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Intangible Asset Valuation Model Using Panel Data

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Abstract In this paper, we design a valuation model for intangible assets using panel data, and empirically investigate the model validity. The approach using panel data is an evaluation method that uses unobserved firm-specific effects based on panel analysis. Our model first estimates production function using panel analysis, and then develops cost function using a duality approach. Next, we discount added value and costs resulting from intangible assets using fixed effects. Empirical analysis using the model compares the estimated parameter values in the nonlinear profit function consisting of production function and cost function with those in the production function alone, which becomes linear after logarithmic conversion, and finds that the two are generally similar. Additionally, the market value of equity is more closely associated with both the book value of equity and the value of intangible assets than with the book value of equity alone. These results support the validity of the model for evaluating intangible assets. This model is easy to apply in practice and is based on a simple idea. Further discussion of this model is warranted given the increasing importance attached to the value of intangible assets.

Keywords Intangible asset · Panel data · Fixed effect · Duality · Valuation model

1 Introduction

As distinct to tangible assets, the importance of intangible assets, such as technologies, brands and human assets has long been stressed in corporate activities. Simultaneously, the rapid progress towards a knowledge-driven economy has been accompanied by

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concerns regarding the decreased benefits of general accounting information (Rimerman 1990; Elliott and Jacobson 1991; Jenkins 1994; Nakamura 1999). It has been pointed out that one of the causes of such decreased benefits is that intangible assets are not balanced (Lev and Zarowin 1999). General accounting practices do not consider spending on intangible assets such as research and development costs to be investment, leading to profits and assets being understated. Thus, valuation of intangible assets is important for stakeholders, including investors and creditors.

However, because intangible assets cannot be directly measured, it is difficult to quantify and explain them. The Japanese Ministry of Economy, Trade and Industry (2005) suggested disclosure guidelines for use in the management of intellectual property in Japan, and various approaches have been adopted in reality in relation to information disclosure regarding intellectual property (Mourtisen et al. 2005; Nielsen and Madsen 2009). However, because intangible assets are off balance it would be useful if investors and others who need timely information could properly evaluate the intangible assets of a firm using published financial data.

As the knowledge-driven economy develops and intangible assets attract more attention, the importance of valuing off-balance intangible assets has increased. However, there is no consensus on concrete evaluation methods and various evaluation methods need to be verified. Therefore, we present a valuation model for intangible assets that uses panel data and empirically investigate its validity.

The purpose of our model is to make it possible to evaluate the intangible assets that are difficult to measure because of the inevitable inclusion of invisible and off-balanced items. This model provides a useful tool for stakeholders (such as investors, creditors and management) for decision-making when used in conjunction with a financial statement analysis. For example, an investor or creditor can use the combined tangible and intangible assets estimated by this model when making investment or financial judgments. Moreover, management can create an operating plan based on the combined assets.

The model defines production and cost functions, using panel analysis for estimation, and discounts added value and costs associated with intangible assets by using fixed effects. Previous studies estimated organization assets with models using panel data including (Lev and Radhakrishnan 2003); however, we model the value of intangible assets as a comprehensive corporate value and verify the validity through empirical analysis using a sample of listed companies, including estimating the association with equity market value.

2 Previous Studies

2.1 Intangible Assets Valuation Model

The representative methods for evaluating intangible assets include cost, market and income approaches (Reilly and Schweis 1999; Smith and Parr 2000).

The cost approach is a method of evaluating the costs necessary to create intangible assets. This method estimates costs actually borne in the past or costs necessary to recreate equivalent assets. Using past costs requires estimating depreciation expenses owing to the obsolescence of intangible assets, which can be difficult. The cost approach has the additional problem of not considering the profits actually realized by assets. The market approach is a method of evaluation based on the price at which intangible assets are traded in the market. This method is direct and objective, but requires that an active market exists and comparable assets are traded at fair prices. The income approach discounts future profits created with intangible assets to a present value. Because it reflects future benefits, it is qualitatively superior to other methods, but it is difficult to estimate future profits.

Most existing evaluations of intangible assets are based on the above methods (Smith and Parr 2000). For example, Lev and Sougiannis (1996) evaluated research and development assets based on the cost approach, and Interbrand (1997) applied the income approach to brand evaluation. Kossovsky et al. (2002) designed an evaluation model based on option pricing theory called TRRU that values intellectual property using the residual value after subtracting the book value of equity from the market value of equity. This model is considered an application of the market approach because it is based on market value.

There are some differences between the model presented in this study and these latter three methods, in addition to some correlations.

Lev and Sougiannis (1996) estimated the relationship between operating income and the lag structure of research and development expenses using the Almon lag model in industries for estimating amortization rates and the useful life of research and development costs. They calculated research and development assets by accumulating the research and development expenses that are depreciated by the estimated amortization rates. The evaluation method is clear: that of accumulating costs such as research and development expenses. However it is difficult to estimate the amortization rates and the useful life, hence the Almon lag estimation is implemented repeatedly to decide polynomial order and distributed lag period. In contrast, although our model also estimates a relationship between added value and production factors, it uses panel analysis that is both easy to estimate and practical. Moreover, in Lev and Sougiannis' model it is necessary to record costs because it is based on a variety of costs, while it is irrelevant in our presented model whether costs are recorded or not.

The brand management agency, Interbrand, used an income approach to capitalize company brand value (Interbrand 1997). The model evaluated brand value by discounting the earnings created from a brand using different discount rates that reflected brand strength. The earnings and the discount rate are estimated by interviewing company management and market research. There is a specific methodology to derive earnings and discount rates but, again, the estimation is difficult. Our presented model uses panel analysis and a simple estimation method (described in Sect. 3) to easily derive the added value sourced from intangible assets. Capital cost is used as a discount rate to obtain overall intangible assets rather than partial intangible assets, such as brand assets.

The TRRU metrics developed by Kossovsky et al. (2002) used options pricing theory to calculate the patent value by considering technology to be an underlying asset and the value of the corresponding call option to be the patent value. This method regards the value of underlying asset as the market value of equity minus the book value for a pure play company specializing in a single technology. Therefore, the prerequisites for valuating by TRRU metrics are pure play and being listed on public market. In contrast, our presented model needs neither factor.

In contrast to these three methods, the model presented in this study uses panel data. Moreover, because the value is estimated by discounting added value and costs resulting from intangible assets, the model presented here also incorporates the income approach. Thus, our presented model has the advantage that panel analysis allows relatively easy estimation of profits resulting from intangible assets, something that is problematic in the income approach. Additionally, the disadvantages of the cost and market approaches are resolved and it is not necessary either to estimate the obsolescence of intangible assets or for an active market to exist.

2.2 Evaluation Model Using Panel Data

The panel data approach is an evaluation method that uses unobserved firm-specific effects with panel analysis. It is based on the simple idea of estimating the production function with a versatile quantitative analysis method such as panel analysis. Motohashi (2005) explains that firm-specific effects in panel analysis of the production function indicate unobservable factors such as managerial capabilities, workers' motivation and technical innovation ability. Subsequent modeling by Lev and Radhakrishnan (2003), Ramirez and Hachiya (2006a,b, 2008) and Sadowski and Ludewig (2003) conducted applied analysis.

Lev and Radhakrishnan (2003) defined a production function to explain sales growth based on the growth of production factors. There, research and development capital are added to capital and labor, and the growth of total factor productivity is estimated as organization capital growth with panel analysis, to obtain sales attributable to organization capital by considering fixed effects as the growth of organization capital. METI (2004) obtained sales attributable to organization capital in Japanese firms using a similar method. Ramirez and Hachiya (2008) also consider that the growth of organization capital can be indicated using fixed effects of a production function consisting of the explained variable with sales growth, the explanatory variable with the growth of production factors, including research and development capital and advertising expenditure, and multiple control variables with the growth of sales, general administrative expenses, and gross income on sales.

Ramirez and Hachiya (2006a,b) also developed an estimation model that used panel analysis to explain sales and the market value of equity with production factors including research and development capital, also with multiple control variables like sales and general administrative expenses, and to consider specific effects as effects of organization capital. Considering total factor productivity an effect of organization capital, Sadowski and Ludewig (2003) used panel analysis for estimation in a production function with added value as an explained variable, production factors like capital and labor and multiple control variables (e.g., human assets, social capital) as explanatory variables, obtained added value resulting from organization capital with fixed effects as effects of organization capital, and discounted the added value with the risk-free rate to determine the asset value. The model presented in this current paper also uses firm fixed effects as effects of intangible assets to evaluate them as stocks by discounting the flow from intangible assets. However, the presented model differs from previous studies mainly in that it values corporate assets by discounting the added value and costs resulting from intangible assets.

3 Valuation Model of Intangible Assets Using Panel Data

A valuation model of intangible assets using panel data is presented in this paper. The model is a supply side evaluation method that estimates the production function with panel analysis and uses unobserved firm-specific fixed effects.

3.1 Model Concept

First, intangible assets are defined here as assets other than real assets and financial assets that have the possibility of achieving future profits. Thus, intangible assets are considered to comprise not only intellectual properties, including industrial rights such as patent rights and trademark rights, but also research and development results, brands, sales power, organizational power, managerial ability, human resources, and know-how.

The intangible assets in this model are based on the state of technology in the production function. The Cobb–Douglas production function suggested by Cobb and Douglas (1928) is given by

$$Q_{it} = a_i K_{it}^{\alpha} L_{it}^{\beta} e^{\varepsilon_{it}^{Q}}, \quad (1)$$
$$\varepsilon_{it}^{Q} \sim N(0, (\sigma_{it}^{Q})^2) \text{ and } Cov(\varepsilon_{it}^{Q}, \varepsilon_{js}^{Q}) = (\sigma_{it}^{Q})^2 \delta_{ij} \delta_{ts},$$

where Q_{it}, K_{it} and L_{it} indicate the added value, capital and labor in period t for firm i, respectively. Meanwhile, a, α and β are parameters, ε_{it}^{Q} is the error term, and $\delta_{ij}\delta_{ts}$ are the functions that form the Kronecker delta, and are independent and identically distributed. The set V containing all firms is expressed with $V = \{i \in \{1, \ldots, N\}\} \subset \mathbb{N}$, where $\mathbb{N}$ is a set of natural numbers.

In Eq. 1, the parameter a indicates the state of technology, i.e., catch-all effects on the added value Q other than production factors, including not only technologies embodied in capital K or labor L as production factors but also sales power, organization power, and know-how; thus a is considered to indicate the effects of intangible assets.

The previous studies outlined in Sect. 2.2 showed that estimating Eq. 1 with panel analysis can obtain the added value from intangible assets. However, because the added value has associated costs such as depreciation expenses and personnel expenses, the value of intangible assets in a corporate sense cannot be obtained simply by discounting the added value. Therefore, we define the cost and production functions and estimate them with panel analysis, to evaluate the value by obtaining and discounting the added value and costs associated with intangible assets by using fixed effects.

3.2 Model Description

In growth accounting, mainly Solow (1957), there has been repeated discussion of technological progress, i.e., growth of total factor productivity as indicated by Hulten (2000). Therefore, we separately include the effects of intangible assets a into firm-specific effects A and the growth rate λ as the time trend in accordance with

$$\begin{aligned} &Q_{it} = A_i e^{\sum_h^M \lambda_h D_h(i)t} K_{it}^{\alpha} L_{it}^{\beta} e^{\varepsilon_{it}^Q}, \\ &\alpha + \beta = 1, \\ &\varepsilon_{it}^Q \sim N(0, (\sigma_{it}^Q)^2) \text{ and } Cov(\varepsilon_{it}^Q, \varepsilon_{js}^Q) = (\sigma_{it}^Q)^2 \delta_{ij}\delta_{ts}, \end{aligned} \tag{2}$$

where the growth rate λ by segment h is represented as the parameter of the interaction term with the segment dummy D and time variable t, $V = \cup_{h=1}^M V_h$. Here, we set D as

$$D_h(i) := \begin{cases} 1 & i \in V_h \\ 0 & i \notin V_h. \end{cases} \tag{3}$$

Assume that the function has linear homogeneity, as indicated by Cobb and Douglas (1928). ε_{it}^Q is the error term and $\delta_{ij}\delta_{ts}$ are the functions that form the Kronecker delta, which are independent and identically distributed. Here, we apply logarithmic formation to both sides of Eq. 2 and substitute $\beta = 1 - \alpha$ in the equation, which gives

$$\ln \frac{Q_{it}}{L_{it}} = \ln A_i + \sum_h^M \lambda_h D_h(i)t + \alpha \ln \frac{K_{it}}{L_{it}} + \varepsilon_{it}^Q. \tag{4}$$

Then, we estimate Eq. 4 with panel analysis and obtain $\ln A_i$ as fixed effects for firm i. Here, the added value Q is given by

$$pQ = OperatingProfit + DepreciationCost + PersonnelExpenses, \tag{5}$$

where p denotes deflator. The profit π is given by

$$\pi = OperatingProfit - Interest - Tax. \tag{6}$$

Furthermore, the profit π can be replaced by Eqs. 5 and 6 as

$$\pi = pQ - (DepreciationCost + PersonnelExpenses + Interest + Tax), \tag{7}$$

where the second term on the right side in Eq. 7 represents cost C as

$$C = DepreciationCost + PersonnelExpenses + Interest + Tax. \tag{8}$$

By Eqs. 7 and 8, the profit π_{it} for firm i in period t can be defined as

$$\pi_{it} = p_t Q_{it} - C_{it}. \tag{9}$$

In this model, the cost C can be obtained using the duality approach. Thus, by combining production factors to minimize costs for certain products borne by a firm, the cost function can be specified in accordance with the production function. Duality of the production and cost functions is a fundamental concept in microeconomics, and has been discussed by Samuelson (1947), Shephard (1953, 1970), Uzawa (1964), Diewert (1971), Fuss and McFadden (1978), and Nadiri (1982). Based on Eq. 2 as the production function, the cost C_{it} for firm i in period t can be defined as the Cobb–Douglas cost function in

$$\begin{aligned} C_{it} &= (\alpha+\beta)(A_i e^{\sum_j^M \lambda_h D_h(i)t}\alpha^\alpha\beta^\beta)^{-\frac{1}{\alpha+\beta}} R_{it}^{\frac{\alpha}{\alpha+\beta}} W_{it}^{\frac{\beta}{\alpha+\beta}} Q_{it}^{\frac{1}{\alpha+\beta}} e^{\varepsilon_{it}^C}, \\ &\alpha+\beta = 1, \\ \varepsilon_{it}^C &\sim N(0,(\sigma_{it}^C)^2) \text{ and } Cov(\varepsilon_{it}^C,\varepsilon_{js}^C) = (\sigma_{it}^C)^2\delta_{ij}\delta_{ts}, \end{aligned} \tag{10}$$

where R_{it} and W_{it} represent the nominal capital rental rate and nominal wage rate for firm i in period t, respectively. Assume that the cost function possesses linear homogeneity, like the production function. ε_{it}^Q is the error term and $\delta_{ij}\delta_{ts}$ are the functions that form the Kronecker delta, and are independent and identically distributed. The estimated equation of the cost function can be obtained from Eq. 10, the added value Q_{it} estimated using Eq. 2, and parameters a, α and β, as follows:

$$\hat{C}_{it} = \left(\widehat{a_i}\hat{\alpha}^{\hat{\alpha}}\hat{\beta}^{\hat{\beta}}\right)^{-1} R_{it}^{\hat{\alpha}} W_{it}^{\hat{\beta}} \hat{Q}_{it}. \tag{11}$$

Additionally, by Eq. 9 the profit function consists of production and cost functions, which can be obtained as

$$\begin{aligned} \pi_{it} &= \{p_t A_i e^{\sum_j^M \lambda_h D_h(i)t} K_{it}^\alpha L_{it}^\beta (A_i e^{\sum_j^M \lambda_h D_h(i)t}\alpha^\alpha\beta^\beta)^{-1} R_{it}^\alpha W_{it}^\beta Q_{it}\}(1+\varepsilon_{it}^\pi), \\ &\alpha+\beta = 1, \\ \varepsilon_{it}^\pi &\sim N(0,(\sigma_{it}^\pi)^2) \text{ and } Cov(\varepsilon_{it}^\pi,\varepsilon_{js}^\pi) = (\sigma_{it}^\pi)^2\delta_{ij}\delta_{ts}, \end{aligned} \tag{12}$$

where the error term is a relative error, similar to the production function in this model, but the variable can have a negative value. $\delta_{ij}\delta_{ts}$ are the functions that form the Kronecker delta, and are independent and identically distributed.

Estimating the non-linear profit function Eq. 12 is preferable in principle, because a company decides output and cost simultaneously for profit maximization as true business activities. However, estimating this function is impractical given the difficulty of solving such non-linear equations. Therefore, in this model we first apply logarithmic transformation to the variables of the product function, and then obtain the parameters in linear function Eq. 4, which is easy to solve. Next, assuming firms attempt to maximize profits, we obtain the estimated equation (Eq. 11) by substituting the estimated added value and parameters into cost function Eq. 10. Thus, we develop an easy to estimate and practical model.

The estimated value E for the nominal equity containing the effects of intangible assets for firm i in period t is obtained as

$$E_{it} = \frac{p_t Q_{it} e^{\lambda_h}}{r_i - \lambda_h} - \frac{C_{it}}{r_i}, \tag{13}$$

where p_t and r_i represent the deflator in period t and cost of equity for firm i, respectively. The right side means the present value of the nominal cost in the second term is subtracted from the present value of the nominal added value in the first term. Generally, the present value of equity can be obtained by discounting profits with the discount rate. However, because the nominal added value grows at rate λ_h for the segment h and the nominal cost is considered to be constant, the value is obtained by subtracting the value after discounting the cost from that after discounting the added value, instead of discounting the profit π obtained by subtracting the cost from the added value. The estimated value E^{nonI} of the nominal equity with no effect of intangible assets is obtained as

$$E_{it}^{nonI} = \frac{p_t K_{it}^{\alpha} L_{it}^{\beta}}{r_i} - \frac{(\alpha\beta)(R_{it}^{nonI})^{\alpha}(W_{it}^{nonI})^{\beta} K_{it}^{\alpha} L_{it}^{\beta}}{r_i}, \tag{14}$$

where R^{nonI} and W^{nonI} represent the nominal capital rental rate and the nominal wage rate, respectively, with no effect of intangible assets for firm i in period t and can be expressed as

$$R_{it}^{nonI} = R_{it} \frac{p_t K_{it}^{\alpha} L_{it}^{\beta}}{r_i} \frac{r_i - \lambda_h}{p_t Q_{it} e^{\lambda_h}} \quad \text{and} \tag{15}$$

$$W_{it}^{nonI} = W_{it} \frac{p_t K_{it}^{\alpha} L_{it}^{\beta}}{r_i} \frac{r_i - \lambda_h}{p_t Q_{it} e^{\lambda_h}}. \tag{16}$$

In Eqs. 15 and 16, the ratio of the present value of the added value in the case where intangible assets do not affect the present value of the estimated added value, is multiplied by R_{it} and W_{it}, respectively. Thus, in Eq. 14 the present value of the costs in the case of no effect of intangible assets in the second term on the right side is subtracted from the present value of the added value in the case of no effect of intangible assets in the first term on the right side. According to Eqs. 13 and 14, the value of intangible assets I_{it} for firm i in period t is obtained as

$$I_{it} = E_{it} - E_{it}^{nonI}. \tag{17}$$

4 Empirical Analysis

Next, we estimate the model parameters and the value of intangible assets for listed companies. We then verify the model validity using the estimated parameters and value of intangible assets.

4.1 Data

By using balanced panel data for fiscal years 2003–2007 for 6,065 listed companies for which data exists in a full series (excluding financial firms, for which financial data are significantly different from ordinary business corporations) we estimate the model and the value of intangible assets in fiscal year 2007.[1] The continuous panel data for these firms are successfully obtained from the Nikkei Electronic Databank System.

Capital K represents property, plant, and equipment from which construction in progress is subtracted, labor L represents the number of employees, and personnel expenses represent total personnel expenses, welfare expenses, compensation for directors' and labor costs. For tax accounting, it is difficult to consider extraordinary income or losses that are temporary or deferred tax accounting, and the tax rate ideally should be mid- and long-term; therefore the tax rate is a flat 40 % of income after subtracting interest and discount expenses from operating profits, a rate based on the effective corporate tax rate in Japan. Property, plant, and equipment, construction in progress, capital investment, and depreciation expenses are deflated with the private non-residential investment deflator, and operating profits, personnel expenses, welfare expenses, compensation for directors, labor costs, interest and discount expenses are deflated with the gross domestic product (GDP) deflator for substantiation. According to the above definition, we can set capital K as

$$K_{it} = p_t\,(Property,\, plant,\, and\; equipment_{it} - Construction\; in\; progress_{it})\,, \tag{18}$$

where property, plant, and equipment in production are deflated by p_t, $p_t = P_t/P_u$. P_t and P_u represent the deflator, especially the private non-residential investment deflator for the variable, in period t and the base period u, respectively. The essence of our model is to evaluate a catch-all value of intangible assets not currently included in the public financial data; hence we simply define production factors K and L. If intangible asset effects, such as the embodied technology and quality, are reflected in the production factor ultimately the value of intangible assets estimated by this model largely disappears. Previous evaluation model studies using panel data including Lev and Radhakrishnan (2003), and Ramirez and Hachiya (2006a,b, 2008) also simply defined the production factors. Moreover, in this paper we subtract construction in progress to eliminate overvalued bias in capital K.

To obtain stable estimation results, 17 industrial sectors on the Tokyo Stock Exchange were summarized and categorized into three basic segments: i.e., V_1 = suppliers of materials for manufacturing, V_2 = manufacturing processors, and V_3 = non-manufacturing.

The cost of equity r is estimated from the capital asset pricing model, while the risk premium is 9.9 % based on the long-term equity risk premium for 1952–2006 by Ibbotson (2007) as used in many Japanese empirical analyses. To estimate future mid- and long-term costs of equity, the beta value is estimated in accordance with Bayesian adjustment (Vasicek 1973) of the TOPIX 60-month beta at the end of 2007. The costs of equity are substantiated using the GDP deflator.

[1] We used balanced panel data to exclude incomplete observations to show the basic panel data method of evaluating intangible assets. Using unbalanced panel to include full observations, would require a more complex estimation method. Matyas and Lovrics (1991) indicate that if the sample size is large enough (NT>250), there is a negligible loss of efficiency in using incomplete balanced panel.

Table 1 Estimation results of Eq. 19

Coefficients	Estimated results	t-values
λ_1	0.019	7.441***
λ_2	0.016	6.617***
λ_3	0.010	4.191***
α	0.309	22.824***
Adj.R^2	0.087	
Obs	6,065	

Adj. R^2 is adjusted for the degree of freedom of the coefficient of determination. Obs denotes observations. The Adj. R^2 of Eq. 4 including the Fixed effect is 0.926. *** indicates 1 % level of significance

Table 2 Validity test results of the fixed effects model

Types of test	Types of statistics	Statistical results
F test	F-value	38.359***
Hausman test	χ^2-value	79.453***

*** indicates 1 % level of significance

4.2 Estimation of Intangible Assets

First, within-group estimation is used to estimate Eq. 4. We estimate Eq. 19, which is used to perform within-group transformation, where each variable is the difference from the average value for the i firm. Here, the tilde above the variable denotes that it has been subjected to within-group transformation. Note that $\widetilde{\ln A_i} = 0$, and fixed effects are removed.

$$\widetilde{\ln \frac{Q_{it}}{L_{it}}} = \widetilde{\ln A_i} + \sum_{h}^{M} \lambda_h D_h(i)t^{\sim} + \alpha \ln \widetilde{\frac{K_{it}}{L_{it}}} + \varepsilon_{it}^{Q}. \tag{19}$$

Examining the estimation results shown in Table 1: both α and λ indicate strong positivity. When we estimate Eq. 19 with 17 sectors before summarizing into three segments, five sectors λ are not statistically significant.

In accordance with the estimated parameters and the average value of variables for the i firm, fixed effects are obtained with

$$\widehat{\ln A_i} = \overline{\ln \frac{Q_{it}}{L_{it}}} - \sum_{j}^{M} \widehat{\lambda_h} \delta_h(i)\bar{t} - \hat{\alpha} \ln \overline{\frac{K_{it}}{L_{it}}}. \tag{20}$$

As indicated in Table 2, the null hypothesis that considers all the fixed effects to be equal is rejected based on the results of the F test.

Because the null hypothesis that considers specific effects not correlated with explanatory variables is also rejected from the results of the Hausman test, the random effects model is inconsistent and the fixed effects model can achieve consistent and efficient estimations.

Next, the value of intangible assets is obtained by sequential estimation from Eq. 11 to 17 using parameters obtained by estimating Eq. 4.

The top 20 firms in terms of intangible assets for fiscal year 2007 include public utility firms such as those involved in the information and telecommunication, and electric power and transportation sectors, also global firms such as those involved in transportation equipment, or electrical and precision instruments, as indicated in Table 3. Additionally, Table 4 shows the average and median of intangible assets, total assets, book value of equity, and the ratio of intangible assets to these assets.

4.3 Validity Verification

The model validity is verified by comparing the estimated values of parameters in the profit function with those in the production function, comparing the association between the market and book values of equity with that in the case where intangible assets are added, and estimating the association of the intangible assets with factors that may influence them.

4.3.1 Comparing the Parameters of the Production and Cost Functions

We verify the model validity to compare the estimated values of parameters in the profit function Eq. 12, consisting of the production and cost functions, with those in the production function. It is preferable in principle to estimate the non-linear profit function Eq. 12, because a company decides output and cost simultaneously for profit maximization as true business activities. However, estimating this function is impractical given the difficulty of solving such non-linear equations. Therefore, in this model we first apply logarithmic transformation to the variables of the product function, and then obtain the parameters in linear function Eq. 4, which is easy to solve. Next, assuming firms attempt to maximize profits, we obtain the estimated equation Eq. 11 by substituting the estimated added value and parameters into cost function Eq. 10. Thus, we compare the parameters in the profit function with ones in the product function to establish whether both values are similar to verify the model.

As presented in Table 5, for the sample firms, the overall estimated parameters of the profit function Eq. 12 are similar to those of production function Eq. 18 in Table 1. We use the nonlinear least square method to estimate Eq. 12, a calculation which takes 20 min and 45 s to complete (CPU:2.27 GHz, RAM:4.00 GB).

Moreover, for specific segments, namely basic materials suppliers, manufacturing processors and non-manufacturing firms, there is little difference between this model and the production function estimation results as indicated in Table 6. This supports the validity of the model.

Additionally, in a further sample, we compare the estimated values of parameters in the profit function Eq. 12, with those in the production function Eq. 19. This includes panel data for fiscal years 2002–2006 for the same 6,065 listed companies as the original sample panel data for 2003–2007. Table 7 provides a further sample showing that the estimated parameters of the profit function Eq. 12 overall are similar to those of production function Eq. 19. This robustly indicates the model validity.

Incidentally, the α in Eq. 19 is the universal capital share for all companies, derived by controlling the individual effects in the estimation of the equation. One of the main

Table 3 Lop 20 Japanese firms by intangible asset value, 2007

	Company names	Intangible assets	Segments	Industries	Book value of equity
1	Nippon Telegraph and Telephone	29,373,748	Non-manufacturing	IT& Services, Others	7,410,761
2	NTT DOCOMO	18,597,895	Non-manufacturing	IT & Services,Others	4,276,496
3	TOYOTA MOTOR	17,815,276	Manufacturing processors	Automobiles & Transportation Equipment	11,869,527
4	The Tokyo Electric Power	11,025,600	Non-manufacturing	Electric Power & Gas	2,653,763
5	CHUBU Electric Power	9,045,467	Non-manufacturing	Electric Power & Gas	1,712,665
6	Honda Motor	7,264,882	Manufacturing processors	Automobiles & Transportation Equipment	4,544,265
7	NISSAN MOTOR	7,129,274	Manufacturing processors	Automobiles & Transportation Equipment	3,504,964
8	Canon	6,335,579	Processing	Electric Appliances & Precision Instruments	2,922,336
9	The Kansai Electric Power	5,752,240	Non-manufacturing	Electric Power & Gas	1,840,533
10	Japan Tobacco	5,581,725	Manufacturing processors	Foods	2,076,074
11	Takeda Pharmaceutical	5,374,546	Manufacturing processors	Pharmaceutical	2,280,783
12	KDDI	4,831,290	Non -manufacturing	IT & Services, Others	1,683,334
13	Kyushu Electric Power	3,893,869	Non-manufacturing	Electric Power & Gas	1,067,047
14	Tohoku Electric Power	3,300,144	Non-manufacturing	Electric Power & Gas	964,232
15	FUJIFILM Holdings	3,141,634	Basic materials suppliers	Raw Materials & Chemicals	1,922,353
16	Central Japan Railway	3,117,224	Non-manufacturing	Transportation & Logistics	915,022
17	NIPPON STEEL	2,924,414	Basic materials suppliers	Steel & Nouferrous	1,908,778
18	Shin-Etsu Chemical	2,227,644	Basic materials suppliers	Raw Materials & Chemicals	1,438,798
19	NIPPON OIL	1,976,452	Basic materials suppliers	Energy Resources	1,309,788
20	The Chugoku Electric Power	1,795,783	Non-manufacturing	Electric Power & Gas	706,032

Note Japanese Yen in millions

Table 4 Average and median values of Japanese firms by intangible asset value and other asset measures, 2007

	Intangible assets	Total assets	Book value of equity	Intangible assets/total assets	Intangible assets/book value of equity
Average	202, 636	456, 585	173, 343	0.36	0.78
Median	25, 529	94, 225	44, 564	0.27	0.61
Obs	1, 213	1, 213	1, 213	1,213	1,213

Obs is observations

Table 5 Overall estimation results for Eq. 12

Coefficients	Estimated result	Standard errors
λ_1	0.021	0.000040
λ_2	0.017	0.000005
λ_3	0.010	0.000089
α	0.317	0.000005
Obs	6,065	

Obs is observations

Table 6 Estimation results for Eqs. 19 and 12—by segment

	Production function Eq. 19		Profit function Eq. 12	
	Estimated results	t-values	Estimated results	Standard errors
λ_1	0.019	7.323***	0.019	0.000021
α	0.287	11.768***	0.298	0.000014
Obs	1,785		1,785	
λ_2	0.016	6.924***	0.015	0.000075
α	0.411	14.403***	0.412	0.000030
Obs	2,170		2,170	
λ_3	0.009	3.684***	0.010	0.000012
α	0.276	13.831***	0.290	0.000028
Obs	2,110		2,110	

Obs is observations.
*** indicates 1% level of significance

Table 7 Estimation results for Eqs.19 and 12—another sample

	Production function Eq. 19		Profit function Eq. 12	
	Estimated results	t-values	Estimated results	Standard errors
λ_1	0.035	13.454***	0.038	0.000184
λ_2	0.026	11.236***	0.027	0.000024
λ_3	0.021	8.632***	0.022	0.000404
α	0.302	22.554***	0.302	0.000023
Obs	6,065		6,065	

Obs is observations.
*** indicates 1% level of significance

Table 8 Overall results by segment

	Average of Intangible assets		t-values	Obs
	Overall	By segment		
Total	0.363	0.353	0.614	1,213
Basic materials suppliers	0.338	0.340	0.082	357
Manufacturing processors	0.364	0.356	0.328	434
Non-manufacturing	0.385	0.360	0.621	422

Obs is observations

features of this model is that the individual effects are solved by setting a common coefficient, hence this model reflects all invisible effects such as technology embodied in production factors to the a.

In this model, overall results are estimated by not dividing the sample into the segments to catch the invisible segment effects in the parameter λ of the interaction term with the segment dummy D and time variable t. If the sample is divided into the segments not including the segment dummies in this model, we cannot catch the invisible segment effect in the intangible effect a, but it is included in the parameter α. However, because of the property $\alpha + \beta = 1$, there is little difference between the overall estimation results and those for each segment.

We compare both intangible asset estimation results by t test. These are based on fiscal year 2007 and deflated with total assets. Table 8 shows no significant differences between them, indicating little difference in the results.

4.3.2 Comparison of Equity and Intangible Assets with the Market Value of Equity

We compare the association between the market and book values of equity with a case where intangible assets are added. The market value of equity consists of the book value of equity and the value of intangible assets, as suggested by Benzion (1978). Therefore, we conduct OLS regression analyses for validation using cross-section data of fiscal year 2007. We first set a model, where the explained variable is the market value of equity and the explanatory variable is the book value of equity. Then, whether the coefficient of determination adjusted for degree of freedom increases is verified in the case where the estimated value of intangible assets is added to the model. Likewise, the market value of equity at the fiscal year-end is used. Each variable is deflated with total assets to eliminate the influence of size, and 3 σ or higher is adopted as a cutoff point to correct outliers and realistically indicate the analysis results.

The association between the market and book values of equity is significantly positive, as indicated in Table 9. This significantly positive association is also indicated by adding the value of intangible assets to the explanatory variable; furthermore, the determination coefficient adjusted for the degree of freedom increased, as indicated in Table 10. The value of intangible assets significantly supports the association of the market value and book value of equity, indicating the model validity. When intangible

Table 9 Association of the market value of the equity with the equity

Coefficients	Estimated results	t-values
Intercept term	0.024	1.011
Book value of the equity	1.100	24.182***
Adj. R^2	0.325	
Obs	1,213	

Adj. R^2 is adjusted for the degree of freedom the coefficient of determination. Obs is observations. *** indicates 1 % level of significance

Table 10 Association between the market value of the equity, the equity and intangible assets

Coefficients	Estimated results	t-values
Intercept term	0.023	1.055
Book value of the equity	0.865	18.586***
Intangible assets	0.320	12.755***
Adj. R^2	0.405	
Obs	1,213	

Adj. R^2 is adjusted for the degree of freedom the coefficient of determination. Obs is observations. *** indicates 1 % level of significance

Table 11 Association of the market value of the equity with the equity, adding segment dummies

Coefficients	Estimated results	t-values
Intercept term	−0.062	−2.037**
Book value of the equity	1.128	21.352***
λ_2	0.117	4.514***
λ_3	0.114	12.755***
Adj. R^2	0.302	
Obs	1,213	

Adj. R^2 is adjusted for the degree of freedom the coefficient of determination. Obs is observations. *** and ** indicate 1 and 5 % level of significance, respectively

Table 12 Association between the market value of the equity, the equity and intangible assets, adding segment dummies

Coefficients	Estimated results	t-values
Intercept term	−0.065	−2.189**
Book value of the equity	0.907	16.041***
Intangible assets	0.266	9.177***
λ_2	0.118	4.806***
λ_3	0.127	5.200***
Adj. R^2	0.347	
Obs	1,213	

Adj. R^2 is adjusted for the degree of freedom the coefficient of determination. Obs is observations. *** and ** indicate 1 and 5 % level of significance, respectively

assets are similarly added before correction for outliers, the coefficient of determination adjusted for the degree of freedom is increased.

Additionally, we undertake a test whereby a segment dummy, processors, and non-manufacturers, are included in the same models. The results indicate, as shown in Tables 11 and 12, that the coefficientof determination (adjusted for degree of freedom) increases in the case where the estimated value of intangible assets is added to the model.

5 Conclusion

As the importance of evaluating the value of intangible assets increases, we design a valuation model of intangible assets that uses panel data, and empirically investigate the model's validity. The panel data approach is an evaluation method that uses unobserved firm-specific effects based on panel analysis. In this model, we first estimate production function with panel analysis, and then develop cost function using a duality approach. Next, we discount added value and costs resulting from intangible assets using fixed effects, to evaluate the value of intangible assets.

In the empirical analysis using data from listed companies, the estimated parameter values for the nonlinear profit function, consisting of the production function and cost function, are compared with those for the production function alone, which become linear after logarithmic transformation, and thus have approximately similar values. The association of the market and book values of equity and the value of intangible assets are stronger than that with only the book value of equity, supporting the model validity.

This model is easy to use and based on a simple idea. The valuation of intangible assets is an important task, particularly in areas such as investment management. Through further discussion we hope to develop this model into a practical method for the valuation of intangible assets.

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