1 = \Delta q_t - \alpha_t^K \Delta k_t - \alpha_t^L \Delta l_t - \alpha_t^D \Delta dm_t - \alpha_t^F \Delta fm_t \tag{6}$$

where the lowercase letters, $z_t, q_t, \cdots, fm_t$ denote the log form of $Z_t, Q_t, \cdots, FM_t$ and Δ is the first difference operator that expresses the rate of change in a variable. α_t^X indicates the factor share of variable X.

In order to exclude the market power effect from the factor share in revenue, Hall(1990)[8] suggested the cost-based factor share, which is defined as the factor share divided by total cost, $TC = P_L L + P_K K + P_D DM + P_F FM$. The Solow residual based on the cost-based share is defined as

$$\Delta z_t^2 = \Delta q_t - \alpha_t^{K'} \Delta k_t - \alpha_t^{L'} \Delta l_t - \alpha_t^{D'} \Delta dm_t - \alpha_t^{F'} \Delta fm_t \tag{7}$$

where $\alpha_t^{K'} = P_K K/TC$, $\alpha_t^{L'} = P_L L/TC$, $\alpha_t^{D'} = P_D DM/TC$, and $\alpha_t^{F'} = P_F FM/TC$.

As the production function is assumed to be homogeneous degree of γ, we can factorize the cost function as follows.

$$TC(P_K, P_L, P_D, P_F, Q) \equiv Q^{1/\gamma} A(P_K, P_L, P_D, P_F) \tag{8}$$

where $A(\cdot)$is a function of factor prices and it is proved that the production function is homogeneous degree of γ with respect to $L, K, DM,$ and FM. Then the output elasticity of total cost is defined as

$$\frac{\partial TC}{\partial Q} \cdot \frac{Q}{TC} = \frac{1}{\gamma} \tag{9}$$

where $\partial TC/\partial Q$ is the marginal cost that is the Lagrange multiplier λ in the cost minimization problem. Using Eq.(9) and the first-order conditions for cost minimization, marginal productivity of each input factor can be written as follows.

$$Z\frac{\partial F}{\partial K} = \gamma \cdot \frac{P_K Q}{TC},\quad Z\frac{\partial F}{\partial L} = \gamma \cdot \frac{P_L Q}{TC},\quad Z\frac{\partial F}{\partial DM} = \gamma \cdot \frac{P_D Q}{TC},\quad Z\frac{\partial F}{\partial FM} = \gamma \cdot \frac{P_F Q}{TC} \tag{10}$$

Substituting Eq.(10) into Eq.(4), we have the Solow residual equation adjusted to the returns to scale.

$$\Delta z_t^3 = \Delta q_t - \gamma\,(\alpha_t^{K'} \Delta k_t + \alpha_t^{L'} \Delta l_t + \alpha_t^{D'} \Delta dm_t + \alpha_t^{F'} \Delta fm_t) \tag{11}$$

In order to measure the Solow residual Δz_t^3, we first have to estimate γ representing the industrial returns to scale. To estimate a returns to scale we assume the generally accepted equation (Basu and Fernald(1997)[16]).

The first order condition implies that the Lagrangian multiplier is maginal cost and under the assumption of perfect competition in output and factor markets output price is equal to marginal cost and marginal revenue.
$MC = P_K/MP_K = P_L/MP_L = P_D/MP_D = P_F/MP_F = MR$
Using these equations Eq.(5) is transformed into Eq.(6).

$$\Delta z_t = c + \epsilon_t, \ \ \epsilon_t \sim i.i.d. \qquad (12)$$

where c is a constant which means the average growth rate of Solow residual. Equation(12) shows that Solow residual is assumed to fluctuate around a constant c at random. Using Eqs.(11) and (12), we set up the simple regression model which regresses Δq_t on X.

$$\Delta q_t = c + \gamma X_t + \epsilon_t \qquad (13)$$

where $X_t = \alpha_t^{K'} \Delta k_t + \alpha_t^{L'} \Delta l_t + \alpha_t^{D'} \Delta dm_t + \alpha_t^{F'} \Delta fm_t$ and c is the intercept for regression equation. Substituting the estimated value $\hat{\gamma}$ into Eq.(11), we can construct the time series data for Solow residual.

2.2 Factor utilization

Basu and Fernald(1997)[16] pointed out that the estimates for returns to scale in Eq.(13) tend to be biased upward due to variable factor utilization such as labor hoarding or capacity utilization. Therefore we set up the estimation model to estimate unbiased returns to scale with the upward bias being removed. Based on the estimation model in Hall(1990)[8] we specify the production function to incorporate the degree of factor utilization.

$$Q_t = Z_t F[(C_t \cdot L_t), DM_t, DF_t, (U_t \cdot K_t)] \qquad (14)$$

where C_t and U_t are coefficients to represent the degree of labor and capital utilization respectively. We can't, of course, observe the data on C_t and U_t. As done previously in Eq.(1), taking a log of Eq.(14) and differentiating with respect to time t, we obtain

$$\frac{\dot{Q}}{Q} = \frac{\dot{\Theta}}{\Theta} + \frac{\partial F}{\partial(C \cdot L)} \frac{1}{F(\cdot)} \left[\frac{\partial(C \cdot L)}{\partial L}\dot{L} + \frac{\partial(C \cdot L)}{\partial C}\dot{L}\right] + \frac{\partial F}{\partial DM}\frac{1}{F(\cdot)}\dot{DM} + \frac{\partial F}{\partial FM}\frac{1}{F(\cdot)}\dot{FM} + \frac{\partial F}{\partial(U \cdot K)}\frac{1}{F(\cdot)} \left[\frac{\partial(U \cdot K)}{\partial K}\dot{K} + \frac{\partial(U \cdot K)}{\partial U}\dot{U}\right] \qquad (15)$$

Multiplying each one from the second term in the right hand side of Eq.(15) by L/L, DM/DM, FM/FM and K/K respectively gives the equation

$$\frac{\dot{Q}}{Q} = \frac{\dot{Z}}{Z} + Z\frac{\partial F}{\partial(C \cdot L)}\frac{CL}{Q}\frac{\dot{L}}{L} + Z\frac{\partial F}{\partial DM}\frac{DM}{Q}\frac{\dot{DM}}{DM} + Z\frac{\partial F}{\partial FM}\frac{FM}{Q}\frac{\dot{FM}}{FM} + Z\frac{\partial F}{\partial(U \cdot K)}\frac{UK}{Q}\frac{\dot{K}}{K} \qquad (16)$$

In similar way to derive Eq.(11) with the first order condition for cost minimization, $\partial TC/\partial Q = \lambda = P_Q$, Eq.(16) can be rearranged into

$$\Delta z_t = \Delta q_t - \alpha_t^L \Delta l_t - \alpha_t^K \Delta k_t - \alpha_t^D \Delta dm_t - \alpha_t^F \Delta fm_t - (\alpha_t^L \Delta c_t + \alpha_t^K \Delta u_t) \qquad (17)$$

where the last term $(\alpha_t^L \Delta c_t + \alpha_t^K \Delta u_t)$ demonstrates the difference from the original Solow residual Δz_t^1. The data on Δc_t and Δu_t are not available. But there are two approaches to solve the data availability problem: one is to use a proxy such as capacity utilization ratio in the industry and the other is the method that Basu and Fernald(1997)[16] suggested.

In order to explain Basu and Fernald (1997)[16]'s method, we set up the CES production function

$$Q=\Theta\left[\delta V^{-\rho}+(1-\delta)M^{-\rho}\right]^{-1/\rho}$$
$$V=V(L_t,K_t),\ M=M(DM_t,FM_t) \quad (18)$$

where V is a value added function of labor(L_t) and capital(K_t) and M is also a intermediate goods function of domestic(DM_t) and foreign(FM_t) goods. Both functions are assumed to be homogeneous. Using the first order condition for cost minimization, marginal productivities of value added and intermediate goods can be written respectively,

$$\frac{\partial Q}{\partial V}=\frac{\delta}{\Theta^{\rho}}\left(\frac{Q}{V}\right)^{1+\rho} \quad (19)$$

$$\frac{\partial Q}{\partial M}=\frac{(1-\delta)}{\Theta^{\rho}}\left(\frac{Q}{M}\right)^{1+\rho} \quad (20)$$

Rearranging Eqs.(19) and (20), the optimal input factor ratio becomes

$$\frac{V}{M}=\left(\frac{\delta}{1-\delta}\right)^{1/(1+\rho)}\left(\frac{P_M}{P_V}\right)^{1/(1+\rho)} \quad (21)$$

Taking a log of Eq.(21) and differentiating with respect to time t, we can express Eq.(21) in terms of first order difference form.

$$\Delta v_t=\Delta m_t-\sigma(\Delta p_t^v-\Delta p_t^m) \quad (22)$$

where $\sigma=1/(1+\rho)$. $\sigma=0$ and $\sigma=1$ indicate the Leontief and homogeneous case respectively. That is, σ has values between 0 and 1. Since the functions, $V=V(L_t,K_t)$ and $M=M(DM_t,FM_t)$ are homogeneous we can also express Δv_t and Δm_t in terms of Divisia index.

$$\Delta v_t=\frac{\alpha_t^{L'}(\Delta l_t+\Delta c_t)+\alpha_t^{K'}(\Delta k_t+\Delta u_t)}{\alpha_t^{L'}+\alpha_t^{K'}} \quad (23)$$

$$\Delta m_t=\frac{\alpha_t^{L'}\Delta dm_t+\alpha_t^{K'}\Delta fm_t}{\alpha_t^{L'}+\alpha_t^{K'}} \quad (24)$$

Substituting Eqs.(23) and (24) into Eq. (22), we obtain

$$\Delta z_t^4=\Delta q_t-\gamma\,[\Delta dm_t+\Delta fm_t-\sigma(\alpha_t^{L'}+\alpha_t^{K'})(\Delta p_t^v-\Delta p_t^m)] \quad (25)$$

In order to estimate γ we set up the simple regression model which regresses Δq_t on X.

$$\Delta q_t=c+\gamma X_t+\epsilon_t \quad (26)$$
$$X_t=\Delta dm_t+\Delta fm_t-\sigma(\alpha_t^{L'}+\alpha_t^{K'})(\Delta p_t^v-\Delta p_t^m)$$

where c is an intercept for the regression equation. Substituting the estimated value $\hat{\gamma}$ into Eq.(25), we can construct the time series data for Solow residual adjusted to factor utilization. We estimate $\hat{\gamma}$ using the 2SLS method with an instrument variable[4)] in consideration of the endogeneity for the explanatory variable X_t(Ramsey(1989)[18]; Hall(1990)[8]).

4) Burnside et. al.(1995)[17] used Federal Fund Rate as an instrument variable. This paper uses as an instrument variable the oil import price index, which is expected to have little correlation with Solow residual.

2.3 Data

For the estimation of the Solow residual in the electricity·gas·water industry we use quarterly data over the sample period 1975:Q1 ~2010:Q4. All data come from quarterly and monthly reports issued by the Economic Statistical System(ECOS) at the Bank of Korea and Korean Statistical Information Service(KSIS) at the Bureau of Statistics.

The data we use are quarterly, being both aggregated from monthly original data and disaggregated down from yearly data. The data on labor hour, employers, wages, and interest rate are available on a monthly basis, so we have aggregated them up to quarterly. Capital stocks are issued on a yearly basis, so we have disaggregated them down to quarterly by using the following formula:

$$K_{it} = K_{t-1} + [K_t - K_{t-1}] \times \frac{i}{4}, \quad (27)$$

$$i = 1, 2, 3, 4$$

where K_{it} indicates the capital stock at ith quarter and year t.

In order to divide intermediate inputs into domestic and imported shares, we use the ratios derived from the Input-Output Tables issued by the Bank of Korea. The data on input-output tables which are available only annually are disaggregated into quarterly data using a quarterly Industrial Production Index in the electricity·gas·water industry.

The price index for value added in Eq.(22) is obtained from the following formula:

$$P_t^V = R_t \times \frac{\alpha_t^{K'}}{\alpha_t^{L'} + \alpha_t^{K'}} + W_t \times \frac{\alpha_t^{K'}}{\alpha_t^{L'} + \alpha_t^{K'}} \quad (28)$$

where R_t is the private bond rate and W_t is the real hourly wage in the Electricity·Gas·Water industry. We can construct the price index for intermediate goods in Eq.(22) by using the following formula:

$$P_t^M = PPI_t \times \frac{\alpha_t^{D'}}{\alpha_t^{D'} + \alpha_t^{F'}} + IPI_t \times \frac{\alpha_t^{F'}}{\alpha_t^{D'} + \alpha_t^{F'}} \quad (29)$$

where PPI_t is producer price index and IPI_t is import price index.

3. Estimation Results

3.1 Estimates for Solow residual

We estimate 4 types of Solow residual in the Electricity·Gas·Water Service Sector: the original Solow residual(Δz_t^1), cost-based residual(Δz_t^2), residual(Δz_t^3) adjusted by return to scale, and residual(Δz_t^4) adjusted by factor utilization. Fig. 1 displays Solow residual time series for 4 types of Solow residual in the electricity·gas·water service sector. We observe the fluctuations in Solow residual around the average values as presented in Eq.(13). Fig. 1 demonstrates Δz_t^1 to fluctuate around the average value 0.00534 with the variance $(0.0421)^2$, Δz_t^2 around -0.00227 with the variance$(0.04253)^2$, Δz_t^3 around -0.0016 with the variance$(0.00414)^2$, and Δz_t^4 around -0.0016 with the variance $(0.01986)^2$.[5)]

5) The negative value in the average growth rate for Solow residual during the sample period does not mean that industrial productivity is declining.

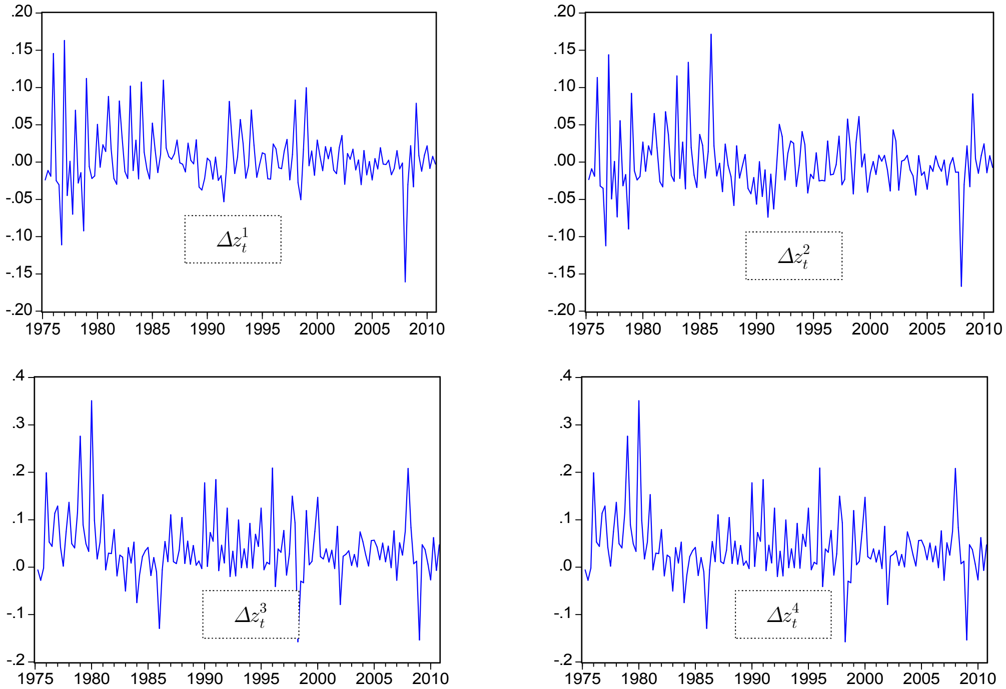

Fig. 1 Estimates for 4 types of Solow residual in the electricity·gas·water industry

3.2 Comparison with productivity in manufacturing industry

Table 2 summarizes the average growth rates and standard deviations for Δz_t^1 and Δz_t^2 in the electricity·gas·water industry and manufacturing industry. Δz_t^1 indicates the growth rate for the original Solow residual as shown in Eq.(6). On the other hand Δz_t^2 represents the growth rate for the cost-based Solow residual measured with market power being removed as expressed in Eq.(7). To express the average growth rate in terms of annual percentage we multiplied it by 400 since the data is quarterly. Δz_t^1 is shown to be 0.00534 (2.136%) in the electricity·gas·water industry and 0.00838(3.352%) in the manufacturing industry. Δz_t^2 proved to be - 0.00227(0.908%) in the electricity·gas·water industry and 0.00016(0.064%) in the manufacturing industry.

The differences between the two residual Δz_t^1 and Δz_t^2, which are called market power effect are shown to be - 0.00761(- 3.044%) in the electricity, gas, water and −0.00822 (−3.288%) in the manufacturing industry. The fact that the market power effect is negative implies that both industries have market power and imperfect market structure. The greater difference between Δz_t^1 and Δz_t^2 in the manufacturing implies that the manufacturing industry has higher industrial markup than the electricity·gas ·water industry. These results are consistent with the previous studies.[6)]

6) see Bernanke and Parkinson(1991)[19], Domowitz et. al.(1988)[20], and Kang et. al.(1998)[21].

Table 2 Average growth rate for productivity during 1975-2010

Industry	Δz_t^1	Δz_t^1 (%)	Δz_t^2	Δz_t^2 (%)	$\Delta z_t^2 - \Delta z_t^1$	$\Delta z_t^2 - \Delta z_t^1$ (%)
Electricity·Gas·Water	0.00534 (0.04210)	2.136%	-0.00227 (0.04253)	-0.908%	-0.00761	-3.044%
Manufacturing Industry	0.00838 (0.01968)	3.352%	0.00016 (0.01406)	0.064%	-0.00822	-3.288%

Sources: The data for manufacturing industry come from Park and Zhu(2011)[10]. ( ) denotes standard deviation.

3.3 Returns to scale and its effect on productivity

In order to estimate industrial returns to scale, we need to measure σ in Eq.(22). There is no consensus for magnitude for σ. Bruno(1984)[22] proved σ to have the range 0f 0.3-0.4 in the estimation for return to scale but Rotemberg and Woodford (1991)[23] and Basu and Fernald(1997)[16] used 0.7 as the σ value. We tried various values ranging from 0.3 to 0.8, but there are little differences in their influence on the magnitude for returns to scale. This paper used intermediate value 0.5 like Malley et. al.(1998)[24]. Table 3 summarizes estimates for industrial returns to scale and average growth rate of Solow residual for Δz_t^3.

The estimation for parameters proved to be statistically significant and stable as shown in high R^2, high t-ratio, and no autocorrelation, even though the intercept coefficients shows an insignificance in t-ratios. As shown in Table 3, the returns to scale(γ) are estimated to be 0.860 in the electricity·gas·water and to be higher value 1.013 in the manufacturing industry. These results are consistent with those in the previous studies such as Park and Zhu(2011)[10] and Kang and Kim(2004)[25].

The intercept value, which is average growth rate for Solow residual as shown in Eqs.(12) and (13), are estimated to be 0.00329(1.136%) in the electricity·gas· water and to be -0.00031(-0.124%) in the manufacturing industry. It is noteworthy for the electricity· gas·water to have higher value in Solow residual adjusted with returns to scale Δz_t^3 than the manufacturing industry while lower values in Δz_t^1 and Δz_t^2. The difference between the two residual Δz_t^1 and Δz_t^3, which reflects the returns to scale effect is shown to be larger value -0.00205 in the electricity·gas·water than -0.00869 in the manufacturing industry. The effect of returns to scale on industrial productivity proved to be greater in manufacturing industry than the electricity·gas·water industry.

3.4 Factor utilization and properties for productivities

Table 4 summarizes two stage least square(2SLS) estimates for industrial returns to scale and average growth rate of Solow

Table 3 Estimates for returns to scale and average growth for productivity

Industry	c (Δz_t^3)	Δz_t^3 (%)	γ	R^2, $D.W.$	$\Delta z_t^3 - \Delta z_t^1$
Electricity·Gas·Water	0.00329 (0.00414)	1.316%	0.860*** (0.052)	$R^2=0.65$ $D.W.=2.29$	−0.00205
Manufacturing Industry	−0.00031 (0.00142)	−0.124%	1.013*** (0.021)	$R^2=0.95$ $D.W.=1.84$	−0.00869

Sources: The data for manufacturing industry come from Park and Zhu(2011)[10]. ( ) is standard error. *** denotes the 1% significant level.

residual for Δz_t^3. When we include the degree of factor utilization into the estimation model, all coefficients showed to be statistically significant and stable as shown in high R^2, high t-ratio, and no autocorrelation. The coefficients in the electricity·gas·water industry are estimated to be lower in both intercept coefficient(Δz_t^4) and return to scale(γ) than without considering the degree of factor utilization. These results are consistent with those in Park and Zhu(2011)[10], in which the return to scale was estimated to be 0.633 in manufacturing.

The difference between the two residual Δz_t^4 and Δz_t^3, which implies factor utilization effect is estimated to be smaller value −0.01683 in the electricity·gas·water than −0.00895 in the manufacturing industry. Thus the effect of factor utilization ratio on industrial productivity proved to be greater in the electricity·gas·water industry than the manufacturing industry.

3.5 Cyclicality of the Solow residual

Table 5 shows the correlation coefficients between Solow residual and HP-filtered GDP to evaluate the cyclicality of Solow residuals in the electricity·gas·water industry and manufacturing industry. First, all types of Solow residual are shown to be weakly countercyclical in the electricity·gas·water industry. On the other hand the first three types of residuals in the manufacturing industry proved to be countercyclical but Solow residual adjusted to factor utilization shows to be weakly procyclical. Thus, it may be concluded that the degree of factor utilization had negative effects on the cyclicality for the Solow residuals in the

Table 4 Factor utilization and 2SLS estimates for returns to scale

Industry	$c(\Delta z_t^4)$	Δz_t^4 (%)	γ	R^2, $D.W.$	$\Delta z_t^4 - \Delta z_t^1$
Electricity·Gas·Water	−0.01149 (0.01986)	−4.596%	0.579*** (0.230)	$R^2=0.55$ $D.W.=2.00$	−0.01683
Manufacturing Industry	−0.00057 (0.01179)	−0.228%	0.633*** (0.152)	$R^2=0.86$ $D.W.=1.94$	−0.00895

Sources: The data for manufacturing industry come from Park and Zhu(2011)[10]. This paper uses as an instrument the oil import price index, which is assumed to have little correlation with Solow residuals. ( ) is standard error. *** denotes the 1% significant level.

Table 5 Correlation Coefficients between Solow residuals and GDP

Industry	Δz_t^1	Δz_t^2	Δz_t^3	Δz_t^4
Electricity·Gas·Water	-0.109	-0.106	-0.128	-0.016
Manufacturing Industry	-0.119	-0.046	-0.034	0.190

The data for manufacturing industry comes from Park and Zhu(2011)[10].

manufacturing industry as Basu and Fernald (1997)[16] suggested.

4. Conclusion

This paper is to provide the indirect evidence to the argument that the public sector may be more inefficient than the private sector by estimating the productivity in the electricity·gas· water industry of which services have been provided mostly by the central or local government and by comparing its productivity with one in the manufacturing industry. The major results are summarized as the following.

First, The annual average growth rates for the original Solow residual and the cost-based Solow residual are estimated to be 2.136% and -0.908% in the electricity ·gas·water industry and to be higher value 3.352% and 0.064% in the manufacturing industry. On the other hand the electricity ·gas·water industry proved to have higher value 1.316% in Solow residual adjusted with returns to scale than -0.124% in the manufacturing industry. Hence the empirical results do not support the proposition that the public sector may be less productive than the private sector. Second, the higher market power effect in the manufacturing industry implies that the manufacturing industry has higher industrial markup than the electricity·gas·water industry. Third, all types of Solow residuals in the electricity·gas·water industry are shown to be weakly countercyclical while factor utilization adjusted Solow residual in the manufacturing industry proved to be weakly procyclical.

References

[1] H. Leibenstein, "Allocative Efficiency vs. 'X-Efficiency," American Economic Review, Vol. 56, No.3, pp. 392-415, 1966.

[2] F. Machlup, "Theories of the Firm: Marginalist, Behavioral Managerial," American Economic Review, Vol. 57, pp. 405-419, 1967.

[3] J. Bae, J. Kang, S. Hong and A. Yoon, "Estimation of the Closed Form in NKPC Inflation Model Focusing on the Korean Manufacturing Industries," Journal of the Korea Industrial Information Systems Research, Vol. 19, No.3, pp. 75-85, 2014.

[4] Yan H. Zhu, S. Park and J. Kang, "Exports and Economic Growth in the 8 manufacturing Industries: Cointegration and Error Correction Models:1975-2010," Journal of the Korea Industrial Information Systems Research, Vol. 18, No.4, pp. 61-72, 2013.

[5] Yan H. Zhu, S. Park and S. Jeong,

"Comparative Analysis of Solow Residuals in Korean and Chinese Manufacturing Industries," International Areas Studies Review, Vol. 18, No.1, pp. 65-81, 2014.
[6] S. Park, J. Kang and Y. Jung, "Empirical Analysis on Market Power and Productivity in the Korean Medical Service Industry," Journal of the Korea Industrial Information Systems Research, Vol. 19, No.2, pp. 93-103, 2014.
[7] Robert M. Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, Vol. 39, pp. 312-320, 1957.
[8] R. Hall, "Invariance Productivity Residual," in Growth, Productivity Employment, P Diamond (ed), Cambridge, MIT Press, 1990.
[9] S. Basu, "Procyclical Productivity: Increasing Returns or Cyclical Utilization?" Quarterly Journal of Economics, Vol. 111, pp. 719-51, 1996.
[10] S. Park and Y. H. Zhu, "The Cyclicality of Productivity, Market Power, and Returns to Scale in the Korean Open Economy: An Empirical Analysis 1975-2010," International Areas Studies Review, Vol. 15, No.3, pp. 239-261, 2011.
[11] N, Batini, B. Jackson and S. Nickell, "An open-economy new Keynesian Phillips Curve for the United Kingdom," Journal of Monetary Economics, Vol. 52, pp. 1,061-71, 2005.
[12] Fabio. Rumler, "Estimates of the Open Economy New Keynesian Phillips Curve for Euro Area Countries," ECB Working Paper No. 496, 2005.
[13] C. Leith, and C. Malley, "Estimated Open Economy New Keynesian Phillips Curves for the G7," Open Economies Review, Vol. 18, pp. 405-426, 2007.
[14] J. H. Kang and U. Jeong, "Openness and Markups in Korean Manufacturing Industries," Kyong Je Hak Yong Gu, Vol. 49, No.4, pp. 123-150, 2001.
[15] J. H. Kang and S. Park, "Factor Prices and Markup in the Korean Manufacturing Industry:An Empirical Analysis 1975-2007," International Areas Studies Review, Vol. 15, No.2, pp. 78-100, 2011.
[16] Susanto Basu and John G. Fernald, "Return to Scale in U.S. Production: Estimates and Implications," Quarterly Journal of Economics, Vol. 105, pp. 249-283, 1997.
[17] C. Burnside, Martin Eichenbaum, and Sergio Rebelo, "Capital Utilization and Returns to Scale," In NBER Macroeconomics Annual, edited by Julio J. Rotemberg and Ben S. Bernanke, Cambridge, MA: MIT Press, 1995.
[18] V. Ramey, "Inventories as Factors of Production and Economic Fluctuations," American Economic Review, Vol. 89, pp. 339-54, 1989.
[19] B. Bernanke and S. Parkinson, "Procyclical Labor Productivity from Interwar U.S Manufacturing Industries," Journal of Political Economy, Vol. 99, pp. 439-459, 1991.
[20] I. G. Domowitz, Hubbard and B. Petersen, "Market Structure and Cyclical Fluctuations in U.S. Manufacturing," Review of Economics and Statistics, Vol. 70, pp.55-66, 1988.
[21] J. Kang, U. Jeong and J. Bae, "Cyclicality of Markups and Real Wages in Korea," Economics Letters, Vol.60, pp. 343-349, 1998.
[22] M. Bruno, "Profits and the Productivity Slowdown," Quarterly Journal of Economics, Vol. 99, pp. 1-30, 1984.
[23] J. Rotemberg and M. Woodford, "Markups and the Business Cycle,"

NBER Macro Annual, 1991.
[24] J. Malley, V. Muscatelli and U. Woitek, "The Interaction Between Business Cycles and Productivity Growth; Evidence from US Industrial Data," in van Ark, B. Kuipers, S .and Kuper, G.(eds.), Productivity, Technology and Economic Growth, Dordrecht: Kluwer Academic Publishers, 2000.
[25] J. Kang and S. Kim, "Estimation for Total Factor Productivity in Korean manufacturing industries," Business Administration Review, Published in Kwandong University in Korea, Vol.22, pp. 81-98, 2004.

Yan Hua Zhu

• Yan Bian University, B.A.
• Yan Bian University, M.A. in Economics
• Kwandong University, Ph,D. in Economics
• Dept. of Economics, Yan Bian University
• Interest Field: Industrial Economics

Joo Hoon Kang

• Seoul University, B.A.
• University of Iowa, M.A. in History
• University of Tennessee, Ph,D. in Economics
• Dept. of Economics, Catholic Kwandong University
• Interest Field: Industrial Organization

Sehoon Park

• Gangwon University , B.A.
• University of Oregon M.A. in Economics
• Purdue University Ph,D. in Economics
• Dept. of Economics, Catholic Kwandong University
• Interest Field: Public Finance