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Firm size, age, industrial networking, and growth: a case of the Korean manufacturing industry

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Abstract This paper investigates the roles of firm size, age, and industrial networking in determining firm growth. Analyses using the 2-year panel data of 7,889 Korean manufacturing firms between 1994 and 2003 confirm that firm size and age have significant negative effects on firm growth and significant positive impacts on firm survival. R&D and export activities are found to facilitate both firm growth and survival. The primary focus of this study is to examine the effects of industrial networking, such as subcontracting and clustering, on firm growth. The results show that subcontracting does not yield any positive effect for firm growth, but encumbers survival, which may be accounted for by the high subcontracting intensity among small firms. Clustering, on the other hand, is found to promote firm growth and survival. There is, however, little evidence that such a positive effect of clustering is derived from network externalities through cooperation and competition among firms in a cluster per se.

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1 Introduction

The role of small and young firms[1] in economic growth has been of critical interest to policy-makers for many decades. Numerous studies have been inspired by Gibrat's "law of proportionate effect" (Gibrat 1931) and found that smaller, younger firms are more likely to grow faster than larger, older firms in terms of the number of employees or amount of sales (Dunne and Hughes 1994; Evans 1987a, b; Geroski 1995; Hall 1987; Harhoff et al. 1998; Hart and Oulton 1996; Liu et al. 1999; McPherson 1996; Weiss 1998; Yasuda 2005).[2] The second set of

[1] In this paper, establishments, plants, and firms are used interchangeably.

[2] For a review, see Sutton (1997) and Audretsch et al. (2004). There are exceptions against this conventional wisdom. Acs and Audretsch (1990), Audretsch et al. (2004), and Delmar et al. (2003) reported that Gibrat's law on a firm's size-growth relationship cannot be rejected. Wagner (1992) found no strong evidence that smaller firms tend to grow faster than larger

determinants of firm growth considered in the succeeding studies of Mansfield (1962) includes strategic behaviors of firms, such as R&D and exporting activities (Doms et al. 1995; FitzRoy and Kraft 1991; Hall 1987; Yasuda 2005).

Since the 1980s, both firms and policy-makers have constantly intensified their attention to the growing importance of *industrial networking* in innovation and growth at the national, regional, or individual firm level. The notion of "network," often referred to as "quasi firms," has gained worldwide recognition as one of the major sources for economic growth, and this recognition is further stimulated by increased competition and rapid evolution of intricate technology in the context of fortifying economic uncertainty. In particular, networks of small and medium-sized enterprises have been considered to drive learning and innovation, which would enhance competitiveness of involving firms by providing vehicles to overcome their relatively scarce internal resources. These observations on the role of industrial networking in economic development provided a suitable arena for active policy intervention to nurture industrial networking among firms both in industrialized and in developing economies (Altenburg and Meyer-stamer 1999; Berry 1997; Organization for Economic Co-operation and Development 1999, 2001).

The previous studies on firm growth, however, have paid relatively little attention to the effect of *industrial networking*, and even fewer studies address the experience of newly industrialized economies (henceforth, NIEs). In the studies on industrial networking, "networking" of firms broadly means strategic alliances, research alliances, or any kind of collaborations between firms that involve exchange of goods, services, and technology. In practice, industrial networking is mostly identified as forms of either subcontracting or clustering.[3] Set against the vital policy interest in industrial networking as a development strategy, the existing empirical studies on the functions of industrial networking in firm growth provide ambiguous evidence and mostly rely on the cases of developed countries or particular industries (Yasuda 2005 for Japan; Wynarczyk and Watson 2005 for UK; Hill and Naroff 1984 for high-technology firms in the Silicon Valley). Few studies have addressed the role of industrial networking in growth by considering firm-level data in comprehensive industries based on the cases of NIEs where the growth of the small firm sector has mainly been explained by the intensity of industrial networking. Acknowledging this gap in the literature, this study aims to examine the relationship between size, age, industrial networking, and firm growth in the case of Korean manufacturing firms over the period of 1994–2003. Special attention is devoted to the roles of two industrial networking activities, subcontracting and clustering, on firm growth. Korea[4] is an exemplary country to understand whether industrial networking can be an effective strategy to support firm growth. First, Korean manufacturing firms have been comprehensively involved in industrial networking and large firms[5] have served a core role in this practice. Second, the growth of the 'small and medium enterprise' (SME) sector in Korea has been remarkable since the mid-1970s, as observed by Nugent (1996, 2002). Third, there has been an active role of the Korean government in the formation and evolution of industrial networks as one of the strategies of industrial policy during its rapid growth period, which might yeild some policy implications for developing countries.

This paper attempts to provide an empirical analysis of the patterns and determinants of firm growth among Korean manufacturing firms based on the long-term and micro-level data. The findings confirm "the stylized fact" (Geroski 1995) involving size, age, and growth relationships in the case of the Korean manufacturing industry: firm size and age have significant negative effects on firm growth and significant positive impacts on firm survival. R&D

Footnote 2 continued
firms. Lotti et al. (2003) suggested that smaller firms are likely to grow faster only in the early stage of their life cycle, while in the subsequent years the Gibrat's law cannot be rejected. Das (1995) suggested a strong positive effect of firm age on growth in the case of an infant computer hardware industry in India. Heshmati (2001) found a positive firm age-growth relationship in terms of assets and sales, while negative in the employment model of firm growth.

[3] In this paper, clustering, industrial complex, and industrial districts are used interchangeably.

[4] Korea means South Korea, unless otherwise noted.

[5] These big business conglomerates are often called *chaebols*. Among developed countries, Japan shares similar industrial structure with Korea, in which large firms play a leading role in the economy (Johnson 1982).

and exporting activities both are positively correlated with firm growth and survival when the relationship appears statistically significant. Subcontracting has no significant effect on firm growth and encumbers survival, which may be accounted for by the high subcontracting intensity among small firms. Clustering, on the other hand, significantly facilitates both firm growth and survival. There is, however, little evidence that such a positive effect of clustering is derived from network externalities through vertical cooperation and horizontal competition among firms in a cluster per se.

The remainder of this paper is organized as follows: Section 2 discusses previous studies on firm growth and industrial networking, and introduces the Korean manufacturing industry. Sections 3 and 4 describe the data and empirical methodology. In Sect. 5, the estimation results are presented. Section 6 concludes with policy implications and suggestions for future studies.

2 Firm growth and industrial networking

2.1 Previous studies on firm growth

The relationship between size and growth has been a major issue both in the theoretical and empirical literature on firm growth since Gibrat (1931). In his salient book, *Les Inegalites Economiques*, Gibrat postulates that the growth rate of firm size is equal for all firms regardless of the size of firms in their initial stage, which he names the law of proportionate effect (also known as "Gibrat's law"). Many empirical studies on firm growth have been conducted to verify Gibrat's law.[6] Early studies (Samuels 1965; Simon and Bonini 1958) support Gibrat's law, but subsequent empirical studies cast doubt on such an independence between firm growth and size. A negative relationship between growth and size is found in the US (Hymer and Pashigian 1962; Hall 1987; Mansfield 1962), whereas Singh and Whittington (1975) find a positive relationship in the UK. Though the sign is mixed, these studies all together renounce Gibrat's law.

To reconcile the discrepancy around Gibrat's law, most recent studies have related firm growth to firm age as well as size based on Jovanovic's "learning model" (Jovanovic 1982). This model assumes that firms learn their efficiency level through production experience, and only efficient firms grow and survive. Empirical evidence supports that growth is inversely related with age as well as size of a firm. Evans (1987a, b)[7] finds the inverse relationship among firm size, age, and growth using the data of US manufacturing firms between 1976 and 1982 and asserts that this finding is robust to the specification of the growth function, alternative assumptions on the sample censoring, and heteroskedesticity.[8] Bounded efficiency of a firm and diminishing returns to learning are the rationales for the inverse relationship of size, age, and growth since larger and older firms have less scope for further efficiency gain from growing and learning. Since Evans' study, the inverse relationships among firm size, age, and growth have been widely well established in a number of succeeding studies.

More recently, empirical studies for testing Gibrat's law have been enriched by an introduction of new methodology in the context of (un)balanced panel data models. Goddard et al. (2002) apply panel unit root tests to investigate the size-growth relationship among Japanese manufacturing firms and find strong evidence against Gibrat's law. Motivated by the methodological advantages of panel analysis over the conventional cross-sectional approaches, several studies carried out the panel unit root tests to verify Gibrat's law (Del Monte and Papagni 2003; Chen and Lu 2003; Geroski et al. 2003; Goddard et al. 2005;

[6] For details on Gibrat's law and follow-up studies, see Sutton (1997) and Caves (1998).

[7] There are more relevant studies using data from European, Asian, and African countries: Dunne and Hughes (1994); Hart and Oulton (1996); Kumar (1985), and Reid (1993) using UK data; Contini and Revelli (1989) for Italian firms; Almus and Nerlinger (2000); Harhoff et al. (1998), and Wagner (1992) using West German data; Mata (1994) for Portuguese manufacturing firms; Weiss (1998) for Austrian firms; Liu et al. (1999) using Taiwan data; Yasuda (2005) for Japan, and finally, McPherson (1996) using data on five countries in Southern Africa.

[8] Jovanovic (1982) proposes the special assumptions under which Gibrat's law still holds. If the distribution of firm efficiency is lognormal, firm growth is independent of size for firms of the same age. If firm costs are Cobb-Douglas with decreasing returns to scale, firm size is not relevant for age. If firm costs are Cobb-Douglas with decreasing returns to scale, firm size is not relevant for mature firms. However, these assumptions fail to be proved in Evans (1987a).

Oliveira and Fortunato 2006; Aslan 2008). With the variations in samples and estimation methods, the results are mixed in these studies.[9] Using the dynamic panel data models for an unbalanced panel of Portuguese manufacturing firms, Oliveira and Fortunato (2006) found that firm growth is not random and therefore Gibrat's law does not hold. On the contrary, Goddard et al. (2005) support Gibrat's law based on unit root tests for heterogeneous panels (Im et al. 2003) with a case of large US credit unions.

Another collection of empirical studies has considered firm-specific strategic behaviors, such as innovation and internationalization, as key determinants of firm growth. Findings suggest a positive relationship between firm growth and innovative activities (e.g., R&D investment and new technology adoption) (Doms et al. 1995; Ericson and Pakes 1995; FitzRoy and Kraft 1991; Hall 1987; Mansfield 1962; Yasuda 2005).[10] In relation to internationalization, a number of studies suggest the positive role of export activities in firm growth (McDougall and Oviatt 1997; Yasuda 2005).

The role of industrial networking has long been a prominent topic in the discussion both of firm growth and regional economic development. Industrial networking may benefit firms by augmenting the acquisition and spillover of knowledge or technology among participating firms. This, subsequently, enhances innovation and growth of a firm in the network. Among various forms of industrial networking, subcontracting and clustering have attracted special attention of policy-makers in their economic development.

Subcontracting is regarded to build up long-term business relationships between involving firms and thus to be an effective mechanism for small and medium firms to overcome their relatively weak knowledge status (Dore 1983; Friedman 1988; Grabher 1993; Powell 1990; Nishiguchi 1994; Hayashi 2005). Stimulated by the remarkable success of the Japanese automobile industry, the concept of "subcontracting" has attracted much attention in promoting the economic development of a country and managerial successes for a firm. Cooperative and competitive relations among firms that are organized in local community "clusters" may perform similar beneficial functions in firm growth (Chen 2002; Marshall 1920; Piore and Sabel 1984; Saxenian 1994). In particular, the economic geography and innovation literature has suggested that industrial location is a primary determinant of a firm's competences, such as R&D capacity (Narula and Santangelo, forthcoming). These advantages from "being there" can be obtained from the existence of positive agglomeration externalities, such as local supply of non-traded assets (Iammarino and McCann 2006 for a review).

Despite a number of case studies to analyze how subcontracting works in various industries and economies, empirical evidence for its relationship with growth at the firm level has been limited and inconclusive. Using data of Japanese manufacturing firms between 1992 and 1998, Yasuda (2005) shows that subcontracting to only one customer company, so-called "exclusive" subcontracting, has a negative but statistically insignificant effect on firm growth, whereas subcontracting significantly increases the probability of firm survival. In contrast, Wynarczyk and Watson (2005) find a significant positive relationship between growth and inter-firm partnership arrangements with members of their supply chain with the data of UK subcontractors from 1993 to 1999. It suggests that developing particularly close, long-standing, and strategically important ties with other supply chain members contributes to the growth of firms in terms of sales and employment.

As for clustering, its positive relations to firm growth are found most for high technology firms, such as in the biotechnology and pharmaceutical industries (DeCarolis and Deeds 1999; Hill and Naroff 1984). For example, Hill and Naroff (1984) find that firms within the Silicon Valley and Boston clusters have significantly higher actual returns than a sample of similar firms located elsewhere, using a sample of 102 firms from 1978 to 1981. This shows that high-technology firms benefit more from clustering because of knowledge spillovers as Pavitt (1987) suggested. Even if these studies emphasize the

[9] Geroski et al. (2003), Del Monte and Papagni (2003), and Goddard et al. (2005) have shown results in support of Gibrat's law. In contrast, Goddard et al. (2002), Chen and Lu (2003), Oliveira and Fortunato (2006) and Aslan (2008) demonstrated that Gibrat's law does not hold.

[10] For example, Mansfield (1962) finds that the successfully innovating firms grow about twice as rapidly as other comparable firms. The rewards for successful innovation seem to have been substantial for the short-term growth of smaller firms.

importance of clustering for innovation and growth of firms, most of empirical studies devoted the most attention to high-technology sectors in developed countries. There is little research on this issue, to our knowledge, to provide empirical evidence from firm-level data in comprehensive industries in NIEs.

2.2 Industrial networking in Korea

What really distinguishes Korea from other developed economies is the presence of greater industrial networking and a higher policy intervention in industrial network formation. Of the various types of industrial networking, subcontracting is the most prevalent form of networking among firms. According to the *Survey of Small and Medium Enterprises* conducted by the Korean Federation of Small and Medium Business (henceforth, KFSB), 59.2% of small and medium firms are involved in subcontracting transactions in 2006 (Korea Federation of Small and Medium Business 2007). Nugent and Yhee (2002) convincingly comment that in countries like Korea where the technology and associated intellectual property rights are rapidly evolving, collaboration of small and medium firms with successful large enterprises and other firms can be an effective way of overcoming the various constraints on their development. In fact, 42.8% of subcontracted firms receive technological support from the customer—the so-called "parent company" (Korea Federation of Small and Medium Business 2007). The share of subcontracted firms that receive the product design support from the parent company accounts for 36.3%. Management and finance supports are endowed to 19.4% and 8.1% of subcontractors, respectively.

Nevertheless, the expected positive networking effects from subcontracting are continuously controversial. The skeptical view is generated by the extraordinarily highly dependent and exclusive relationships between big parent companies and small subcontractors in Korea. The subcontracting intensity measured as the share of a firm's revenue from subcontracting relative to its total sales is 83.1% on average as of 2006 (Korea Federation of Small and Medium Business 2007). About 75% of small and medium subcontractors rely on subcontracting for over 90% of their total sales (Korea Federation of Small and Medium Business 2007). As for the relationship between subcontracting and firm growth, Song et al. (2004) argue that relentless deepening of the downward trend of employment size in subcontracted firms is mainly attributed to excessive price-cut pressure from the parent company. In a survey (Korea Federation of Small and Medium Business 2007), about 70% of subcontracted firms point out that they had difficulties because of price-cut pressure from their customers.[11] These firms also report that such pressure forces them to increase re-subcontracting to smaller firms, and this deteriorates their profit rate compared with that of large firms.[12] Correspondingly, there has been a concern that the government policy supporting small firms tied in cooperation with the local large firms might impede the growth of small and medium firms under the system where a very small number of large firms dominate the market and globalization becomes more intensified.

Networked firms in a cluster are expected to enhance learning, increase flexibility to respond to changing circumstances, and achieve easy and open exchanges of information. The information about business opportunities, innovation, and incremental improvement in products or processes can circulate swiftly in industrial districts. However, whether clustering produces such benefits for firms in Korea is barely substantiated.

Industrial complexes are also a widespread form of industrial networking in Korea. The number of industrial complexes in Korea reached 650 in 2007 (Korea Ministry of Commerce, Industry and Energy, and Korea Industrial Complex Corporation 2008). There were over 40,000 firms and about 1.3 million employees working in these industrial complexes. According to the *Industrial Census,* 22.9% of all manufacturing firms were located in industrial complexes, and they produced 56.8% of the total value of shipments in 2003 (Korea National Statistical Office 2004).

It should be noted that unlike the Third Italy in which volunteering, mutually competitive and

[11] Other difficulties in relation to subcontracting transactions include the receipt of irregular and unexpected orders (47.2%) and sudden curtailment of delivery terms (39.2%) (Korea Federation of Small and Medium Business 2007).

[12] In 2004, more than half of subcontracted firms partly or totally re-subcontracted their work to other firms (Korea Federation of Small and Medium Business 2005). The gap between big firms and SMEs in terms of the profit rate and productivity has become wider (ibid.).

cooperative traits are driven by networked small firms, Korea's industrial complexes originated from and evolved through one of the industrial policies steered by the central government. In its early stage, the industrial complex was designed to support exporting large firms by means of mitigating their initial investment with various taxation support systems and by means of providing a well-established infrastructure, such as transportation and water services (Seo and Park 2003). In this regard, much research (Bok et al. 2002; Cho 2005; Koh 2004; Hassink 2001) concerns the fallacy of a central government-driven policy on the industrial complexes, indicating the lack of both spontaneous networking among small firms and a strong partnership with the local community (Hassink 2001 for a discussion of the *dirigiste* innovation system). In order to verify previous debates on industrial networking and to better understand the role of industrial networking in Korea, this study presents empirical evidence about the effect of subcontracting and clustering on firm growth following the model in Evans (1987a, b).

3 Data

The primary data for this study are extracted from the *Report on Mining and Manufacturing Survey* (henceforth, RMS). This survey is annually conducted by the Korea National Statistical Office on manufacturing establishments whose number of employees is five or more.[13] The survey includes a variety of information, such as paid-up capital, opening year, number of employees, value of shipments, and value added. As plant level data, the survey also provides information regarding a firm's strategic behavior, such as whether a firm conducts R&D and whether it exports or not. The information on industrial networking is divided into two categories: subcontracting and clustering. The definition of subcontracting in this survey is confined to the contract work that was done by a firm with materials provided by the parent company. A firm is identified as clustered if it is located in any industrial complex designated and managed under comprehensive plans by the central or local government according to the Industrial Site and Development Act of Korea.

We used a two-year panel of 1994 and 2003 RMS waves. In 1994, a total of 91,372 firms were observed (all firms), but some of these firms exited from the market[14] by year 2003, and only 7,889 firms (surviving firms) are captured in the 2003 wave. We show the descriptive features of all firms and surviving firms, respectively, for the purpose of illustrating whether these two groups of firms are distinctively characterized due to the survival selection.

In the remaining multivariate analyses, we explicitly address the possible bias from selective survival of firms. For the identification of the survival selection equation, we use the sample of all firms to classify the base group of exiting firms and the treatment group of surviving firms.

The growth rate of a firm is measured as the annual logarithmic growth rates of the number of employees between 1994 and 2003.[15] Since this measure of firm size can be obtained only for surviving firms, the firm growth equation is estimated using the sample of surviving firms.

Table 1 shows the descriptive statistics of key variables for surviving firms and for all firms, respectively. The average growth rates between 1997 and 2003 are negative for both groups of firms. Not surprisingly, surviving firms seem to be in a

[13] The Korean government conceals information of certain firms for the purpose of confidentiality. For example, if a firm is the only one to run the business of a particular industry in an administration district, data on this company are missing. In order to secure as much data as possible, the two-digit industry code is used instead of the five-digit one following the Korea Standard Industrial Classification.

[14] Usually, "exit" of a firm means that the firm fails and disappears during the observation period. However, in this paper, firms in which the number of employees has shrunk below five are also regarded as the exiting firms due to the survey design.

[15] There are alternative ways to measure the extent of firm growth, such as sales or employment of a firm. According to Delmar (1997), 30.9% of the previous studies on firm growth relied on the sales variable, while 29.1% of studies used the number of employees of a firm as the measure of firm growth. However, the employment size is regarded as most reliable in terms of data quality compared to alterative measures (Liu et al. 1999). Using the size of employment as the proxy of firm size, we were able to compare the case of Korean manufacturing firms with other studies on developed countries without facing with the measurement incompatibility across studies (Acs and Audretsch 1990; Evans 1987a, b; Farinos and Moreno 2000; Harhoff et al. 1998; Organization for Economic Cooperation and Development 2002).

Table 1 Descriptive statistics

Sample	Surviving firms		All firms (including exit firms)	
Variables	Mean	SD	Mean	SD
Growth rate				
Overall	−0.02	0.07	−0.04	0.20
Positive	41.3%		44.8%	
Negative	58.8%		55.2%	
Size				
Overall	72.1	580.5	32.1	221.5
Small (<50)	76.8%		89.6%	
Medium (<300)	20.2%		9.35%	
Big (>300)	3.02%		1.00%	
Age				
Overall	10.1	7.6	7.8	6.6
Young (0–9)	59.4%		72.4%	
Old (>10)	40.6%		27.6%	
Subcontracting				
Subcontracting	24.0%		29.1%	
Intensity[a]	73.6%		85.1%	
Total dependency[b]	64.9%		79.3%	
Clustering				
Clustering	27.0%		15.4%	
Subcontracting[c]	24.7%		27.3%	
Major industry[d]	34.2%		36.4%	
Exporting	21.2%		11.9%	
R&D	11.4%		6.1%	
N (the number of firms)	7,889		91,372	

Notes: [a, b] Subcontracted firms only. [c,d] Clustered firms only

Subcontracting intensity is measured as the ratio of revenue from subcontracting to total value of shipment

better position in growth as their average growth rate (−0.02) is larger than that of all firms (−0.04). However, 58.8% of surviving firms show negative growth rates, whereas the figure is 55.2% for all firms. These findings, put together, suggest that surviving firms may have a stronger tendency to shrink in size, but once they have a chance to grow, the growth rate is on average higher than the case of all firms, which explains the smaller average extent of size reduction among surviving firms. Much lower standard deviation of surviving firms (0.07) than of all firms (0.20) also indicates that surviving firms are more homogenous in terms of their characteristics related with growth determination.

The most conspicuous contrast between the two samples is found in the average firm size. The average number of employees of surviving firms is 72.1, while the figure for all firms is 32.1. This means that out of all firms, relatively large firms are more likely to survive for 10 years. In both samples, the number of small firms, defined as having fewer than 50 employees, is overwhelmingly large: 76.8% for surviving firms and 89.6% for all firms. These ratios clearly indicate the heavy reliance of the Korean manufacturing industry on small firms. Firm age is calculated by counting years between the year of establishment and the year of 1994 with 1 year added to it. Surviving firms (10.1) are on average older than all firms (7.8), which suggests that older firms on average have a better chance to survive.

With respect to industrial networking, the share of subcontracted firms among surviving firms (24.0%) is lower than among all firms (29.1%). In the sub-sample of subcontracted firms, the subcontracting intensity, measured by the ratio of a firm's revenue from subcontracting to its total value of shipments, is lower for surviving firms (73.6%) than for all firms (85.1%). The percentages of totally dependent firms, defined as the firms whose intensity of subcontracting is 100%, are very high in both cases: 79.3% of all firms and 64.9% of surviving firms. It implies that intensive subcontracting activity and strong dependency on it may have a detrimental effect for firms to survive.

Surviving firms are more likely to be clustered (27.0%) than all firms (15.4%). Among clustering firms, however, the tendency of subcontracting is not very distinct for both groups (24.7% for surviving firms and 27.3% for all firms). In addition to subcontracting, the concentration of a major industry[16] is considered as the key source for benefits from clustering. Hypothetically, subcontracting activity among clustered firms may be beneficial for firms through vertical cooperation among clustered firms, and running in highly condensed industry in a cluster may generate horizontal competition among clustered

[16] The major industry is defined as the industry of the highest concentration ratio within a cluster. The concentration ratio of an industry within a cluster is calculated by dividing the number of employees in a given industry into that of all firms in a given cluster. The variable of "major industry" is used as the indicator for the density of networking among firms in the same industry within a cluster. Industry is classified according to the two-digit Korean Standard Industrial Classification.

firms, which may drive these firms to yield better performance and thus to have higher chances of surviving and growing. The concentration ratio of the major industry within a cluster is just above 30%, not much different between surviving (34.2%) and all firms (36.4%).[17]

4 Estimation model

In line with Evans (1987a, b) and followers (Das 1995; Heshmati 2001; Liu et al. 1999; Yasuda 2005), we define firm growth (G) as the function of firm size (S) and age (A):

$$G \equiv (\ln S_{t'} - \ln S_t)/(t' - t) = \ln G(S_t, A_t) + \upsilon_t \quad (1)$$

where t and t' denote the date to which the 1994 and 2003 data apply, respectively, and υ_t is the disturbance term assumed to be normally distributed with mean zero and possibly a non-constant variance, and to be independent of size (S) and age (A). Using a second-order logarithmic expansion of $\ln G(S_t, A_t)$, the regression equation of the firm growth function in Eq. 1 is rewritten as follows:

$$G = \beta_0 + \beta_1 \ln S_t + \beta_2 \ln A_t + \beta_3 (\ln S_t)^2 + \beta_4 (\ln A_t)^2 + \beta_5 (\ln S_t)(\ln A_t) + \upsilon_t \quad (2)$$

In Eq. 2, age (A) is measured in years from the birth of a firm to 1994. The size (S) is measured by the number of employees in a firm. Both age and size measurements are of logarithmic form.

To investigate the relationship between firm growth and industrial networking, the firm growth function in Eq. 2 is extended to include variables for subcontracting, clustering, and other firm characteristics given as:

$$G = \ln G(S_t, A_t) + \gamma_1 \mathrm{subc}_t + \gamma_2 \mathrm{clstr}_t + \delta X_t + v_t \quad (3)$$

where v_t is the normally distributed error term with possibly a non-constant variance across firms. The key explanatory variables in Eq. 3 are industrial networking dummy variables: subcontracting and clustering. The binary variable of subcontracting, subc, takes 1 if a firm conducts subcontracting and 0 otherwise. The clustering dummy, clstr, takes 1 if a firm belongs to an industrial complex and 0 otherwise. X includes a set of dummy variables for a firm's strategic behaviors, such as R&D and exporting status, both of which are well established as key determinants of firm growth. The R&D dummy variable takes 1 if a firm invests in R&D activity and 0 otherwise. The exporting dummy variable takes 1 if a firm undertakes exporting activity and 0 otherwise.

We follow the framework of Rauch (1999) to consider the effects of "the degree of product differentiation" and "proximity" on networking. These factors (henceforth, Rauch factors) are noted to influence the choice of produce to order among networked firms (Rauch 1999). To inspect these possibilities, first we reclassify the Korean Standard Industrial Classification (KSIC ver8) codes into Rauch's three categories of the differentiation of goods: "organized exchange," "reference priced," and "differentiated" products. These categories are quantified as three dummy variables in our models. Second, the distance is approximated by the "regional concentration" of a particular industry in a given region as a proxy of proximity attribute. Specifically, we use the logarithm variable of "location quotient (LQ)" as the indicator of proximity (Bennet et al. 1999).[18]

The issue of sample selection bias, acknowledged first by Mansfield (1962), may rise if the growth–size–age relationship is estimated using Eq. 3, since firms that were in operation in 1994 but exited before 2003 are not considered in the sample. If the exiting status of a firm is determined by an unobserved or uncontrolled factor that also determines the growth–size–age relationship, the estimated coefficients drawn from the surviving firm sample would represent a biased effect of firm size and age on firm growth. Table 1 implies that the exit rate may be closely related to beginning-of-period firm size, age, and other variables. If smaller and younger firms are more likely than larger and older firms to exit, the estimated parameters drawn based on surviving firms alone will be biased due to the negative size–age–survival relationship.[19] Unlike Liu et al.

[17] Results of Table 1 on differences in characteristics between surviving firms and all firms are all statistically significant at the 5% level by the mean equivalence test.

[18] Details on how to obtain the LQ variable may be derived from Bennet et al. (1999) and Fingleton et al. (2004).

[19] This issue is acknowledged and empirically investigated in many studies related to Gibrat's law using US and European countries, such as Dunne and Hughes (1994), Hall (1987), Harhoff et al. (1998), Mata (1994), and Weiss (1998).

(1999) who also pay attention to the possibility of sample selection bias but are unable to incorporate this issue in the analysis of Taiwanese firms, we explicitly control the sample-selection problem caused by endogenous survival of firms using Heckman's selection correction model (Heckman 1979).

The probability that a firm survives from t to t' is represented by the following selection function:

$$\text{survival}^* = \alpha_0 + \alpha_1 \ln S_t + \alpha_2 \ln A_t + \theta_1 \text{subc}_t + \theta_2 \text{clstr}_t + \phi X_t + u_t \quad (4)$$

where survival* is a latent variable observed as a binary indicator, survival in 2003. Survival = 1 if survival* > 0 and survival = 0 otherwise. The error term (u_t) is assumed to have a normal distribution. Similar to the firm growth function in Eq. 3, the selection process in Eq. 4 is defined to linearly depend on firm size and age (Evans 1987b) and additionally rely on industrial networking and other firm-specific conditions.

In addition to the sample selection problem, the possibility of heteroskedasticity should be taken into account since Jovanovic (1982) predicts in his learning model that the variance of firm growth rate is inversely related to firm age. More generally, if the variance of unobserved factors that affect the growth rate depends on any of covariates, such as firm size, heteroskedasticity may arise. To address this statistical issue, the heteroskedasticity-robust consistent estimator for standard errors is calculated using a method proposed by White (1980).

5 Results

5.1 Firm size, age, and growth

Table 2 presents the selectivity-corrected maximum likelihood estimates. Model 1 is a simple form to specify firm growth as a function of logarithms of size, age, and their quadratic and interaction terms. Industrial networking and other firm-specific variables are excluded. In model 1, we examine first whether the stylized facts regarding the relation among firm size, age, and growth rate hold true in the Korean case.

A pair of industrial networking variables is added to model 2, and the role of remaining variables such as R&D and exporting are estimated in model 3. In models 1–3, the estimated coefficients of size and age are negative and statistically significant at the the 1% level. The negative relationship between firm growth and size confirms renouncing evidence against Gibrat's law suggested by Liu et al. (1999), McPherson (1996), and Yasuda (2005). The negative relationship between growth and age is consistent with Jovanovic's model and Evans' results. In model 4, when we additionally control for Rauch factors, the negative relation between firm size-growth remains statically significant, but the firm age-growth association becomes insignificant.

In all four regression models, the quadratic term of firm size is found to have positive effects on growth, whereas the quadratic term of age has negative effects on growth. The interaction variable of size and age is statistically insignificant with its coefficient close to zero. This finding shows the convex relationship between growth rates and size, indicating diminishing marginal effects of size, which is consistent with Evans (1987b), Dunne et al. (1989), and Liu et al. (1999) in the case of US firms. In contrast, the concave relationship between growth rates and age suggests that firm growth depreciates more rapidly as firms get older.[20]

The coefficients of firm size and age are positive and statistically significant in the survival-selection function in all four specifications. This implies that a larger and older firm is more likely than a smaller and younger one to survive, indicating the possible selectivity in the sample of surviving firms. Even when the selectivity in firm survival due to observed factors such as size and age is controlled for in models 1–3, a statistically significant negative selection bias remains, generated by unobservable determinants of firm survival. Model 4, however, finds a positive selection bias, which suggests that once Rauch factors of a firm are controlled for, unobserved firm-specific characteristics may work in such a way that surviving firms tends to grow faster.

[20] As it is not easy to directly investigate the relationships among firm size, age, and growth due to their quadratic and interaction coefficients, the percentage of firms of which partial derivatives of the growth function with respect to size and age are positive (or negative) is computed using the estimates of model (4): for 96.3% of all firms, size effects were negative, and for 93.5% of all firms, age effects were negative. This result shows that, in most firms, firm size and age have a negative effect on firm growth, which confirms the result of most previous studies, including Evans (1987a, b).

Table 2 Firm size, age, industrial networking, and growth

	Variables	(1)	(2)	(3)	(4) (Rauch factors)
Growth function	ln(size)	−0.063**	−0.066**	−0.063**	−0.038**
		(19.34)	(19.95)	(19.49)	(10.39)
	$\ln(size)^2$	0.004**	0.004**	0.004**	0.004**
		(10.01)	(10.05)	(9.41)	(8.59)
	ln(age)	−0.013**	−0.013**	−0.012**	0.005
		(3.35)	(3.31)	(3.06)	(1.26)
	$\ln(age)^2$	−0.002*	−0.002*	−0.002*	−0.002*
		(1.97)	(2.46)	(2.08)	(2.34)
	ln(size)*ln(age)	−0.000	0.000	−0.000	−0.001
		(0.24)	(0.41)	(0.45)	(1.06)
	Subcontracting		−0.000		−0.001
			(0.04)		(0.72)
	Clustering		0.005*		0.024**
			(2.22)		(9.28)
	Exporting			0.003	0.005*
				(1.43)	(2.14)
	R&D			0.015**	0.016**
				(4.95)	(5.23)
Selection function	ln(size)	0.268**	0.244**	0.258**	0.235**
		(47.23)	(39.62)	(39.29)	(34.44)
	ln(age)	0.136**	0.133**	0.134**	0.127**
		(17.92)	(17.14)	(17.27)	(16.17)
	Subcontracting		−0.089**		−0.042**
			(6.32)		(2.84)
	Clustering		0.203**		0.201**
			(12.56)		(12.29)
	Exporting			0.046*	0.029
				(2.40)	(1.49)
	R&D			0.056*	0.026
				(2.30)	(1.06)
	ρ(rho)	−0.763**	−0.763**	−0.772**	0.677**
	λ(lambda)	−0.069**	−0.068**	−0.070**	0.055**
	Log pseudolikelihood	−14,964.56	−14,284.18	−14,390.82	−14,124.59
	No. of observations	91,156	88,350	88,350	88,350
	Censored observations	83,278	80,784	80,784	80,784

Notes: Robust z statistics in parentheses

* Significant at 10%;
** Significant at 5%;
*** Significant at 1%

5.2 Subcontracting and firm growth

The results of models 2 and 4 presented in Table 2 show that subcontracting has no statistically significant effect on firm growth, whereas it negatively affects firm survival. The negative relationship between subcontracting and firm survival calls for careful consideration. One of the major advantages of subcontracting is business stability of subcontracted firms as subcontracting is usually long-term and trust based. An empirical study by Yasuda (2005) using data of Japanese firms supports this idea by finding that a subcontracted firm is more likely to survive than a non-subcontracted firm.[21] The contradictory findings here may be attributed to the discrepancy in

[21] Insignificance of subcontracting effect on growth is also inconsistent with Song et al. (2004), who suggest that the

market structure across countries.[22] In particular, the high subcontracting intensity in Korean subcontracted firms might challenge the survival of these firms, for example from the relatively weak profit status due to price-cut pressure from the large customer firms. To explore this possibility, a subsample of subcontracted firms is used to estimate the growth function and survival-selection function. In Table 3, the subcontracting intensity is found to be negatively related to subcontracted firms' growth in model 1, but this effect turns out insignificant in model 2 where the Rauch factors are controlled for. On the other hand, the intensity of subcontracted firms is significantly and positively related to firm survival at a diminishing rate, and this finding is robust to the Rauch factors as shown in models 1 and 2. This nonlinear relationship between the dependency rate on subcontracting and firm survival is consistent with findings in Park (2006).

Although subcontracted firms are more likely to survive if they depend more on subcontracting activity, this benefit of subcontracting on survival seems to rapidly dwindle as the dependency gets intense. Similarly, total dependency is found in models 3 and 4 to be negatively related with a subcontracted firm's survival. This negative effect of total dependency along with the small and diminishing positive effect of the subcontracting intensity on firm survival is likely to yield the inverse relationship between subcontracting and firm survival for the entire firms. It implies that in the case of Korea, the risk from heavy reliance of subcontracting outweighs the potential benefit of business stability from the long-term relationship.

5.3 Clustering and firm growth

Table 2 also presents the estimated effects of clustering on firm growth and survival. The results demonstrate that clustering has statistically significant and positive effects both on growth and on survival, as Porter (1990, 1998) points out. Clustering seems to facilitate positive externalities through networking under the circumstance in which firms in the same and related industries, specialized suppliers, and services in a particular field are geographically adjacent to each other.

Nevertheless, one question needs to be carefully addressed before we discuss the causal relationship between clustering and firm growth: what mechanism yields such positive effects of clustering? This question is particularly relevant in the case of Korea since the lack of voluntary networking among firms and the prevailing role of government in creating industrial networking have pointed out a distinctive feature of Korea. To examine if such positive effects are derived from industrial networking per se or from other industrial aspects, we used the sub-sample of clustered firms and investigated the effects of networking in a cluster using two explanatory variables: the subcontracting status as an indicator of vertical cooperation and the major industry dummy as an indicator of horizontal competition among clustered firms.

In all three models of Table 4, subcontracting has no statistically significant effects on firm growth and on survival. The major industry indicator has a negative but only insignificant effect both on firm growth and on survival. These findings suggest that the positive effects of clustering on firm growth and survival might not stem from networking among clustered firms.

6 Conclusion

In this paper, the relationships among firm size, age, industrial networking, and growth are analyzed using the plant-level survey data of the Korean manufacturing industry. Special attention is paid to the role of industrial networking defined as subcontracting and clustering. We find first firm growth decreases with firm size and age, which suggests that Gibrat's law does not hold, but empirically verifies Jovanovic's prediction. By contrast, firm size and age are positively correlated with firm survival. In general, the relationship of size and age with manufacturing firm growth is found similar among NIEs, including Korea and developed economies.

Footnote 21 continued
subcontracting firm is less likely to grow due to excessive price-cut demand from the parent company.

[22] Technically, different data sources and variable definitions may also bring on ambiguity in empirical results. Yasuda's study (2005) is based on Japanese manufacturing firms with 50 employees or more and subcontracting firms for only one parent company. This paper, on the other hand, deals with Korean firms with five employees or more, and subcontracting is limited to the form that the parent company provides material for subcontractors.

Table 3 Subcontracting dependency rate and firm growth: subcontracted firms only

	Variables	(1)	(2) (Rauch factors)	(3)	(4) (Rauch factors)
Growth rate function	ln(size)	−0.072**	−0.043**	−0.072**	−0.042**
		(9.28)	(5.04)	(9.35)	(4.99)
	$\ln(size)^2$	0.006**	0.005**	0.006**	0.005**
		(5.24)	(4.88)	(5.31)	(4.86)
	ln(age)	−0.005	0.007	−0.005	0.008
		(0.76)	(1.01)	(0.72)	(1.02)
	$\ln(age)^2$	−0.001	−0.001	−0.001	−0.001
		(0.49)	(0.40)	(0.56)	(0.41)
	ln(size)*ln(age)	−0.004*	−0.005**	−0.004*	−0.005**
		(2.50)	(2.69)	(2.40)	(2.68)
	ln(s_intensity)	−0.006*	0.015		
		(2.50)	(0.39)		
	$\ln(s\_intensity)^2$	0.001*	−0.028		
		(2.48)	(0.57)		
	Total dependency			0.007	−0.003
				(1.59)	(0.65)
	Exporting	−0.000	−0.009	0.003	−0.008
		(0.01)	(1.37)	(0.38)	(1.25)
	R&D	0.013***	0.015*	0.017*	0.015*
		(1.81)	(2.37)	(2.27)	(2.39)
Selection function	ln(size)	0.285**	0.286**	0.280**	0.282**
		(21.34)	(21.44)	(21.26)	(21.34)
	ln(age)	0.137**	0.131**	0.133**	0.129**
		(8.87)	(8.35)	(8.64)	(8.23)
	ln(s_intensity)	0.046*	0.753*		
		(1.99)	(2.10)		
	$\ln(s\_intensity)^2$	−0.018**	−1.229**		
		(4.08)	(2.75)		
	Total dependency			−0.191**	−0.147**
				(6.10)	(4.50)
	Exporting	−0.078	−0.085	−0.102***	−0.101***
		(1.35)	(1.46)	(1.82)	(1.79)
	R&D	0.043	0.030	0.026	0.021
		(0.72)	(0.50)	(0.44)	(0.35)
	ρ(rho)	−0.812**	0.375***	−0.813**	0.380***
	λ(lambda)	−0.076*0*	0.025***	−0.076**	0.025
	Log pseudolikelihood	−3,753.90,	−3,722.48	−3,751.52,	−3,721.83
	No. of observations	26,081	26,081	26,081	26,081
	Censored observations	24,242	24,242	24,242	24,242

Notes: Robust z statistics in parentheses

* Significant at 10%;
** Significant at 5%;
*** Significant at 1%

Second, subcontracting does not have a statistically significant effect on firm growth, but has a negative significant effect on survival. In the analysis of the sub-sample of subcontracted firms, intensive subcontracting is found to be detrimental for firm survival. This finding suggests that although subcontracting conceivably provides small firms with multiple benefits, such as technology transfer from interactive cooperation with large firms, the subcontracting intensity, if excessive, might make small

Table 4 Industrial networking and firm growth: clustered firms only

	Variables	(1)	(2)	(3) (Rauch factors)
Growth function	ln(size)	−0.050**	−0.036**	−0.035**
		(8.19)	(8.02)	(5.10)
	$\ln(size)^2$	0.003**	0.003**	0.003**
		(3.74)	(3.72)	(3.08)
	ln(age)	−0.015***	0.001	0.001
		(1.94)	(1.72)	(0.13)
	$\ln(age)^2$	−0.002	−0.003***	−0.003***
		(1.30)	(1.30)	(1.69)
	ln(size) * ln(age)	−0.000	−0.001	−0.001
		(0.22)	(0.46)	(0.61)
	Subcontracting	−0.006	−0.006***	−0.001
		(1.56)	(1.47)	(0.31)
	Major industry	−0.005	−0.009**	−0.004
		(1.14)	(1.28)	(1.16)
	Exporting		−0.005	−0.004
			(1.90)	(1.26)
	R&D		0.019**	0.018**
			(2.53)	(4.51)
Selection function	ln(size)	0.184**	0.163**	0.164**
		(15.46)	(12.15)	(11.98)
	ln(age)	0.138**	0.139**	0.137**
		(8.20)	(7.95)	(8.20)
	Subcontracting	−0.038	−0.022	0.010
		(1.18)	(0.78)	(0.30)
	Major industry	−0.030	−0.032	0.007
		(1.28)	(1.13)	(0.22)
	Exporting		0.058	0.059***
			(1.75)	(1.67)
	R&D		0.090*	0.081*
			(2.10)	(2.07)
	ρ(rho)	−0.857**	0.065	0.051
	λ(lambda)	−0.086**	0.004	0.003
	Log pseudolikelihood	−2,826.70	−2,835.91	−2,811.30
	Observations	13,576	13,576	13,576
	Censored observations	11,532	11,532	11,532

Notes: Robust z statistics in parentheses

* Significant at 10%;
** Significant at 5%;
*** Significant at 1%

firms vulnerable to risk and the failure of their contractors, which eventually hinders firm survival.

Third, we find supporting evidence that clustering enhances a firm's capability to grow and survive. However, the benefit of operating in an industrial complex might not come from either vertical cooperation or horizontal competition among clustered firms, which implies that other government support targeted to clustered firms, for instance, low financing costs, long-term land lease, and certain tax exemptions may be underlying reasons for the positive clustering effect on firm performance.

Although the close business ties among firms mostly driven by the central government have been partly dismantled and restructured since the financial crisis in 1997, the hardship of an individual firm to enhance and maintain international competitiveness keeps raising policy demand for industrial networking

(Bok et al. 2002). Findings of this paper may shed a light on policy strategies for restructuring industrial networking in Korea at a crossroads. Further lessons for other countries that plan to pursue industrial networking as a key to economic growth can be drawn. Subcontracting may not be a valid strategy in enhancing the growth and survival of small firms if their dependency on parent companies is so high as to undermine the expected positive effect of subcontracting. Clustering can be a fine alternative strategy to subcontracting in terms of firm growth and survival. It is noteworthy, however, that such positive effects of clustering may not be the pure networking effect among firms, but rather the effect of government policy on popularizing clustering activity among firms.[23] Therefore, additional policy efforts are necessary in order to circumvent potentially undesirable networking effects of high subcontracting intensity and to create a better environment for networking-based mechanism in a cluster.

Some limitations of this study should be noted. Subcontracting in this study is restricted to the form of transactions conducted by a firm with materials provided by the parent company. Also, the classification of the major industry in a cluster fails to include interconnected industries that have forward and backward linkages. Firms' internal features, such as human capital characteristics of proprietor or ownership structure, are excluded from our analyses due to the lack of information. Further research using richer data would be helpful to make conclusive indications on the interactive role of industrial networking and non-networking incentives of clustering.

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