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# Firm Growth, Size, Age and Behavior in Japanese Manufacturing

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ABSTRACT. This paper investigates the relationship between firm growth and firm size, firm age and firm behavior, such as R&D activity and subcontracting, based on the data of nearly 14,000 Japanese manufacturing firms. "The stylized facts" that firm size and age have a negative effect on firm growth are confirmed in the case of Japanese manufacturing firms. Also, a firm's survivability rises with its size and age. R&D expenditure per employee has a significant positive effect on firm growth, which justifies the argument made by Hall (1987). Although subcontracting to only one company has no significant effect on firm growth, it has a significant positive effect on a firm's survivability. In addition, subcontracting firms depending on only one company as a customer are subject to no significant age effects. This possibly suggests that the age effect itself has some relation to the extent of the trade network.

## I. Introduction

Since the 1960's, much research as to whether "the law of the proportionate effect" is valid or not has been carried out in Western countries.[1] Since the 1980's the research in those fields has made it clear that firm age, namely, the time passed from the startup of the firm, is the important explanatory variable of firm growth.

Evans (1987a, b) discovered on the basis of panel data from U.S. manufacturing firms that firm size and age have a negative effect on firm growth. In England, Dunne and Hughes (1994) reached the same conclusion by using data from 2000 manufacturing firms. As for non-manufacturing industries, Variyam and Kraybill (1992) offered a result similar to that which Evans (1987a, b) argued for on the basis of a sample including mining, wholesale and retail firms. Audretsch et al. (1997), however, discovered a relationship between firm growth, size and age, which is different in the manufacturing industry, by the analysis of wholesale and hospitality industries in The Netherlands. In West Germany, Harhoff et al. (1998) investigated the age-size effect on firm growth in the fields of construction, trade and service industries as well as manufacturing, and confirmed the negative effects of size and age on growth.

Such a relationship regarding factors related to firm growth has also been reported in developing countries. For example, MacPherson (1996) reported the same relation between firm growth and firm size and age, as in the case of manufacturing industries of advanced countries, on the basis of surveys done in the Republic of South Africa, etc.

The fact is that a firm, which is devised in order to overcome the mortality of a human being, gets old and the growth rate falls off slowly because of aging, which has an important meaning for economic policy. That is, to keep the economy vital and to create new employment opportunities, it is necessary for small, young firms to enter into the economy successively. For that, it is assumed that government support is necessary.

Actually, after the 1980's, the governments of advanced countries began to show an interest in the role of small firms from the viewpoint of maintaining economic power and creating employment opportunity.[2]

Also in Japan, small businesses got positive appraisals in the subsequent economic stagnation of the 1990's. Although the small business policy in Japan has been in effect since the 1950's from the viewpoint of helping the weak overcome economic disadvantages, Japan's government revised the Small and Medium Enterprise Basic Law for the first time in 36 years in 1998, which

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characterized small and medium enterprises positively as the source of our country's economic vitality. The revised law declared that the government has the responsibility of offering the necessary support to promote the start-up of new firms. Furthermore, "the numerical target" that the number of newly born firms should rise from 140,000 to 240,000 within 5 years was determined the same year in the Action Plan for New Birth of the Economy settled in 1999 by Japan's government.

Although the idea that the birth of new firms can lever economic revival was commonly accepted after the 1990's, there has been no research investigating whether the conclusions confirmed in those cases in the West applied to Japan. That is, to say, the fact that firm size and firm age negatively affect firm growth remains unidentified in the case of Japan empirically.

The first purpose of this article is to investigate whether or not "the stylized fact" about firm growth, size and age is applicable to Japan. It is frequently pointed out that in Japanese corporations, the pattern of behavior differs from that in U.S corporations. Nevertheless, if the relation between firm growth rate, firm size and firm age is similar in Japan to that of the U.S. and other countries, the stylized fact is understood as a general fact that exceeds the diversities of economic systems among countries.

The second purpose of this article is to analyze the relation between firm growth rate and variables other than firm size and firm age, which represent a firm's basic strategy. To the best of our knowledge, most of preceding articles in this field used firm size, age and firm ownership type (single plant or not) as explanatory variables for firm growth and survival. On the other hand, there were only a few papers that investigated the relationship between firm growth and such positive strategies as R&D or trade.[3] In addition such papers dealing with these matters used rather small samples of firms. The data used in this report, though they focus on medium-sized firms in the small business sector, involve information on about 14,000 firms on their R&D activities and subcontracting transactions so that it is possible to analyze the relation between firm growth rate and a firm's basic strategy.

This article is organized as follows: In the next section, the data is described. Following that, Section III presents the model specification. In Section IV, the estimation and empirical results are reported. Finally, the paper is concluded in Section V.

## II. Data

The data set that is used in this paper was extracted from the "MITI Basic Survey of Business Structure and Activities (SBSA)." This survey is conducted by the Ministry of International Trade and Industry (MITI) of Japan[4] in order to acquire a collective and quantitative understanding of the actual conditions of R&D, business diversification and globalization. The first survey was carried out in 1992. After that the 2nd survey was done in 1995, and a SBSA has been carried out every year since then. The date the survey was conducted was October 1 and the survey items are the situations of the firms on March 31 of that year, namely at the end of the Japanese fiscal year. As for sales etc., the survey investigates the values of the previous fiscal year.

The scope of this survey covers whole enterprises with 50 or more employees, or whose paid-up capital or investment fund is over 30 million yen and whose operation falls under the Japan Standard Industrial Classification (JSIC) Division D: Mining, Division F: Manufacturing, and Division I: Wholesale and Retail, and Food and Beverage Establishments (excluding those falling into Major Groups No. 61 "Other Food and Beverage Establishments"). The total number of firms surveyed was 25,185 in the 1998 survey.

SBSA are "Designated Statistics" of the Statistics Law of Japan. It is the legal duty of firms surveyed to complete the questionnaire of this survey.

The questionnaires are extracted from various fields. For example: paid-up capital, type of opening (the newly opened, merged or divided) and opening year, organization, number of employees and activities of enterprise, foreign country transactions, status of R&D, patent possession and technology transaction situation, parent company, subsidiary companies and status of subcontracting.

Each objective firm of the SBSA has a perma-

nent firm number, and according to this number, it is possible to trace the history of a firm. That is, SBSA data can be compiled in the form of longitudinal panel data. The sample used in this paper is the firms' data from the manufacturing industry in the SBSA of 1992 and 1998. This is the longest period traceable from our data.

To use the SBSA panel data, according to Article 15 of the Statistics Law of Japan, one must acquire permission[5] from the Ministry of General Coordination to use the private firms' information and disclose the object of use through the government newsletter. The standard of judgment of permission by the Ministry of General Coordination is described in the bylaws of the Statistics Law. The basic standard of judgment of permission is to keep secret the objective firms' personal information and to admit the use of personal data that has high value to the public. One example of high value to the public is specialized and publicly useful academic research. According to the bylaws of the Statistics Law, the use of the personal data is limited to the public officer, the staff of government related organizations and academic research organizations such as universities and research institutes. We have obtained this permission for this research.

This paper deals with manufacturing as a research objective, because most of the preceding articles researched manufacturing and because it is in manufacturing firms that R&D activity and subcontracting transactions affect firms' performances.

In this paper, firm size, age, firm growth, R&D and subcontracting positions are defined as follows:

### *Firm size*

As a measure of firm size, the amount of property, amount of sales or total number of employees is usually adopted in conventional research. None of these measures are a satisfactory means with which to grasp the bulk of management resources of a firm such as human resources and tangible assets. Much of the recent literature, however, adopted the number of employees as a measure of size. In addition to that, it is thought that one of the main reasons for investigating this issue is to determine whether large or small firms are the main source of new employment. Thus, we adopt the number of employees as a measure of size.

As for the number of employees of a firm, the SBSA offers information about the number of (a) regular employees, (b) regular employees excluding part-time workers and (c) total employees (= regular employees + temporary and daily employees). From these categories, this paper has adopted the number of regular employees as a measure of size of the firm because it is conceivable that the essential human capital of the firm appears to be accumulated in the regular employees. In addition, as in preceding papers, we adopted the natural logarithm of this.

As we mentioned previously, the sample of SBSA excludes firms with fewer than 50 regular employees. Indeed there is a limitation of data at this point, but for the objective of focusing on the effect of firms' behavior on their performances, it appears to be a small problem. For firms with fewer than 50 regular employees, the strategy for conducting R&D, or for keeping a subcontracting position appears less selective. For example, according to the "Report on the Basic Survey of Commercial and Manufacturing Structure and Activity" conducted once in 1998 by the Ministry of Economy, Trade and Industry, within manufacturing firms with fewer than 50 employees, about half are subcontractors and only 9.7% spend for R&D. In this paper, using the data excluding small-sized firms in the small business sector, we attempt to focus on the relationship between firms' strategies and performances.

### *Firm age*

To measure the firm age, we adopted the natural logarithm of a value that adds 1 to the number obtained by subtracting the year when the firm was established from 1992. Because the SBSA does not include the formation date of firms established before 1945, we regard firms developed before 1945 as 48 (= 1992 – 1945 + 1) years old.

### *R&D activity*

To measure the R&D status of firms, this paper adopted a R&D dummy variable as a measure of a firm's R&D activity for a total sample, and for a sub-sample made up of firms spending R&D

expenditure, the natural logarithm of R&D expenditure per regular employee is adopted as a measure of a firm's R&D activity.

Because the number of regular employees measures firm size, it is natural to measure R&D activity compared to firm size in terms of R&D expenditure per regular employee. The R&D expenditure is the sum of the individual expenditure for R&D conducted in each company and R&D entrusted to other companies.

As a measure of the status of R&D, R&D divided by sales, i.e. R&D intensity is often used in research. Therefore, for a sub-sample of firms spending R&D expenditure, an estimation using the natural logarithm of R&D intensity is conducted in this paper.

*Subcontracting transactions*[6]

As for subcontracting, the SBSA investigates whether a firm had a subcontracting transaction in the period surveyed and the number of firms with whom a firm had a subcontracting transaction. In this paper, "exclusively subcontracting firms", which is defined as a firm trading with only one customer as a business partner, are analyzed on their differences with other firms by using a dummy variable.

The reason why we focus on R&D expenditure and subcontracting trade is presented as follows. First, both are general strategies that many middle-sized firms in the small business sector can adopt. Second, it has been suggested by preceding research that both have an influence on the firm growth rate. According to Hall (1987), the R&D investment of a firm is a more important prediction factor of firm growth rate than the investment in material capital. Also, according to Asanuma (1988) etc., it has been pointed out that subcontracting exclusively brings about a low but stable firm performance.

At the end of this section, the outline of the data used in this paper is described (Table I).

## III. The model

In this section, the model that is used for estimation in this paper is described. The basic model that is employed in this paper is similar to the one that was used in preceding research.

The dependent variable is the growth rate of firm $i$ in period $t$, i.e. $G_{i,t}$.

Let the size of firm $i$ in period $t$ be $SIZE_{i,t}$, then, $G_{i,t} \equiv \ln SIZE_{i,t} - \ln SIZE_{i,t-1}$.

The basic independent variables are firm size ($SIZE_{i,t}$), firm age ($AGE_{i,t}$), R&D dummy variable ($RDDUM_{i,t}$) which takes 1, if firm $i$ conducted R&D activity and 0 otherwise, and dummy variable for exclusively subcontracting firms ($SUB_{i,t}$) which takes 1, if firm $i$ is exclusively subcontracting and 0 otherwise. R&D expenditure per employee ($RDEMP_{i,t}$) or R&D expenditure per sales ($RDSALE_{i,t}$) is also used instead of $RDDUM_{i,t}$ for the sub-sample of R&D conducting firms.

TABLE I
The outline of the data

| | SIZE[a] (in 1992 yr) | AGE[b] (in 1992 yr) | R&D expenditure per capita Employee (1992fy) (mil. Yen) |
|---|---|---|---|
| Mean | 440.8 | 33.0 | 0.28 |
| Variance | 3,782,465 | 159.8 | 0.51 |
| Maximum | 82,171 | 48 | 12.27 |
| Minimum | 50 | 1 | 0 |
| Mode | 70 | 48 | 0 |
| No.of observation | 13,688 | 13,688 | – |

The number of firms conducting R&D: 7,086 (1992fy).
The number of exclusive subcontracting firms (defined later): 891 (1992fy).
*Note:* [a] Measured by regular employees.
[b] Referred in the 2nd section.

*The regression model*

The model for estimation is sample selection type that is usually used in the preceding analyses of the relation between firm size, firm age and firm growth rate.

Our basic estimation model is written as follows.

$$G_{i,t} = \alpha + \beta \ln SIZE_{i,t-1} + \gamma \ln AGE_{i,t-1} + \delta RDDUM_{i,t-1} + \varepsilon SUB_{i,t-1} + u_{i,t-1} \quad (1)\text{ (Growth rate function)}$$

The dependent variable, $G_{i,t}$, however, is not always observed. $G_{i,t}$ is observed if firm $i$ is observed both in 1992 sample and in 1998 sample. Let us express this status as $SEL_{i,t} = 1$, and the status that firm $i$ is observed only in 1992 sample is expressed as $SEL_{i,t} = 0$. Then we can define the selection function defined as follows.

$$SIZE^*_{i,t} = \phi + \varphi SIZE_{i,t-1} + \eta RDUM_{i,t-1} + \iota SUB_{i,t-1} + v_{i,t-1} \quad (2)\text{ (Selection function)}$$

$$SEL_{i,t} = \begin{cases} 1 & if \quad SEL^*_{i,t} \succ 0 \\ 0 & if \quad SEL^*_{i,t} \leq 0 \end{cases} \quad (3)$$

Also, the error terms $(u_{i,t-1}, v_{i,t-1})$ are assumed to have normal distribution, that is

$$\begin{pmatrix} u_{i,t-1} \\ v_{i,t-1} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} \sigma & \rho\sigma \\ \rho\sigma & 1 \end{pmatrix}\right) \quad (4)$$

In addition, instead of (1) and (2), we estimate equation, (1)′ and (2)′ which include the quadratic terms of size, age and their interactive effect in growth rate function.

$$G_{i,t} = \alpha + \beta \ln SIZE_{i,t-1} + \gamma \ln AGE_{i,t-1} + \delta(\ln SIZE_{i,t-1})^2 + \varepsilon(\ln AGE_{i,t-1})^2 + \phi(\ln SIZE_{i,t-1})(\ln AGE_{i,t-1}) + \varphi RDDUM_{i,t-1} + \eta SUB_{i,t-1} + u_{i,t-1} \quad (1)'$$

$$SEL^*_{i,t} = \iota + \kappa \ln SIZE_{i,t-1} + \lambda \ln AGE_{i,t-1} + \mu RDDUM_{i,t-1} + \nu SUB_{i,t-1} + \upsilon_{i,t-1} \quad (2)'$$

As for the variables related to R&D, $RDEMP_{i,t}$ and $RDSALE_{i,t}$ are adopted in estimation using a sub-sample of R&D conducting firms.

To estimate the model presented above, we use a sample selection model with full-information maximum-likelihood (FIML) estimator in this paper.

To explain the selection model with full-information maximum-likelihood (FIML) estimator, equations (1) or (1)′ and (2) or (2)′ are rewritten as follows.

$$G_{i,t} = \beta' X_{i,t-1} + u_{i,t-1} \quad (5)$$

$$SEL_{i,t} = \gamma' W_{i,t-1} + v_{i,t-1} \quad (6)$$

With respect to FIML, the likelihood function is given by

$$L = \prod_{i \in (SEL_{i,t}=0)} [1 - \Phi(\gamma' W_{i,t-1})] \times \prod_{i \in (SEL_{i,t}=1)} \left[\frac{\gamma' W_{i,t-1} + \frac{\rho}{\sigma}(G_{i,t} - \beta' X_{i,t-1})}{\sqrt{1-\rho^2}}\right] \frac{1}{\sigma} \times \phi\left(\frac{G_{i,t} - \beta X_{i,t-1}}{\sigma}\right)$$

where $\phi(\bullet)$ and $\Phi(\bullet)$ represent the normal probability density function and cumulative distribution function, respectively. By maximizing the logarithm of this likelihood function, log $L$, we obtain maximum likelihood estimators.

Here, it is necessary to point out the implication of sample selection in this paper. Usually, sample selection means the firm failed and disappeared during the observation period. However, in this paper, it does not have the same meaning as usual. The objective firms of the "Survey of Business Structure and Activities (SBSA)" are those having 50 or more employees. Therefore, the firms of which data are not to be observed at the end of the period ($SEL_{i,t} = 0$) did not necessarily fail and disappeared during the observation period. In reality, most of them reduced their size less than 50 employees,[7] while others are actually failed.

At the end of this section, we mention the expected sign of the coefficient of the variables in (1) and (3).

(i) $\beta \prec 0, \gamma \prec 0, \varphi \succ 0$

In many countries, firm size and firm age have already been confirmed as having a negative correlation with firm growth and a positive correlation with firm survival.

(ii) $\delta \succ 0, \eta$ ?

There are two types of innovation that are introduced by R&D activity, i.e. product innova-

tion and process innovation. As for product innovation, it is usually conceivable that the firm size calculated by numbers of employees will expand through the rise of sales. However, process innovation, if it is related to laborsaving technology, possibly reduces the firm size calculated by the number of employees. While there are two theoretical possibilities, Hall (1987) reported empirically that R&D expenditure per employee has a positive influence on the future growth rate. From here, the sign of the coefficient of R&D is expected to be positive.

On the other hand, the effect of R&D activity on the survival of a firm is not clear, because there is the possibility that R&D activity itself gives birth to new risk, while it is conceivable that the management stabilizes and survivability becomes high through the results given by the R&D activity.

(iii) $\varepsilon ?, \iota \succ 0$

In many cases, exclusively subcontracting firms are monitored by their customers on their technology levels and management strategies. Therefore the profit rates tend to become low and that might hinder the expansion of firm size. However, if the growth rate of the parent company is high, the exclusively subcontracting firm has the chance to accomplish high growth. Therefore, the sign of the coefficient of the exclusively subcontracting firm dummy is not clear.

On the other hand, in Japan where long-term business connections are respected, the decline of an exclusively contracting firm harms the credibility of the parent company for the other firms. Therefore, regarding the selection function, it is expected that the coefficient of the exclusively subcontracting dummy is positive.

## IV. The result

### *The relation between firm size, age and growth rate*

Before analyzing a firm's performance and strategy, we examine first, the relation between firm size, firm age and firm growth rate. Table II shows the result of the analysis of the regression on the relation among them. The first column shows the results of the sample selection model of the first order equation, (1) and (2). In growth function, the coefficient of firm size is –0.029 and significantly negative at the 1% level and the coefficient of firm age is –0.055, which is also significantly negative. As for the selection function, the coefficient of the firm size is 0.329 and significantly positive. In the second column, age is adopted instead of size as an explanatory variable of the selection function. The coefficient of age in the selection function is 0.174 and significantly positive.

These confirm the significant negative relation among firm size, firm age and firm growth rate, and also confirm the significant positive relation among firm size, firm age and firm "survivability"[8] (see note). These results are similar to those already stated in the previous research.

In many preceding studies, it has been confirmed that there is probably heteroskedasticity in the disturbance term of the growth function and this might not warrant the coincidence of the estimation (Greene, 1993). Therefore, some of the weighted regression with the sample selection is also estimated. The weights are calculated by consulting the method adopted by Hall (1987) and Aaronovitch and Sawyer (1975). The residuals of the estimation are regressed by using first and second order in the natural logarithm of firm size and age and this gives the square of the estimated residual. The weights are calculated from the estimated residuals. The results are reported in the third and forth columns of Table II, and these results are almost the same as in the first two columns.

However, the results reported above could be obtained when comparatively small and young firms concentrate on new industries with high growth rates, and vice versa for big and old firms. In this case, the result is not because there is an age-size effect in firm growth, but because there is such a difference in the firms' distribution by size between emerging and mature industries. To inspect these possibilities, the fifth and sixth columns report the results in consideration of the dummies according to the three digit industry classifications of the SBSA, which as a whole corresponds to the medium classification of industry in the Japan Industrial Standard Classification. As is shown here, taking industries'

TABLE II
Firm Growth, Firm SIZE and AGE

| | Coefficient | I | II | III (Weighted) | IV (Weighted) | V (Industry Dum) | VI (Industry Dum) | VII | VIII (Weighted) | IX (Industry (Dum) |
|---|---|---|---|---|---|---|---|---|---|---|
| Growth Rate Function | ln(SIZE) | –0.029** (0.003) | –0.041** (0.003) | –0.029** (0.003) | –0.042** (0.003) | –0.033** (0.004) | –0.043** (0.003) | –0.196** (0.027) | –0.278** (0.038) | –0.212** (0.027) |
| | ln(AGE) | –0.055** (0.005) | –0.070** (0.006) | –0.060** (0.006) | –0.078** (0.007) | –0.059** (0.005) | –0.059** (0.006) | –0.006 (0.047) | –0.029 (0.053) | –0.021 (0.046) |
| | $\ln(SIZE)^2$ | | | | | | | 0.011** (0.002) | 0.018** (0.003) | 0.012** (0.002) |
| | $\ln(AGE)^2$ | | | | | | | –0.015* (0.006) | –0.017** (0.006) | –0.015* (0.006) |
| | ln(SIZE)*ln(AGE) | | | | | | | 0.007 (0.006) | 0.017* (0.008) | 0.009 (0.006) |
| | Const. | 0.255** (0.028) | 0.475** (0.026) | 0.277** (0.030) | 0.510** (0.028) | 0.292** (0.036) | 0.388** (0.035) | 0.710** (0.135) | 0.843** (0.156) | 0.804** (0.135) |
| Selection Function | ln(SIZE) | 0.329** (0.014) | | 0.350** (0.015) | | 0.326** (0.015) | | 0.308** (0.014) | 0.473** (0.019) | 0.306** (0.015) |
| | ln(AGE) | | 0.174** (0.021) | | 0.181** (0.027) | | 0.183** (0.021) | 0.123** (0.022) | 0.067** (0.022) | 0.107** (0.022) |
| | Const. | –0.999** (0.074) | 0.102 (0.072) | –1.088** (0.077) | 0.054 (0.094) | –1.090** (0.108) | –0.054 (0.105) | –1.302** (0.096) | –1.926** (0.112) | –1.350** (0.124) |
| ρ | | 0.383** (0.049) | –0.441* (0.052) | 0.398** (0.047) | –0.487** (0.040) | 0.306** (0.062) | 0.001 (0.083) | 0.221 (0.104) | 0.671** (0.020) | 0.125 (0.105) |
| λ | | 0.115** (0.016) | –0.134* (0.017) | 0.115** (0.015) | –0.143** (0.013) | 0.089** (0.019) | 0.000 (0.024) | 0.000 (0.024) | 0.065** (0.031) | 0.206 (0.008) |
| Log Likelihood | | –9213.035 | –9459.298 | –8796.317 | –9002.873 | –8954.173 | –9190.101 | –9171.827 | –8974.285 | –8913.290 |
| Number of obs | | 13688 | 13688 | 13688 | 13688 | 13688 | 13688 | 13688 | 13688 | 13688 |
| Censored obs | | 3355 | 3355 | 3355 | 3355 | 3355 | 3355 | 3355 | 3355 | 3355 |

*Note:* Standard Error in parentheses.
** Statistically significant at 1% level; * Statistically significant at 5% level; † Statistically significant at 10% level.
The coefficients of industry dummies are omitted from the Table.

dummies into account does not change the results obtained above.

In the seventh column and after, the estimation including quadratic terms of size and age is reported. It is difficult to know the direction of the age-size effect from these columns immediately. Therefore, we caliculated the percentage of firms that have a positive or negative sign of a partial differential coefficient obtained from the estimation of the seventh and eighth columns. As we can see, for most firms in our sample it is fitting that the expansion of firm size and the aging process lowers the growth rate and raises the survivability of firms.[9] By examing which variables have a significant effect on growth in the seventh to the ninth columns of Table II, it is understood that linear terms of size and quadratic terms of age have a significant negative effect on growth. As for the selection function, size and age have a significant positive effect and this introduces the positive effect of size on survivability. Accordingly, "the stylized fact" on firm growth in general also holds true for the Japanese economy, which is thought to be somewhat peculiar[10] compared to other market economies.

And the ninth column shows that industries' dummies have little effect on the estimation with the quadratic terms.

*R&D activity and subcontracting relations as another determinant of firm growth*

(i) *R&D activity*

Next, we proceed to the determinants of firm growth other than firm size and age (Tables III and IV).

Table III shows the results of the estimation of the relation between R&D activity and firm growth under the control of firm size and age. As an index of R&D activity, the R&D dummy is adopted here, and the ordinary and weighted estimations are conducted by using linear and quadratic estimation equations. These results indicate that after including the R&D dummy as an explanatory variable, the age-size effect still significantly holds. Moreover, the coefficient of the R&D dummy is significantly positive in the growth rate function of every case from the first to the fourth estimation. These results are the same as was expected and are consistent with the Hall report (1987) using the U.S. manufacturing data, and Liu *et al*. (1999) using Taiwan electronics industry data. The R&D dummy also has a positive effect on a firm's "survivability" in every case.

As was mentioned before, less than half of the objective firms carry out R&D. Thus, another estimation was conducted on the basis of the sub-sample, which is made up of the firms carrying out R&D, and the result is reported in Table IV. Here, as indicators of R&D, logarithm of R&D expenditure per employee and logarithm of R&D expenditure per sales are adopted.

First, we show the results of estimation using logarithm of R&D expenditure per employee (I–IV in Table IV). From these columns we can see at first the negative relationship among firm size, age and firm growth even when taking account of the effect of R&D. Second we can see that R&D expenditure per employee is positively related to firm growth and survivability. As for growth rate fanction, a significantly positive relationship is identified in every case, and as for selection function, in every case the coefficient is positive, although in two cases it is not significant.

Next, we see the effect of R&D expenditure per sales on firm growth and survivability (V–VIII in Table IV). According to the fifth column and after, the coefficient of logarithm of R&D expenditure per sales in growth rate function is significantly positive in every case. On the other hand, in selection function, signs of the coefficients of the logarithm of R&D expenditure are not clear.

In economic anecdotes, R&D is often referred to as the main strategy for survival, but that is not the case observed statistically here. One possible interpretation of no correlation of R&D expenditure per sales with survivability is in the following case: Let R&D expenditure be as *RD*, sales as *SALE*, employee's size as *EMP* respectively, then by definition,

$$RDSALE \equiv \frac{RD}{SALE} = \frac{RD/EMP}{SALE/EMP} \tag{5}$$

The numerator on the right side of (5) is R&D expenditure per employee and it has a significant positive effect on survivability as reported in the first to forth columns of Table IV. The denominator on the right side of (5) is the sales per

TABLE III
R&D activity and firm growth

| | Coefficient | I | II | III (weighted) | IV (weighted) |
|---|---|---|---|---|---|
| Growth Rate Function | ln(SIZE) | –0.035** (0.003) | –0.208** (0.027) | –0.035** (0.003) | –0.207** (0.028) |
| | ln(AGE) | –0.059** (0.005) | 0.008 (0.047) | –0.064** (0.006) | –0.015 (0.056) |
| | $\ln(SIZE)^2$ | | 0.012** (0.002) | | 0.010** (0.001) |
| | $\ln(AGE)^2$ | | –0.016** (0.006) | | –0.017* (0.007) |
| | ln(SIZE)*ln(AGE) | | 0.006 (0.006) | | 0.012 (0.008) |
| | **RDDUM** | **0.036** (0.006)** | **0.037** (0.006)** | **0.035** (0.006)** | **0.035** (0.006)** |
| | Constant | 0.280** (0.029) | 0.728** (0.135) | 0.302** (0.031) | 0.760** (0.152) |
| Selection Function | ln(SIZE) | 0.309** (0.015) | 0.290** (0.015) | 0.329** (0.016) | 0.320** (0.015) |
| | ln(AGE) | | 0.114** (0.022) | | 0.099** (0.026) |
| | **RDDUM** | **0.114** (0.025)** | **0.106** (0.025)** | **0.121** (0.025)** | **0.118** (0.025)** |
| | Constant | –0.950** (0.075) | –1.231** (0.097) | –1.038** (0.078) | –1.351** (0.108) |
| $\rho$ | | 0.374** (0.051) | 0.205 (0.267) | 0.394** (0.048) | 0.262 (0.091) |
| $\lambda$ | | 0.112** (0.016) | 0.060 (0.033) | 0.114** (0.015) | 0.073 (0.026) |
| Log Likelihood | | –9190.727 | –9148.028 | –8772.248 | –8665.527 |
| Number of obs | | 13688 | 13688 | 13688 | 13688 |
| Censored obs | | 3355 | 3355 | 3355 | 3355 |

*Note:* See note to Table II.

employee. It is considered natural that the sales per employee are linked with labor productivity. In addition, according to Grilliches and Regiv (1992), Baily *et al*. (1996), the low labor productivity is a sign of future exit.[11] Therefore, it could be said that given the level of R&D expenditure per employee, the firm that has a low level of sales per employee, and consequently a high value of *R*, has a greater possibility of making an exit. That is to say, a high level of R&D intensity has two meanings: one is active R&D compared with the firm size, which results in high survivability, and the other is a low level of labor efficiency, which is accompanied with a high possibility of future decline. The observed level of R&D intensity is the result of a mixture of these two meanings, and that is why in the selection function, R&D intensity has some significant effect. It is usually interpreted that high levels of R&D intensity are a favorable signal of a firm, but it should be noted that this index has such a negative side.

TABLE IV
R&D activity and firm growth (Subsample of firms conducting R&D)

| | Coefficient | I | II | III (Weighted) | IV (Weighted) | V | VI | VII (Weighted) | VIII (Weighted) |
|---|---|---|---|---|---|---|---|---|---|
| Growth Rate Function | ln(SIZE) | –0.043** (0.004) | –0.143** (0.036) | –0.044** (0.004) | –0.196** (0.038) | –0.039** (0.004) | –0.187** (0.035) | –0.039** (0.004) | –0.177** (0.040) |
| | ln(AGE) | –0.065** (0.008) | 0.150* (0.066) | –0.076** (0.010) | 0.121 (0.081) | –0.064** (0.008) | 0.124 (0.065) | –0.076** (0.010) | 0.102 (0.086) |
| | $\ln(SIZE)^2$ | | 0.010** (0.002) | | 0.010** (0.002) | | 0.012** (0.002) | | 0.009** (0.002) |
| | $\ln(AGE)^2$ | | –0.031** (0.008) | | –0.036** (0.010) | | –0.030** (0.008) | | –0.035** (0.012) |
| | ln(SIZE)*ln(AGE) | | –0.006** (0.009) | | 0.002 (0.011) | | –0.005 (0.009) | | 0.008 (0.011) |
| | **ln(RDEMP)** | **0.017** (0.002)** | **0.016** (0.002)** | **0.017** (0.002)** | **0.015** (0.002)** | | | | |
| | **ln(RDSALE)** | | | | | **0.009** (0.003)** | **0.008** (0.003)** | **0.008** (0.002)** | **0.008** (0.002)** |
| | Constant | 0.439** (0.038) | 0.441* (0.192) | 0.482** (0.043) | 0.788** (0.211) | 0.426** (0.041) | 0.757** (0.178) | 0.465** (0.124) | 0.621** (0.226) |
| Selection Function | ln(SIZE) | 0.236** (0.018) | 0.217** (0.018) | 0.241** (0.019) | 0.234** (0.018) | 0.241** (0.018) | 0.225** (0.018) | 0.245** (0.018) | 0.220** (0.017) |
| | ln(AGE) | | 0.178** (0.032) | | | | 0.128** (0.033) | | 0.171** (0.041) |
| | **ln(RDEMP)** | **0.014 (0.011)** | **0.015 (0.011)** | **0.018** (0.011)** | **0.015** (0.002)** | | | | |
| | **ln(RDSALE)** | | | | | **–0.001 (0.011)** | **–0.004 (0.011)** | **0.003 (0.011)** | **0.003 (0.012)** |
| | Constant | –0.417** (0.105) | –0.927** (0.141) | –0.419** (0.108) | –0.855** (0.211) | –0.475** (0.122) | –0.858** (0.153) | –0.459** (0.124) | –0.936** (0.172) |
| ρ | | 0.140 (0.084) | 0.043 (0.168) | 0.141 (0.083) | –0.603** (0.030) | 0.145 (0.082) | –0.611** (0.030) | 0.143 (0.081) | 0.051 (0.132) |
| λ | | 0.040 (0.024) | 0.012 (0.048) | 0.039 (0.023) | –0.178** (0.011) | 0.042 (0.024) | –0.188** (0.011) | 0.040 (0.023) | 0.014 (0.037) |
| Log Likelihood | | –4372.678 | –4340.205 | –4168.094 | –4103.019 | –4392.166 | –4334.88 | –4184.258 | –4135.958 |
| Number of obs | | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 |
| Censored obs | | 1428 | 1428 | 7086 | 7086 | 1428 | 1428 | 1428 | 1428 |

*Note:* See note to Table II.

(ii) *Subcontracting relations*

As for the subcontracting relation, Table V shows the results of the estimation, which adds an excluding subcontracting firm's dummy variable to the estimation equation as an explanatory variable. Even in this case, the addition of an explanatory variable does not give any deviation of the effect of firm size and age on firm growth. Regarding the growth function, the coefficient of dummy variables for an exclusively subcontracting firm is negative, although they are not significant. As for the selection faction, exclusive subcontracting gives significant positive effects. This result is as expected and is consistent with the achievements of Asanuma (1988), Kawasaki and Macmillan (1987) and Okamuro (2001), which analyzed the insurance mechanism by set makers to suppliers in the automobile industry of Japan.

As is found here and in those articles, subcon-

TABLE V
Exclusive Subcontracting Dummy and firm growth

| | Coefficient for | I | II | III (weighted) | IV (weighted) |
|---|---|---|---|---|---|
| Growth Rate Function | ln(SIZE) | –0.029** (0.003) | –0.197** (0.027) | –0.029** (0.003) | –0.196** (0.028) |
| | ln(AGE) | –0.056** (0.005) | –0.005 (0.047) | –0.061** (0.006) | –0.028 (0.056) |
| | ln(SIZE)2 | | 0.011** (0.002) | | 0.009** (0.001) |
| | ln(AGE)2 | | –0.015* (0.006) | | –0.016* (0.007) |
| | ln(SIZE)*ln(AGE) | | 0.007 (0.006) | | 0.013† (0.008) |
| | **SUB** | **–0.008 (0.012)** | **–0.011 (0.012)** | **–0.004 (0.012)** | **–0.005 (0.012)** |
| | Constant | 0.259** (0.029) | 0.716** (0.136) | 0.279** (0.031) | 0.747** (0.152) |
| Selection Function | ln(SIZE) | 0.331** (0.014) | 0.309** (0.014) | 0.351** (0.015) | 0.342** (0.008) |
| | ln(AGE) | | 0.128** (0.022) | | 0.116** (0.026) |
| | **SUB** | **0.096* (0.048)** | **0.123* (0.049)** | **0.112* (0.050)** | **0.143** (0.050)** |
| | Constant | –1.011** (0.074) | –1.333** (0.097) | –1.100** (0.077) | –1.468** (0.107) |
| ρ | | 0.381** (0.049) | 0.211 (0.107) | 0.398 (0.047) | 0.259 (0.090) |
| λ | | 0.114** (0.016) | 0.062 (0.032) | 0.115 (0.016) | 0.072 (0.026) |
| Log Likelihood | | –9210.375 | –9167.829 | –8796.433 | –8679.999 |
| Number of obs | | 13688 | 13688 | 13688 | 13688 |
| Censored obs | | 3355 | 3355 | 3355 | 3355 |

*Note:* See note to Table II.

tracting brings about business stability. But if this is true, why do many subcontracting firms try to exert the diversification of customers? In consideration of this point, a sub-sample that consists of exclusively subcontracting firms was made in this paper and the estimation was conducted on the relation among firm growth rate, age and size, using this sub-sample. The result[12] is different from the estimation obtained from the whole sample. That is, firm age does not always have a significant influence on growth rate and survivability, although growth rate falls off and survivability rises with firm size. Furthermore, as far as the growth function is concerned, the absolute value of the coefficient regarding age was less than that of the estimation calculated from the whole sample. Namely, the exclusive subcontractors age to a lesser extent.

If this were the case for human beings, not for subcontractors, not aging would be embraced. However, this would not be welcome even in the case of humans if it meant being childish all the time. Similarly, for the subcontracting firm, having few age effects may mean that it won't be able to enjoy high growth in its early stages. Taking this viewpoint, for a young firm to run a business as an exclusively subcontracting firm possibly could mean sacrificing the chance of growth for the sake of stability. If this interpretation is true, it is natural for many subcontractors to look for new business partners.

The next point to consider is why the age effect is observed to such a small extent in the sample of exclusively subcontracting firms. Namely, why does the number of customers change the scale of the age effect? To answer this question, further investigation is necessary. Therefore what has been done in this paper is only an introduction to a study that might be an answer to the question.

Mengistae (1998) investigated the relation between the efficiency of firms and the age-size effect from the data of 125 firms in Addis Ababa. According to this study, although the age-size effect on a firm's efficiency is confirmed as is usually expected, after controlling the firm's location, the firm's owner's human capital characteristics, such as education, job, career, parent's job, and social network, then the explanatory power of age and size disappears. This might suggest that age and size are not independent variables and are the representative variables of human capital and a firm's location. That is to say, age is not an objective time that has passed after the firm's foundation, but is the index of human capital accumulated after the firm's foundation, such as useful experiences for the firm's management, and networks between customers, suppliers and the firm. If so, it is possible that exclusively subcontracting firms, whose customer networks are closely limited to their parent companies, are less mature than their physical ages.

This consideration is not beyond the range of a tentative hypothesis yet. However, the analysis with regard to the influence that the network between firms gives to the performance of a firm will become more important as a future research subject.

We have investigated the effect of R&D activity and subcontracting relations to firm growth rate in this section. From the data set of this paper, it becomes clear that those factors have an influence on the performance of the firms, such as their growth rates and survivability, although the fundamental relation between firm size, age and growth rate does not change even in cases where these strategic variables are added. Finally, the estimation that added both R&D activity and the exclusive subcontract dummy to the explanatory variables is conducted (Table VI). The result regarding the coefficient did not change the previously obtained result.

## V. Summary and conclusion

In this paper, the relationship among the firm growth rate, firm size, and firm age in the Japanese manufacturing sector was analyzed using the survey data conducted by the Japanese government. It is the first analysis to use large-sized data in Japan in this field. The result obtained here is that firm size and firm age have a significant negative effect on firm growth and have a significant positive effect on survivability in general. These results are similar to those observed in the West. Furthermore, the influence of R&D activity and the subcontracting relation to firm growth is investigated. As for R&D, it raises the growth rate and survivability of a firm significantly when the R&D dummy variable and R&D expenditure per employee are adopted as indexes of R&D activity.

TABLE VI
R&D activity, subcontracting and firm growth

| Coefficient for | | I | II | III (Weighted) | IV (Weighted) | V | VI | VII (Weighted) | VIII (Weighted) | IX | X | XI (Weighted) | XII (Weighted) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sub-sample of firms conducting R&D | | | | | | | |
| Growth Rate Function | ln(SIZE) | –0.035** (0.004) | –0.209** (0.027) | –0.035** (0.003) | –0.208** (0.028) | –0.043** (0.004) | –0.143** (0.036) | –0.044** (0.004) | –0.165** (0.039) | –0.039** (0.004) | –0.187** (0.035) | –0.039** (0.004) | –0.178** (0.040) |
| | ln(AGE) | –0.059** (0.006) | 0.009 (0.047) | –0.064** (0.006) | –0.014 (0.056) | –0.065** (0.008) | 0.158* (0.066) | –0.076** (0.010) | 0.131 (0.082) | –0.064** (0.008) | 0.126† (0.065) | –0.076** (0.010) | 0.104 (0.085) |
| | ln(SIZE)$^2$ | | 0.012** (0.002) | | 0.010** (0.001) | | 0.001** (0.002) | | 0.009** (0.002) | | 0.012** (0.002) | | 0.009** (0.002) |
| | ln(AGE)$^2$ | | –0.017** (0.006) | | 0.018* (0.007) | | –0.031** (0.008) | | –0.036** (0.011) | | –0.030** (0.008) | | –0.035** (0.011) |
| | ln(SIZE)* ln(AGE) | | 0.006 (0.006) | | 0.012 (0.008) | | –0.006 (0.009) | | 0.004 (0.011) | | –0.005 (0.003) | | 0.008 (0.011) |
| | **RDDUM** | **0.035** (0.006)** | **0.036** (0.006)** | **0.035** (0.006)** | **0.035** (0.006)** | | | | | | | | |
| | **ln(RDEMP)** | | | | | **0.017** (0.002)** | **0.016** (0.002)** | **0.017** (0.002)** | **0.016** (0.002)** | | | | |
| | **ln(RDSALE)** | | | | | | | | | **0.009** (0.003)** | **0.008** (0.003)** | **0.008** (0.002)** | **0.008** (0.002)** |
| | **SUB** | **–0.005 (0.012)** | **–0.008 (0.012)** | **–0.001 (0.012)** | **–0.002 (0.012)** | **–0.013 (0.018)** | **–0.017 (0.018)** | **–0.006 (0.018)** | **–0.011 (0.018)** | **–0.017 (0.018)** | **–0.034† (0.019)** | **–0.009† (0.018)** | **–0.013 (0.018)** |
| | Constant | 0.283** (0.029) | 0.734** (0.136) | 0.304** (0.031) | 0.762** (0.152) | 0.442** (0.038) | 0.440* (0.190) | 0.484** (0.043) | 0.545* (0.218) | 0.430** (0.041) | 0.757** (0.178) | 0.467** (0.045) | 0.624** (0.225) |
| Selection Function | ln(SIZE) | 0.310** (0.015) | 0.290** (0.015) | 0.330** (0.016) | 0.321** (0.015) | 0.237** (0.018) | 0.218** (0.018) | 0.243** (0.019) | 0.235** (0.018) | 0.242** (0.018) | 0.226** (0.018) | 0.249** (0.019) | 0.227** (0.175) |
| | ln(AGE) | | 0.120** (0.022) | | | | 0.182** (0.032) | | 0.171** (0.040) | | 0.130** (0.033) | | 0.174 (0.041) |
| | **RDDUM** | **0.117** (0.025)** | **0.110** (0.025)** | **0.125** (0.025)** | **0.122** (0.025)** | | | | | | | | |
| | **ln(RDEMP)** | | | | | **0.014 (0.011)** | **0.015 (0.011)** | **0.019† (0.011)** | **0.018† (0.011)** | | | | |
| | **ln(RDSALE)** | | | | | | | | | **–0.000 (0.011)** | **–0.003 (0.011)** | **0.003 (0.011)** | **0.003 (0.012)** |
| | **SUB** | **0.110* (0.048)** | **0.134** (0.049)** | **0.125* (0.050)** | **0.153** (0.050)** | **0.122 (0.082)** | **0.152 (0.082)** | **–0.006 (0.018)** | **0.160† (0.085)** | **0.119 (0.082)** | **0.112 (0.081)** | **0.139† (0.085)** | **0.160† (0.087)** |
| | Constant | –0.962** (0.075) | –1.262** (0.098) | –1.051** (0.078) | –1.388** (0.109) | –0.428** (0.105) | –0.952** (0.018) | 0.484** (0.043) | –1.012** (0.158) | 0.486** (0.122) | –0.876** (0.154) | –0.484** (0.125) | –0.991** (0.017) |
| ρ | | 0.372** (0.052) | 0.193 (0.114) | 0.394** (0.048) | 0.255 (0.094) | 0.137 (0.084) | 0.044 (0.158) | 0.139 (0.083) | 0.060 (0.130) | 0.143 (0.082) | –0.610** (0.030) | 0.145 (0.081) | 0.054 (0.128) |
| λ | | 0.111** (0.016) | 0.056 (0.034) | 0.113** (0.015) | 0.017 (0.027) | 0.039 (0.024) | 0.012 (0.045) | 0.038 (0.023) | 0.016 (0.036) | 0.041 (0.024) | –0.188** (0.011) | 0.040 (0.023) | 0.015 (0.036) |
| Log Likelihood | | –9187.718 | –9143.713 | –8768.736 | –8660.197 | –4371.160 | –4337.94 | –4166.687 | –4124.202 | –4390.536 | –4332.899 | –4188.489 | –4136.123 |
| Number of obs | | 13688 | 13688 | 13688 | 13688 | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 | 7086 |
| Censored obs | | 3355 | 3355 | 3355 | 3355 | 1428 | 1428 | 1428 | 1428 | 1428 | 1428 | 1428 | 1428 |

*Note:* See note to Table II.

When R&D per sales is adopted instead, though it has a positive effect on growth rate, no significant correlation could be found with "survivability". This comes from two characteristics of R&D intensity that are the exact opposites, namely R&D per sales is the mixed index of R&D expenditure per employee and sales per employee.

As for the subcontracting relation, the relation between one company's exclusive subcontract dummy and firm growth rate is analyzed. The result shows that it has a positive effect on survivability, although it does not have a significant influence on firm growth rate. These relations were consistent with the studies of Asanuma (1988) etc., which investigated the relations between set makers and suppliers of the automobile industry. Also, decline of the firm growth rate due to the age effect was not confirmed with the exclusively subcontracting firm.

Consulting the work of Mengistae (1998), which attributes the age effect on a firm's efficiency to the accumulation of human capital, such as business networks, it is pointed out that this might stem from the fact that the trade network experience is limited for the exclusively subcontracting firm. Finally, the estimation that uses the model added R&D and the subcontracting relation to the explanatory variables with firm size and firm age. The result does not upset the wisdom obtained up until now. That is to say, not only firm size and age, but also R&D activity, and the subcontracting connection that could be called the basic strategy variables of a firm, have a possible important influence on firm growth rate and survivability.

Finally, let us highlight the subjects that have become more important in the area of research. The first is to analyze the influence on firm growth rate of various variables other than firm size and age; for example, a firm's direct overseas investment, product diversification, computer network etc. Such an investigation might shed more light on the meanings of size and age.

The second is to analyze the influence of the trade network that has a great effect on the performance of a firm. If we accept the learning process pointed out by Arrow (1962), it should be considered that the speed of learning is different if the number of customers is different, because the more customers a firm has, the more various kinds of needs to which a firm must respond. Even the great work of Jovanovic (1983) seems to concentrate the learning of it's own firm's proper ability and dismiss the development of this ability through the diversification of the network.

As for the network of firms, a relatively small number of surveys have been conducted. However it is important to answer the questions of what a firm is and what affect aging has on a firm's performance. Further investigation is expected.

## Notes

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[1] A compact survey of this field is Wagner (1992).

[2] In England, the Thatcher Cabinet, which was established in 1979, began to promote the birth of new firms through the Enterprise Allowance Scheme. In the U.S., during the Carter Administration in the late 1970's, the policies for small businesses were strengthened on the concept of "Birthright Economy".

[3] The exceptional report is Macpherson (1996), and as for R&D, Hall (1987) and Liu *et al*. (1999).

[4] In January 2001, MITI changed its name to the Ministry of Economy, Industry and Trade (METI).

[5] The application of this permission is usually submitted through the Research and Statistics Department of METI, which conducts SBSA.

[6] In the SBSA, "subcontracting" is defined as the relationship between firms where production and repair work is entrusted from another firm that is larger in size, in terms of the amount of capital or number of employees.

[7] There is another possibility that the firm reduced the capital to less than 30 million yen, but it seems that cases of this are rare compared with the decrease of employees.

[8] As we mentioned in the third section, the implication of sample selection is different from preceding papers. Therefore, the word "survivability" in this paper means to remain in the objective firms of SBSA.

[9] The signs of the partial derivatives of the growth function with respect to size were negative at 96.6% of all firms, while the signs with respect to the age were negative at 99.6% of all firms. As for the selection function, 100.0% firms have positive signs with respect to size, while 97.8% show positive signs with respect to age.

[10] Although not reported in this paper, the estimation using a sub-sample excluding the firms that were set up before 1944 was conducted in order to verify if it biased the estimation whether or not firms founded before 1944 are regarded as being 48 years old. The result is almost the same as the estimation obtained from the total sample. The author is ready to offer this result on demand.

[11] Grilliches and Regiv (1992) expressed this fact as "the shadow of death".

[12] The table of the result is not presented in this paper, however, the author is ready to offer this result on demand.

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