Effects of Advertising and R&D on the Intangible Assets for the Japanese Manufacturing Firms: A Panel Data Analysis

Isamu Ogata* and Yoshihiko Tsukuda*

ABSTRACT

This paper analyzes the effects of advertising and R&D expenditures on the values of intangibles for the 382 Japanese manufacturing firms for 12 years from 1990 to 2001. The advertising and R&D expenditures significantly increase the value of intangibles only for 25% of the firms, but for the other 75% neither the advertising nor R&D expenditure increases the value of intangibles. This finding suggests the inappropriateness of imposing an identical relationship over all the firms. We also demonstrate that the accounting data for our analysis exhibits a panel structure with cross-section and time series properties, which leads to apply a generalized least squares (GLS) method of estimation to the regression model instead of conventional ordinary least squares. To our knowledge, there has never been previous analysis applying the GLS method to the time series data. This method is potentially applicable to many problems in the field of accounting.

Keywords: intangibles, R&D, advertising, market valuation, panel data

1. Introduction

A considerable number of studies on intangible assets have been made in both the demonstrated that the resource of a corporate value in the Japanese firms had shifted from tangible assets to intangible assets mainly based on descriptive statistics. Sakurai and Ishimitsu (2004) found that the brand value is positively correlated to the stock price. They estimated the brand value by a method originally proposed by the Corporate Legal System Study Group.

The accounting data typically comprises a panel structure with both cross-section and time series properties. In other words the accounting data are obtained by observing the activities of many firms over the multiple periods of time. Most empirical studies in the field of accounting so far carried out in the U.S. as well as Japan have only taken account of the cross-section properties of the data but ignored the time series properties. In fact, all the empirical studies referred above from the U.S and Japanese literatures are based on the cross-section analysis. They do not fully consider time series properties of the data. This kind of treatment of data is not correct from a statistical point of view.

The purpose of this paper is twofold. First, the paper extends the issue proposed by Ito and Kagaya (2001). We examine how much advertising and R&D expenditures of a [illegible]

the first- and second sections of the Tokyo Stock Exchange market from the periods of 1990 to 2001. The intangible assets consist of intellectual capital, brand equity, human capital and others. While Sakurai and Ishimitsu (2004) focused on the brand equity, which is one element of the intangibles, we are interested in the intangibles as a whole including, brand equity. The advertising and R&D expenditures are commonly regarded as most important factors for determining intangible assets. Second, we employ a statistical method, which explicitly incorporates the panel data structure for analyzing

$$V^* = TA + IA \tag{1}$$

The V^* is also decomposed into the value of debt (DEBT) and the value of stock (STOCK).

$$V^* = DEBT + STOCK \tag{2}$$

From equations (1) and (2), the IA is defined as

$$IA = DEBT + STOCK - TA \tag{3}$$

[illegible]

expenditures. The DEBT, STOCK, and TA should be measured at the market values in order to be conformable to equation (3) if the IA is measured in terms of market value.

On the other hand, the IA of a firm are conceptually composed of intellectual capital, human capital, brand value and other factors which affect the corporate value but are not classified into intangible assets, i.e.,

$$IA = (\text{Intellectual Capital}) + (\text{Human Capital}) + (\text{Brand Value}) + (\text{Others}) \tag{4}$$

Intellectual capital should be increased in R&D. Human capital can be considered as a function of R&D and brand value since highly qualified researchers are willing to be employed by the firms with large R&D expenditures and high brand values. The brand

and 2001. The 382 firms are chosen by a certain criterion as will be stated in Section 3. We note the data set comprises a panel structure with cross-section and time series characteristics.

Equation (6) presents the effects of the AD and RD expenditures of a firm on the without group. The error terms of the i-*th* firm have a multivariate normal distribution:

$$\varepsilon_{ij.} = \begin{pmatrix} \varepsilon_{ij1} \\ \vdots \\ \varepsilon_{ijT} \end{pmatrix} \sim N(\mathbf{0},\ \Sigma),\quad \Sigma = \begin{pmatrix} \sigma_{11} & \cdots & \sigma_{1T} \\ \vdots & \ddots & \vdots \\ \sigma_{T1} & \cdots & \sigma_{TT} \end{pmatrix} \tag{8}$$

The unknown parameters to be estimated in this model are α_{jt}, β_{1j}, β_{2j} and σ_{st}, the total number of parameters are $J \times T + 2J + (1/2)T(T+1)$.

Not only the current amounts of expenditures for AD and RD but also the accumulated amounts from their past expenditures may have the effects on the values of IA. The effects of AD and RD on IA will persist for several periods. We have to add the variables for measuring the accumulated amounts of AD and RD, the lagged ADs and the lagged RDs, to equation (6) in order to incorporate the above effects. However, we confine our attention only to the current effects of AD and RD in this paper.

The econometric model of (6) and (7) is quite general, and some explanations about the properties of the model are in order. First we note that the constant term (α_{jt}) varies over both the groups and times, and picks up the effects of each group and of each time on the level of IA, although this term is not main interest in this paper.

Second, the coefficients of AD and RD are respectively denoted by β_{1j}, β_{2j}. They possibly differ among different groups. In other words, the effects of AD and RD on the IA can take different values from one group to another. We will test the hypothesis of equality of β_{1j} and β_{2j} among all groups:

$$\begin{aligned} &H_0: \beta_{k1} = \cdot\ \cdot\ \cdot = \beta_{kJ}, \\ &\qquad \text{vs.} \\ &H_1: \beta_{kh} \neq \beta_{kj} \text{ for at least one pair of } (h, j),\ (k = 1, 2) \end{aligned} \tag{9}$$

If the null hypothesis (H_0) is accepted, the coefficients β_{kj} are identical for all groups. In this case we do not need to classify the firms into different groups. On the other hand, if the null hypothesis (H_0) is rejected, the coefficients β_{kj} are different among some groups. In the latter case the classification of the firms into different groups is justified.

Third, concerning the structure of the covariance matrix Σ, our model includes the case

$$\Sigma = \sigma^2 \mathbf{I}_T \tag{10}$$

where $\mathbf{I}_T$ is a $T \times T$ unit matrix as a special case, which in turn implies that the error terms of each firm have no autocorrelation. Empirical researches by standard literatures in the field of accounting typically employ this formulation of equation (10) for the covariance matrix in error terms, and routinely apply the ordinary least squares (OLS) method to estimate the unknown parameters. However, the accounting data with panel structure of cross-section and time series properties is not likely to satisfy equation (10). If we apply the OLS to the model by carelessly assuming equation (10) when the true covariance is in equation (8), the parameters cannot be efficiently estimated. It is important to correctly specify the covariance structure of the error terms and to employ an appropriate estimation method in practice. Hence, we should test the hypothesis

$$H_0 : \Sigma = \sigma^2 \mathbf{I}_T, \quad \text{vs} \quad H_1 : \Sigma \neq \sigma^2 \mathbf{I}_T \tag{11}$$

If the null hypothesis is accepted, error terms of each firm do not have autocorrelations. In this case the use of the OLS method is justified. On the other hand, if the null hypothesis is rejected, the error terms do have autocorrelations.[1] We should use the generalized least square (GLS) method of estimation instead of the OLS. In fact, we apply a feasible generalized least square (FGLS) method for estimating the model of (6) and (7). The estimation method and testing procedures are explained in Appendix.

Assumption (7) excludes the co-movements of error terms among different firms either within or without group. This assumption may not reflect the real world of stock markets since many stock prices often fluctuate simultaneously towards the same direction. However, if we allow the covariance between different firms, we have to estimate too many parameters because we have large number of firms. It is not meaningful formulation to take account of possible covariance structure between firms for the purpose of this paper.

3. Empirical Study for the Japanese Manufacturing Firms

3.1 Data Source and Descriptive Statistics

The data sources for this study are "NIKKEI NEEDS - CD-ROM Financial Statement (Nikkei, 2002)," "The Stock Prices CD-ROM(Toyo Keizai Inc., 2001)," and "NIKKEI Kaisha Jhouhou (2002-III, Summer) (Nikkei, 2002)." We select the firms satisfying all the following eight conditions: (a) Belong to manufacturing industry; (b) Listed on the first- or second sections of the Tokyo Stock Exchange in the year of 2001; (c) Financial data is consecutively available from 1987 (the base year to estimate a replacement value) to 2001; (d) The closing date of the every fiscal year from 1987 to 2001 is on

---

[1] The first-order autoregressive model is often used to formulate the time-series properties of error terms: $\varepsilon_{ijt} = \rho\, \varepsilon_{ijt-1} + \xi_{ijt}$, where ξ_{ijt} follows a white noise process $N(0, \sigma^2)$. Then, the covariance matrix has a specified form

$$\Sigma = \sigma^2 \begin{pmatrix} 1 & \rho & \rho^2 & \cdots & \rho^{T-1} \\ \rho & 1 & \rho & \cdots & \rho^{T-2} \\ \rho^2 & \rho & 1 & \cdots & \rho^{T-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{T-1} & \rho^{T-2} & \rho^{T-3} & \cdots & 1 \end{pmatrix},$$

with only two unknown parameters. This model can save a considerable number of parameters compared with the model of equation (8) in which the number of unknown parameters are T(T+1)/2 (= 78, if T = 12). Since the accounting data typically consists of large number of firms (M = 382 in this paper), we can allow an unspecified structure of Σ. This phenomenon is an advantage for analyzing the accounting data.

Table 1 - Number of Firms.

Group Industry	(1) Very Low	(2) Low	(3) High	(4) Very High	sum
Mining	2	0	0	0	2
Oil & CoalProducts	2	0	0	0	2
Pulp & Paper	2	1	0	0	3
Shipbuilding	0	0	3	0	3
Rubber Products	1	1	1	1	4
Glass & Ceramics Products	2	4	0	4	10
Other Products	2	6	1	1	10
Textiles & Apparels	2	4	0	4	10
Other Transportation Equipment	2	5	2	1	10
Iron & Steel	10	2	3	0	15
Pharmaceutical	1	2	1	14	18
Precision Instruments	2	6	4	5	17
Foods	9	7	3	2	21
Automobile	10	10	1	1	22
Nonferrous Metals	8	6	9	5	28
Construction	7	14	19	2	42
Chemicals	15	14	11	4	44
Machinery	15	6	15	15	51
Electric Appliances	4	7	23	36	70
sum	96	95	96	95	382

Note: Industry classification follows that of NEEDS.

March 31; (e) Have neither increased nor reduced capital during 1987 and 2001; (f) Have not made merger & acquisition with any listed companies during 1987 and 2001; (g) Have disclosed both advertising costs and development & experimental research expenses every year from 1989 to 2001; and (h) Stock prices are consecutively available from 1990 to 2001.

The number of firms satisfying the above conditions are M=382. The data set is made of balanced panel structure having 382 cross-section multiplied by twelve time-series from 1990 to 2001 (T=12). The total number of samples is $N=382\times 12=4584$. The 382 firms are classified into four groups (J=4) according to the criterion stated in Section 2.[2]

Although we want to ideally determine the market value of IA defined by equation (3), it is impossible in practice since the market values of the DEBT and TA are not available. As alternatives for their market values, we use DEBT measured by the book value and TA measured by the replacement value. Further, the replacement value of TA must be estimated because it cannot be directly observed. We employ the estimating method introduced by Hayashi and Inoue (1991) on the line of measuring Tobin's *Q*. The STOCK is measured by the average stock price in May of each year since the financial statements for most of the firms go public in May. The IA measured from the above procedure is standardized by total sales of a firm. The AD is measured by "advertising costs" divided by total sales. The RD is measured by "development expenses and experimental research expenses" divided by total sales.

---

[2] Although we do not report here, we have estimated the model with J = 5. The estimates of coefficients for the model do not hold the order of inequalities $\beta_{k1}<\beta_{k2}<\beta_{k3}<\beta_{k4}<\beta_{k5}$ for k=1, 2. We do not believe that the classification of firms into more than four groups provides any meaningful interpretations.

Table 2 - Descriptive Statistics.

Group	Variable	Mean (%)	Median (%)	Std. Dev. (%)	Min (%)	Max (%)
Total Samples	IA	6.34	-2.66	81.44	-335.19	965.84
N=4584	AD	0.80	0.26	1.65	0.002	25.33
	RD	2.11	0.99	2.82	0.002	20.62
(1) Very Low	IA	-52.48	-45.15	62.57	-335.19	330.50
N=1152	AD	0.65	0.16	1.28	0.004	11.43
	RD	1.61	0.76	2.27	0.002	18.19
(2) Low	IA	-9.08	-11.84	40.19	-190.46	266.76
N=1140	AD	0.74	0.22	1.24	0.003	7.14
	RD	1.45	0.64	2.14	0.004	16.17
(3) High	IA	14.03	10.68	43.49	-202.33	344.32
N=1152	AD	0.47	0.23	0.63	0.002	5.65
	RD	1.83	1.24	1.89	0.004	15.15
(4) Very High	IA	73.41	50.40	104.43	-109.94	965.84
N=1140	AD	1.35	0.51	2.63	0.003	25.33
	RD	3.54	2.06	3.97	0.002	20.62

Note: N = number of observations within group.

Some parts of advertising costs may be included in the manufacturing costs. Although a part of research and development costs was capitalized in the past, all of these costs are currently expensed. Therefore, AD and RD may contain the measurement errors. However, we can not recover the true advertising costs from the published statements. Fortunately, capitalized development expenses and experimental research expenses are negligible compared with the total development expenses and experimental research expenses. Then, we can ignore these expenses as has been done in Liu (2004).

Before conducting the formal analysis, we state some properties of the data based on summary statistics. Table 1 indicates the number of firms classified by group and industry. The firms in pharmaceutical and electric appliance industries mainly fall into the group 4. The values of intangible assets are high in these two industries.

Table 2 summarizes the descriptive statistics for the data set we use in the following analysis. The intangible assets for approximately half of the firms are negative, but those for the firms in the group 4 are highly positive.

Table 3 shows sample correlation coefficients among three variables (IA, AD and RD). The correlations on the groups1 through 3 are small in absolute value, while those on the group 4 are relatively high. This observation may suggest that the AD and RD significantly affects the value of IA in the group 4, but the effects of AD and RD on the values of IA are dubious in the groups 1 through 3.

3.2 Results

We report the estimating results for the Japanese manufacturing firms. Table 4 presents the estimates of coefficients of β_{kj}. (k=1, 2; j=1,...,4). The estimates of α_{kj} are not reported here because they are not main interest of this paper. We find from Table 4 the inequalities $\beta_{k1} < \beta_{k2} < \beta_{k3} < \beta_{k4}$, for k = 1 and 2. That is, the higher the intangible assets of the firms are, the higher the estimates of coefficients of both AD and RD are also. This finding is expected from the earlier discussion in Section 2. The estimates

Table 3 - Sample Correlation Coefficients among Variables

Group		IA	AD
Total Samples	AD	0.197	
	RD	0.240	0.297
(1) Very Low	AD	0.027	
	RD	-0.063	0.163
(2) Low	AD	0.026	
	RD	-0.028	0.146
(3) High	AD	0.050	
	RD	0.008	0.144
(4) Very High	AD	0.208	
	RD	0.238	0.337

of β_{14} and β_{24} only for the group 4 are significantly positive at 5% significance level, while all other estimates of β_{1j} and β_{2j} for the groups 1 through 3 are negative though not significant except in one case.

Table 4 - Estimates of Coefficients for Equation (6)

Group Variables	(1) Very Low	(2) Low	(3) High	(4) Very High
AD	-1.846	-0.418	-0.213	5.033
$\hat{\beta}_{1j}$	(-0.89)	(-0.20)	(-0.06)	(4.63)
RD	-3.435	-1.586	-0.564	1.779
$\hat{\beta}_{2j}$	(-2.97)	(-1.34)	(-0.45)	(2.63)

Note: The values in parentheses indicate t-values.

The results reveal that the expenditures for the advertising and the R&D contribute to increase the values of the intangible assets only for the firms in the group 4. On the other hand, the expenditures for the advertising and the R&D have no contribution to the intangible assets for the firms in the groups 1 through 3. This fact might be counter-intuitive because the AD and RD are generally considered to increase the intangible assets. However, it can be interpreted as follows. The investors judge that three quarters of the firms analyzed in the paper excessively spend their money to the advertising and R&D activities, so that the expenditures of these firms have no contribution to increase the IA.[3]

We formally test the equalities of coefficients for AD and RD. The Wald test [illegible]

Table 5 - Estimates of the Correlation Matrix

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1991	0.66										
1992	0.32	0.59									
1993	0.40	0.64	0.82								
1994	0.31	0.50	0.58	0.83							
1995	0.10	0.32	0.58	0.69	0.81						
1996	0.26	0.42	0.42	0.56	0.65	0.67					
1997	0.02	0.22	0.27	0.35	0.42	0.55	0.66				
1998	-0.14	0.02	0.10	0.13	0.24	0.39	0.40	0.81			
1999	-0.08	-0.03	-0.03	0.07	0.15	0.19	0.31	0.53	0.65		
2000	-0.11	-0.04	-0.12	-0.07	0.09	0.19	0.26	0.54	0.70	0.75	
2001	-0.12	-0.05	0.00	0.01	0.10	0.25	0.24	0.57	0.71	0.71	0.84

Similarly, W = 17.72 (d.f.=3) for testing the equality of the coefficients of RD rejecting the null hypotheses at the 1 % significance revel, as well. The coefficients of RD are different among the four groups.

Table 5 shows the estimates of autocorrelation matrix for the error terms, which are calculated from the estimates of covariance matrix. There are strong autocorrelations for the error terms in our model applied to the Japanese manufacturing firms. This fact is typically observed as for the accounting data as pointed out in Section 2.

We apply the likelihood ratio test static explained in Appendix for testing the hypothesis of equation (11) in Section2. The result indicates LR=4935.69 (d.f.=77), strongly rejecting the null hypothesis at 1% level. The error terms have significant autocorrelations. We should use the generalized least square (GLS) method of estimation. Application of the conventional OLS estimation to the data with panel structure of this study is not justifiable.[4]

We conduct the same analysis as before by using the TA measured from book value instead of the replacement value in order to examine how sensitive the model is to the choice of measurements of TA. Table 6 shows the estimates of parameters. The results are essentially the same as those in Table 4 except for the estimate of the coefficient for the RD in the group 1, (β_{21}). The estimate is significant in Table 4 while it is not in Table 6. We can say that our model is reasonably robust against the measurements of TA.[5]

Regardless of evaluating TA by either replacement costs or book-values, the values of off-balance-sheet asset and liability can not be taken account for as far as IA is defined in equation (3). Hence, it should be very careful to generalize the results of this paper.

---

[4] If we assume the first-order autoregressive made in the error terms as explained in footnote 1 even though it is not fully justifiable, we obtain the estimate $\hat{\rho} = 0.666$. This value of estimate clearly rejects the null hypothesis of $\rho = 0$. Again the error terms have positive autocorrelations.

[5] We estimated the coefficients of the equation (6) by using the OLS when the model is applied for each of the groups separately. The estimates are roughly the same as those from the FGLS though we do not report here. But the residuals exhibit strong autocorrelations, and then the OLS is not justifiable even if the estimates happen to be similar to those from the FGLS.

Table 6 - Estimates of Coefficients for Equation (6) with TA measured from the book value

Group Variables	(1) Very Low	(2) Low	(3) High	(4) Very High
AD	-0.396	-0.059	-5.129	2.316
$\hat{\beta}_{1j}$	(-0.22)	(-0.04)	(-2.32)	(3.34)
RD	-0.323	-0.810	-0.592	2.572
$\hat{\beta}_{2j}$	(-0.22)	(-0.86)	(-0.91)	(5.54)

Note: The values in parentheses indicate t-values.

4. Conclusions

This paper analyzed the effects of advertising and R&D expenditures on the values of intangible assets for the Japanese manufacturing firms listed on the first- and second sections of the Tokyo Stock Exchange market for 12 years during the periods of 1990 and 2001. The 382 firms were chosen by reasonable criteria stated in section 3. The data set comprises a panel structure with cross-section as well as time series properties.

The empirical results revealed the two findings. (i) For the top 25% of the 382 firms examined in this paper, the advertising and R&D expenditures significantly increase the value of intangible assets, but for the other 75% neither the advertising nor R&D expenditure increases the value of intangible assets. This result suggests that it is not a wise strategy to impose an identical relationship among all firms, and we need to classify the firms into subgroups by some criteria when we analyze the intangible assets of the Japanese firms. (ii) The error terms of the model exhibit strong autocorrelations. The conventional use of the OLS method for estimating the model is not justified for the accounting data we investigated; instead we should use an appropriate method of the feasible generalized leased squares (FGLS).

The idea of classification of the firms into subgroups is found in some literatures for analyzing the American firms. Aboody and Lev (2000) and Chan, Lakonishok and Sougiannis (2001) classified the firms by the amount of R&D expenditures, for example. Our result indicates that the classification of the firms is meaningful for studying the Japanese firms. Fujita (2001) proposed a cost approach for initially measuring the home-grown brands of the firms. The result of this paper provides her claim not only an empirical support but also a caution against the application of a uniform rule over all the firms. The other criteria proposed by this paper for dividing the firms are worth investigation as future research.

We focused our attention only on the current effects of AD and RD on IA in this paper, and will leave the extension of the model to analyze the effects of lagged variables of AD and RD for future research. Since we do not take account for the values of off-balance-sheet asset and liability, it should be careful to generalize the results of this paper.

We proposed a rather sophisticated statistical method to empirically study in the field

Appendix

The appendix explains the econometric model, its estimation procedure, and test statistics for the hypotheses of equations (9) and (11) for the readers who are not familiar to econometric literatures. See Greene (2000) for more detailed explanations.

[A] The Econometric Model and Its Estimation Procedure

We consider the regression model

$$y_{ijt} = \alpha_{jt} + \mathbf{x}_{ijt}'\beta_j + \varepsilon_{ijt} \tag{A.1}$$

$$i = 1, 2, \ldots, I_j;\ j = 1, 2, \ldots, J;\ t = 1, 2, \ldots, T;$$

where $\mathbf{x}_{ijt} = (x_{1ijt}, x_{2ijt}, \ldots, x_{kijt})' : k \times 1$; $\beta_j = (\beta_{1j}, \beta_{2j}, \ldots, \beta_{kj})' : k \times 1$;

k=number of independent variables; I_j=number of firms within the j-th group; J=number of groups; T=number of years with t=1 indicating the year of 1990.

We formulate the regression equation of (A.1) in a matrix form for simplifying exposition along with three steps. First stacking the variables with time, we have

$$\begin{pmatrix} y_{ij1} \\ \vdots \\ y_{ijT} \end{pmatrix} = \begin{pmatrix} 1 & & \mathbf{0} \\ & \ddots & \\ \mathbf{0} & & 1 \end{pmatrix} \begin{pmatrix} \alpha_{j1} \\ \vdots \\ \alpha_{jT} \end{pmatrix} + \begin{pmatrix} \mathbf{x}_{ij1}' \\ \vdots \\ \mathbf{x}_{ijT}' \end{pmatrix} \boldsymbol{\beta}_j + \begin{pmatrix} \varepsilon_{ij1} \\ \vdots \\ \varepsilon_{ijT} \end{pmatrix},$$

which in turn reduces to the next formulae by using a matrix notation:

$$\begin{aligned} \mathbf{y}_{ij.} &= \mathbf{I}_T\ \alpha_{j.} + \mathbf{X}_{ij.}\ \beta_j + \varepsilon_{ij.}, \\ &= \left(\mathbf{I}_T \mid \mathbf{X}_{ij.}\right) \begin{pmatrix} \boldsymbol{\alpha}_{j.} \\ \hline \boldsymbol{\beta}_j \end{pmatrix} + \varepsilon_{ij.}, \\ \mathbf{y}_{ij.} &= \mathbf{X}^*_{ij.}\ \beta^*_j + \varepsilon_{ij.}, \end{aligned} \tag{A.2}$$

$$\varepsilon_{ij.} \sim N(\mathbf{0}, \Sigma); \quad \Sigma = \begin{pmatrix} \sigma_{11} & \cdots & \sigma_{1T} \\ \vdots & \ddots & \vdots \\ \sigma_{T1} & \cdots & \sigma_{TT} \end{pmatrix},$$

where $\mathbf{I}_T$ denote a unit matrix of size T, Σ is a symmetric positive definite matrix with unknown parameters T(T +1)/2, and $\mathbf{X}_{ij.}$, $\mathbf{X}^*_{ij.}$, $\alpha_{j.}$, β_j, β^*_j are conformably defined though we do not state each explicitly.

Second stacking firms within j-th group into a vector, we have in a similar manner to (A.2);

$$\begin{pmatrix} \mathbf{y}_{1j.} \\ \vdots \\ \mathbf{y}_{I_j j.} \end{pmatrix} = \begin{pmatrix} \mathbf{X}^{*}_{1j.} \\ \vdots \\ \mathbf{X}^{*}_{I_j j.} \end{pmatrix} \boldsymbol{\beta}_j^{*} + \begin{pmatrix} \boldsymbol{\varepsilon}_{1j.} \\ \vdots \\ \boldsymbol{\varepsilon}_{I_j j.} \end{pmatrix}$$

$$\mathbf{y}_{.j.} = \mathbf{X}^{*}_{.j.}\ \beta^{*}_{j} + \ \varepsilon_{.j.} \tag{A.3}$$

where

$$\mathbf{E}[\boldsymbol{\varepsilon}_{.j.}\ \boldsymbol{\varepsilon}'_{.j.}] = \begin{pmatrix} \mathbf{E}[\boldsymbol{\varepsilon}_{1j.}\ \boldsymbol{\varepsilon}'_{1j.}] & \cdots & \mathbf{E}[\boldsymbol{\varepsilon}_{1j.}\ \boldsymbol{\varepsilon}'_{I_j j.}] \\ \vdots & \ddots & \vdots \\ \mathbf{E}[\boldsymbol{\varepsilon}_{I_j j.}\ \boldsymbol{\varepsilon}'_{1j.}] & \cdots & \mathbf{E}[\boldsymbol{\varepsilon}_{I_j j.}\ \boldsymbol{\varepsilon}'_{I_j j.}] \end{pmatrix} = \begin{pmatrix} \boldsymbol{\Sigma} & \cdots & \mathbf{0} \\ \vdots & \ddots & \vdots \\ \mathbf{0} & \cdots & \boldsymbol{\Sigma} \end{pmatrix} \tag{A.4}$$

and $\varepsilon_{.j.} \sim \mathrm{N}(\mathbf{0}, \mathbf{I}_{I_j} \otimes \Sigma)$, $\otimes$ denote the Kronecker product of two matrices.

Third, stacking groups into a vector, we obtain the final form.

$$\begin{pmatrix} \mathbf{y}_{.1.} \\ \vdots \\ \mathbf{y}_{.J.} \end{pmatrix} = \begin{pmatrix} \mathbf{X}^{*}_{.1.} & & \mathbf{0} \\ & \ddots & \\ \mathbf{0} & & \mathbf{X}^{*}_{.J.} \end{pmatrix} \begin{pmatrix} \boldsymbol{\beta}_1^{*} \\ \vdots \\ \boldsymbol{\beta}_J^{*} \end{pmatrix} + \begin{pmatrix} \boldsymbol{\varepsilon}_{.1.} \\ \vdots \\ \boldsymbol{\varepsilon}_{.J.} \end{pmatrix}$$

$$\mathbf{y}_{...} = \mathbf{X}^{*}_{...}\, \beta^{*}_{.} + \varepsilon$$

$$\mathbf{y} = \mathbf{X}\beta + \varepsilon \quad \text{(A.5)}$$

$$\varepsilon \sim \mathrm{N}(\mathbf{0},\ \boldsymbol{\Omega}), \quad \boldsymbol{\Omega} = \mathbf{I}_{\mathbf{M}} \otimes \Sigma,$$

where $M = \sum_{j=1}^{J} I_j$ (the total number of firms), and β is a (T+K)J × 1 vector.

The equation (A.5) is a canonical form for the general regression model with a covariance structure for error terms. The generalized least square (GLS) method is applied to estimate parameters

$$\hat{\beta} = (\mathbf{X}'\boldsymbol{\Omega}^{-1}\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{\Omega}^{-1}\mathbf{y} \tag{A.6}$$

Unfortunately, this estimator is not applicable in practice because of unknown parameter $\boldsymbol{\Omega}$. However, we can apply an algorithm of feasible generalized least square (FGLS) estimator by estimating the unknown parameters in equation (A.6) as follows:

Step 1: Apply the ordinary least square (OLS) estimator to obtain an initial value of β and $\Sigma = (\sigma_{st})$;

$$\hat{\beta}^{(0)} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y},\quad \hat{\varepsilon}^{(0)} = \mathbf{y} - \mathbf{X}\hat{\beta}^{(0)},\ \text{and}\ \hat{\sigma}_{st}^{(0)} = \frac{1}{M}\sum_{j=1}^{J}\sum_{i=1}^{Ij}\hat{\varepsilon}_{ijs}^{(0)}\hat{\varepsilon}_{ijt}^{(0)} \tag{A.7}$$

Step 2: Use the GLS with replacing $\mathbf{\Omega}$ in (A.6) by $\hat{\Omega}$(k-1) obtained by step 1.

$$\hat{\boldsymbol{\beta}}^{(\mathbf{k})} = (\mathbf{X}'\hat{\mathbf{\Omega}}^{(\mathbf{k-1})^{-1}}\mathbf{X})^{-1}\mathbf{X}'\hat{\mathbf{\Omega}}^{(\mathbf{k-1})^{-1}}\mathbf{y},\quad \hat{\varepsilon}^{(\mathbf{k})} = \mathbf{y} - \mathbf{X}\hat{\beta}^{(\mathbf{k})},$$

$$\hat{\sigma}_{st}^{(k)} = \frac{1}{M}\sum_{j=1}^{J}\sum_{i=1}^{Ij}\hat{\varepsilon}_{ijs}^{(k)}\hat{\varepsilon}_{ijt}^{(k)},\ \text{and} \tag{A.8}$$

$$\hat{\Sigma}^{(\mathbf{k})} = (\hat{\sigma}_{st}^{(\mathbf{k})}),\quad \hat{\Omega}^{(\mathbf{k})} = \mathbf{I_M} \otimes \hat{\Sigma}^{(\mathbf{k})}.$$

Step 3: Go to Step 2 until both $\hat{\beta}^{(\mathbf{k})}$ and $\hat{\Sigma}^{(\mathbf{k})}$ converge.
Denoting thus obtained estimates as $\hat{\beta}$, $\hat{\Sigma}$, we have $\hat{\beta} \sim \mathrm{N}(\beta, \hat{\mathrm{V}})$, $\hat{\mathbf{V}} = (\mathbf{X}'\hat{\Omega}^{-1}\mathbf{X})^{-1}$.

[B] Test statistics for testing the hypotheses in (9) and (11)

We construct the Wald test statistic for testing the hypotheses of a linear restriction on the parameters $\mathbf{R}\beta = \mathbf{r}$, where $\mathbf{R}$: p×(T+K)J, and $\mathbf{r}$: p×1, are known matrices. Under the assumption that the null hypotheses is correct,

$$\mathrm{W} = (\mathbf{R}\hat{\beta} - \mathbf{r})'(\mathbf{R}\mathbf{V}\mathbf{R}')^{-1}(\mathbf{R}\hat{\beta} - \mathbf{r}) \sim \chi_{(\mathrm{p})}^{2} \tag{A.9}$$

is distributed as χ^2– distribution with degrees of freedom p. The Wald statistic in (A.9) is used for testing (9). The likelihood statistics for testing equation (11) in formulated as follows: Let the joint density of y be

$$f(y;\beta,\Sigma) = \frac{1}{(\sqrt{2\pi})^{N}|I_M \otimes \Sigma|^{1/2}}\exp\left\{-\frac{1}{2}(y - X\beta)'(I_M \otimes \Sigma)^{-1}(y - X\beta)\right\}$$

$$LR = -2\log\left(\frac{\max_{\beta,\Sigma} f(y;\beta,\Sigma)}{\max_{\beta,\Sigma=\sigma^2 I_T} f(y;\beta,\Sigma)}\right) \tag{A.10}$$

After some calculations, we have

$$\mathrm{LR} = \mathrm{M}(\mathrm{T}\log(\hat{\sigma}^2) - \log|\hat{\Sigma}|) \sim \chi^2_{\left(\frac{T(T+1)}{2}-1\right)}, \tag{A.11}$$

where $\hat{\sigma}^2 = \frac{1}{N}\mathbf{y}'(\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}')\mathbf{y}$ is the OLS function of $\hat{\sigma}^2$. Under the null hypotheses, LR is distributed on χ^2-distribution with degrees of freedom ($\frac{T(T+1)}{2} - 1$).

References

Aboody, D. and B. Lev. 1998. “The Value Relevance of Intangibles: The Case of Software Capitalization.” *Journal of Accounting Research* 36 (Supplement): 161-191.

Aboody, D. and B. Lev. 2000. “Information Asymmetry, R&D, and Insider Gains.” *Journal of Finance* 55: 2747-2766.

Barth, M., M. Clement, G. Foster and R. Kasznik. 1998. “Brand Values and Capital Market Valuation.” *Review of Accounting Studies* 3: 41-68.

Barth, M. and G. Clinch. 1998. “Revalued Financial, Tangible, and Intangible Assets: Associations with Share Prices and Non-Market-Based Value Estimates.” *Journal of Accounting Research* 36 (Supplement): 199-233.

Blair, M. M. and S. M. H. Wallman. 2001. *Unseen Wealth*. The Brookings Institution.

Chan, L., J. Lakonishok and T. Sougiannis. 2001. “The Stock Market Valuation of Research and Development Expenditures.” *Journal of Finance* 56: 2431-2456.

Fujita, A. 2001. “Goodwill and Brands (Noren to burando, in Japanese).” *Accounting* (Kaikei) 160 (2):

[illegible]

220-231.

Greene, W. 2000. *Econometric Analysis*. 4th Edition. Upper Saddle River, New Jersey: Prentice Hall.

Hayashi, F. and T. Inoue. 1991. “The Relation between Firm Growth and *Q* with Multiple Capital Goods: Theory and Evidence from Panel Data on Japanese Firms.” Econometrica 59: 731-753.

Hirose, Y. 2002. “Summary of ‘A Report of the Corporate Legal System Study Group’ ("Burando kachi hyouka kenkyukai houkokusyo" no gaiyou, in Japanese).” *Corporate Accounting* (Kigyou kaikei) 54 (9): 18-25.

Ito, K. 2004. “Issues of Accounting for Intangibles (Mukei shisan kaikei no ronten, in Japanese).” Accounting (Kaikei) 165 (5): 645-662.

Ito, K. and Kagaya, T. 2001. “The Quest for the Unseen Wealth: Hidden Keys to Creating the Value of Companies (Kigyou kachi to mukei shisan keiei, in Japanese).” *Hitotsubashi Business Review* 49 (3): 44-62.

Kerin, R. and R. Sethuraman. 1998. “Exploring the Brand Value-Shareholder Value Nexus for Consumer Goods Companies.” *Journal of the Academy of Marketing Science* 26 (4): 260-273.

Lev, B. 2001. *INTANGIBLES: Management, Measurement, and Reporting*. Washington, DC. The Brookings Institution.

Lev, B. and T. Sougiannis. 1996. “The Capitalization, Amortization, and Value-relevance of R&D.” *Journal of Accounting and Economics* 21: 107-138.

Lev, B. and P. Zarowin. 1999. “The Boundaries of Financial Reporting and How to Extend Them.” *Journal of Accounting Research* 37: 353-385.

Liu, M. 2004. “R&D Accounting and Managerial Discretion in the Companies Listed on the First Section of Tokyo Stock Exchange (Kenkyuu kaihatuhi no kaikei syori to keieisya no isi kettei ni kansuru kenkyuu, in Japanese).” *Accounting* (Kaikei) 166 (2): 243-257.

Simon, Carol J. and Mary W. Sullivan. 1993. “The Measurement and Determinants of Brand Equity: A Financial Approach.” *Marketing Science* 12 (1): 28-52.

Sougiannis, T. 1994. “The Accounting Based Valuation of Corporate R&D.” *Accounting Review* 69: 44-68.

The Ministry of Economy, Trade and Industry. 2002. “A Report of the Corporate Legal System Study Group (Burando kachi hyouka kenkyukai houkokusyo, in Japanese).” *Corporate Accounting* (Kigyou kaikei) supplement to 54 (8).