Does Structural Hole Relieve Density Dependent Competition? Growth and Exit of Korean Mining and Manufacturing Plants, 1981-1999*

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This paper examines the effect of inter-industrial network on the competitive outcome of Korean firms between 1981 and 1999. We look for a way to integrate "structural hole" theory of market and organizational ecology in explaining the competition among firms for survival and growth. Especially the concept of niche, central to ecological theory, can be measured using the idea that structural autonomy of industry in input-output network determines the industry's niche width. Combining data from input-output table and establishment census between 1981 and 1999, we test two hypotheses that organizations in highly autonomous industry should show lower mortality rates and higher growth rates, and that the competitive effect of density should be lower under the condition of high autonomy in input-output network. Overall, the results from event history analysis for mortality rates and pooled-time series analysis for growth rates confirm our hypotheses.

Keywords: Structural Hole, Niche Width, Organizational Mortality, Organizational Growth, Community Ecology, Density Dependence

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INTRODUCTION

This paper examines the effect of inter-industrial network on the competitive outcome of Korean mining and manufacturing plants between 1981 and 1999. Taking advantage of data from a comprehensive survey covering entire range of industries and plants, we investigate the interplay of inter-industrial network and intra-industrial dynamics in shaping the competitive environment for firms in various industries. More specifically, we look for a way to integrate "structural holes" theory of market (Burt 1992) and ecological theory of organizational population (Carroll and Hannan 2000; Hannan and Freeman 1989) in explaining the competition among firms for survival and growth. While they are two major theoretical resources for understanding competitive dynamics among organizations, differences between two theories have often been highlighted by organizational researchers.

This study is motivated by the belief that two theories are more complementary than competing with each other and that there are many unrealized opportunities for collaboration. Although the possibility has already been suggested (Burt and Talmud 1993), it has yet to be taken up and fully developed by organizational researchers. One of the barriers for this development has been data problem. Combining the ideas of structural holes and organizational ecology in empirical research requires comprehensive data that cover broad time span and various industries. Comprehensive establishment survey in Korea provides us with data on plants over nearly twenty years across various industries so that we can investigate the interplay of industrial network structure and population dynamics in shaping the competitive environment for firms.

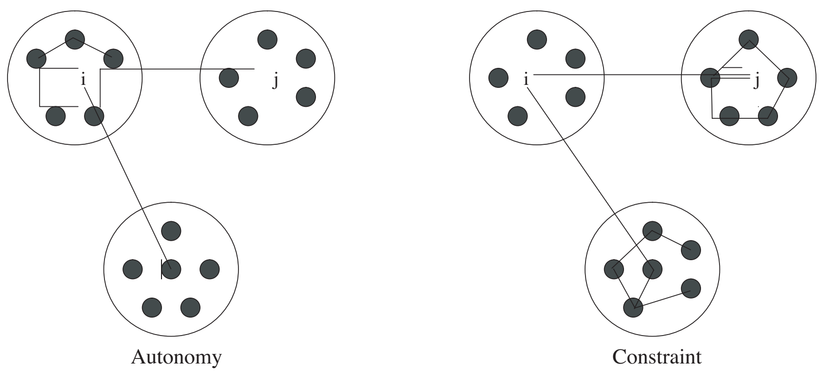
NETWORK-BASED MEASURES OF NICHE

Both social network theory and organizational ecology try to explain social structure of competition among organizations. There are ample possibilities for cross-fertilization between the two approaches. Cooperative efforts between the two have centered on the concept of niche. Niche is defined in ecology as "the set of environmental conditions within which a population can reproduce itself" (Hannan and Freeman 1989: 96). But more concretely niche implies a mix of resources in environment supporting a certain form of organizations. The concept of niche is central in studying the competitive interaction among organizations. In organizational ecology, organizations are in competition as long as they feed on the same niche. The intensity of competition depends on the degree of niche overlap. The higher the degree of niche overlap between two organizational populations, the more intense the competition between the two. Although niche is a central concept in ecology, it has not always been simple or easy for analysts to operationalize and measure in empirical studies.

It was DiMaggio (1986) who first suggested the possibility that network analysis can help empirically measure the concept of niche. However it was much later that such possibility was realized in ecological researches. One line of research tried to model the direct competition between the pairs of organizations employing the tools of social network analysis (Hannan and Carroll 1992: 190-1; Podolny, Stuart, and Hannan 1996). McPherson, Popielarz, and Drobnic (1992) and Popielarz and McPherson (1995) measured voluntary associations' niche position and overlap based on the network ties between the members and also members' socio-demographic characteristics. They analyzed the voluntary associations' membership change as an outcome of competition among these organizations for members, which depends on the member's network ties and multi-dimensional space of socio-demographic characteristics. In their study of worldwide semiconductor industry, Podolny, Stuart and Hannan (1996) measured "technology space" based on the ties of patent citations, located organization-specific niche on that space, and explained differences in organizational growth rate by the organization's position on the niche space.

Similar but slightly different approach came from Burt (1992). Rather than applying network tools for measuring the structure of niche itself, Burt (Burt and Talmud 1993) proposed to measure niche width using social network analysis. Burt claimed that it is the structural autonomy of an industry in the network among industries that determine the niche width of the industry. The greater the structural autonomy of a market, the wider the niche, and the more likely that diverse organizational forms can survive in the market niche (Burt 1992: 226). Structural autonomy is defined as having relationships "free of structural holes at their own end and rich in structural holes at the other end (Burt 1992: 49)," when structural hole is defined as lack of ties in the network (cf. Figure 1). When applied to markets defined by network across industries, the idea of structural autonomy predicts that a market not constrained by its transacting partners and controlled by small number of dominant players will

Figure 1. Network Autonomy and Constraint



enjoy higher profit margin and potential for future growth. In the language of organizational ecology, structural autonomy allows a population to enjoy wide niche supporting more organizations and thus lowers competitive intensity.

Following Burt's suggestion, Han (1992) and Talmud and Mesch (1997) found that firms within markets characterized by low structural autonomy tend to show higher levels of instability. Their analysis of rank turnover of leading firms in US and Israeli markets showed that market leaders survive longer as leaders in more autonomous markets. Burt (1992) reanalyzed the data that Carroll (1983) used for the test of age dependence in organizational mortality and showed that structural autonomy of market that organizations belonged to increased survival chances of organizations early in their life histories. We can find evidence of autonomy effect on organizational outcome from Korean case as well. Yee (1996)'s analysis of Korean input-output table in 1990 has shown that the profit margins of markets and firms vary according to the autonomy or constraint derived from the structure of networks among markets.

We derive the first hypothesis from the foregoing discussion as follows:

Hypothesis 1: Autonomous industry has wider niche and should lower exit rates and increase growth rates of organizations in the industry.

MARKET AUTONOMY AND DENSITY DEPENDENCE

Previously we discussed the relationship between market autonomy and opportunities for survival and growth enjoyed by organizations in the market. If we call this a *first-order* effect of market autonomy on organizational outcome, we can also think of *second-order* effect of market autonomy in addition. The *second-order* effect of autonomy on organizational outcome is mediated by the density dependent competition in organizational population.

The theory of density dependence in organization ecology claims that two underlying macro-sociological processes, legitimation and competition, generate observed variation in organizational vital rates and growth rates. More specifically, density (the number of organizations in a population) relates to both legitimation and competition, but in a countervailing way. While density increases legitimation at a decreasing rate, competition increases with density at an increasing rate. Except for some historically exceptional cases (Dobrev 1997), increasing density's contribution to legitimation is usually limited to the early period of an organizational population. Density dependent competition intensifies when density increases beyond certain threshold and accelerates with increasing density. Density dependent process in organizational population has been extensively tested and received broad support from empirical studies in diverse settings (for comprehensive review of empirical tests of density dependence theory, see Carroll and Hannan 2000).

Despite general empirical support for density dependence, systematic comparison of density dependence across diverse populations has been fairly limited so far. With strong orientation for general theory (Hannan and Carroll 1995), organizational ecologists have attempted to compare results from various empirical studies (Carroll and Hannan 2000; Hannan and Carroll 1992). However, their efforts have been hampered by the lack of adequate parameters to compare various organizational populations. One way to compare organizational population has been suggested by neo-institutional theory (Scott et al. 2000). Socially constructed nature of institutions, they say, constrains the operation of ecological processes in organizational populations. However, most institutional accounts of organizational populations are rather descriptive and weak in providing general framework for comparison (Barnett and Carroll 1983).

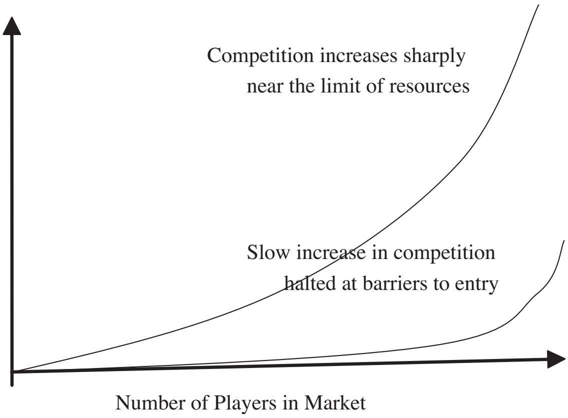
A different and more promising approach can be found in network theory of market. Burt (1992) claims that while organizational ecology predicts survival within a market, structural autonomy predicts survival differences across markets. His network account of market boundaries and market position allow ecologists to compare organizational populations in terms of their niche width or carrying capacity. Burt argues that niche width or carrying capacity is a consequence of structural autonomy (Burt 1992: 219). Organizational ecology posits that while changing organizational density drives competitive dynamics within a population, competition among organizations are further affected by the carrying capacity of the population, which depends on the environmental conditions including other populations. Burt builds on this idea and argues that:

> Structural autonomy decelerates the growth of competition associated with an increasing number of players in a market … Competition increases more slowly for two reasons. There are more resources available from the higher rates of return that can be obtained, and competition is more managed through the social organization of players (Burt 1992: 227).

Burt's argument is summarized and graphically shown in the Figure 2. The upper curve in the graph represents the case of market with low autonomy, in which addition of organizations intensifies competition in niche with narrow width. On the other hand, the lower curve represents the case of highly autonomous market, in which broad niche width can accommodate additional entrants into the industry. We can conclude from the graph that the competitive effect of density is stronger in the market or population with low autonomy. Hence our second hypothesis is as follows:

Hypothesis 2: Market autonomy lowers the competitive effect of density.

Figure 2. Density Dependent Competition Varying by Structural Autonomy



Source | Burt (1992: 227)

DATA AND MEASURES

The data for this study come from two different sources. First, the plant level data with information on the entry and exit events, and other background variables come from the *Mining and Manufacturing Survey* annually conducted by Korea National Statistical Office. The survey covers all plants with five or more employees in mining and manufacturing industries. Plant codes are consistently followed over time so that it is possible to collect information on plants over their life histories. Survey data from 1981 to 1999 are pooled and transformed into a panel data for cross-sectional time-series analysis and event history analysis. Second, the industry level data come from the input-output tables published by the Bank of Korea. Input-output tables are published for the years of 1980, 1983, 1985, 1988, 1990, 1993, 1995, and 1998. The input-output table reports the volume of transaction between pairs of industries in matrix form, which can be readily used for social network analysis. Network measures of structural autonomy for industries at different time points are matched with firm level data to generate final data.

Industry classification codes for both plant survey data and input-output tables vary over time. The classification system has been revised several times during the observation period. We collapsed several industries to make industrial codes consistent over time. Inconsistencies arise not only from revision in classification system. Industrial classification scheme for input-output table is not exactly identical to the standard industrial classification system used by National Statistical Office. Additional collapses of industrial codes have been made to make two classification schemes identical. The industrial classification scheme applied to our final data consists of 38 mining and manufacturing industries.

We measure exit event of plants by tracking the annual appearance of plant codes. If a plant appears in previous year's data and does not show up for more than three years, we regard the firm as having experienced exit at the end of previous year. It is possible that a plant reappears in the data after several years' absence. The possibility comes from the survey's design to cover only the plants with more than five employees. A typical case is when a plant with more than five employees decreases its number of employees to less than five and then increases to more than five later. The situation becomes more complicated by the erroneous practice of assigning the code of exited plant to a newly entered plant for some years. We have corrected such errors by cross-checking background variables such as founding years. Organizational growth (or decline) is measured by the annual increase (or decrease) in the amount of capital for each plant.

Structural autonomy at the industrial level is measured as a combination of two, the level of concentration in each industry and the degree of constraints imposed by the transacting industries. According to Burt, more concentrated and less constrained industries can enjoy benefits from structural autonomy. Organizations in a concentrated industry can enjoy the benefit of easier coordination among themselves vis-à-vis organizations in other industries.[1] Following Burt (1992), we measure the degree of concentration as the share of four largest firms in the total output of an industry. The network constraint measure is calculated as follows:

$$C_i = \sum_i (P_{ji} + \sum_q P_{jq} P_{qi})^2$$

where C denotes constraint, and P denotes strength of ties measured by resource flow. Industries are indexed by the subscripts i and j. P_{ji} denotes the strength of relationship from industry j to industry i. The expression in the parentheses stands for the sum of direct relationship (P_{ji}) and mediated relationship ($P_{jq}P_{qi}$) between industry j and industry i.

Organizational density is measured by annually counting the number of plants operating in each industry. As competition among organization tend to get localized, while legitimation operates much more broadly, it is best to measure density in industries or sectors defined as narrowly as possible. However we compromise at the level of 38 rather broadly defined industries for the purpose of matching with input-output table data.

Usually density dependence in organizational mortality or growth is specified as quadratic

[1] One reviewer mentioned that minor organizations in concentrated industry may not be able to enjoy autonomy. Autonomy can be defined at various levels but we define autonomy exclusively at the industry level. Therefore we are assuming here that small and large organizations in an industry enjoy the same amount of autonomy. Ideally, we should be able to calculate network autonomy at the organizational level as suggested by Burt (1992). Our lack of information on the network ties at the level of individual organization keeps us from doing that.

function of density (Hannan and Freeman 1989). The reason for such specification is to represent both legitimation and competition with one variable, density. As we use left-truncated data missing the early period of legitimation and focus theoretically on competition within and among organizational populations, we use log-linear function of density to test only the competition effect of density. If high density increases mortality rate or decreases growth rate, then we would interpret these results as evidencing the density dependent competition among organizations.

Finally we measure age, amount of capital, and number of employees for each plant-year and include them in models as control variables.

METHODS AND MODELS

We employ dynamic models to investigate the effects of structural autonomy and density on the competition among organizations.

Event-history model is employed to analyze exit rates of manufacturing plants in Korea. The exit rate is defined as

$$\mu_i(u) = \lim_{\Delta u \to 0} \frac{\Pr(Y(u+\Delta u) = 1 \mid Y(u) = 0)}{\Delta u}, \quad u \geq 0$$

where $Y(u)$ is a random variable, recording whether a plant has exited at duration u (in which case $Y(u) = 1$) or has not exited ($Y(u) = 0$). In other words, the exit rate is the instantaneous rate of a plant leaving an industry given that it operated in the previous period. The unit of analysis for exit rate analyses is an organization-year and an organization's tenure in an industry serves as a clock for measuring duration. The exit rate of a plant is calculated when a plant's spell ends in exit event, while the firm is treated as censored if it does not exit at the end of a spell. The calculated exit rate is predicted by regression models including various plant-level and population- or environmental-level covariates. In order to allow the updating of covariates that are measured annually, we use the method of spell-splitting (Blossfeld and Rohwer 1995) for the plants that operated more than one year. Event history models for exit analyses are estimated by the parametric survival regression method in *STATA*.

The growth of plants is investigated using regression models estimated on pooled cross-section and time-series data. Following the logic implied in Gibrat's law of proportional growth of firms (Gibrat 1931), the growth (or decline) of a plant is defined as the ratio of current size to previous size:

$$G_{it} = \frac{S_{i,t}}{S_{i,t-1}}$$

where G is the growth rate and S is organizational size measured by the amount of capital. Models of organizational growth rate can be tested by estimating regression models with the following specification:

$$\log(S_{it}) = \alpha + \beta \log(S_{i,t\text{-}1}) + \gamma' X_{i,t\text{-}1} + \varepsilon$$

Lagged dependent variable is included in our model to represent the above-mentioned proportional growth of organizations. We employed random-effect specification for estimating this cross-section time-series regression model to take into account and control for the within-plant variation. Cross-sectional time-series models for growth analyses are estimated by the cross-sectional time-series regression method in *STATA*.

Although out first hypothesis on the first-order effect of structural autonomy on organization outcome can be directly tested with the plant level analysis of exit model and growth model, our second hypothesis on the interaction between structural autonomy and density dependence cannot be directly tested by including the product of concentration or market constraint with industrial density in the models. The problem of multicollinearity between concentration or market constraint and the interaction terms keeps us from testing the second hypothesis directly using interaction models. Instead of interaction approach, we rely on two-step procedure of estimating the density dependent model first and then analyzing the relationship between the density effect and structural autonomy at the industrial level.

RESULTS

Figure 3 shows the changes in the total number of mining and manufacturing plants in Korea during 1981 and 1999. The number of plants has increased from 34,620 in 1981 to the peak of 163,561 in 1993 and decreased subsequently to 89,131 in 1999. This non-monotonic pattern of change in density applies to most industries except for a few industries that are highly concentrated to small number of firms (see figures in Appendix showing density changes by industry). Such temporal variability of density provides an ideal setting for testing the hypothesis of density dependence.

The rise and decline of plants in Korea during 1981 and 1999 reflects the rapid industrialization guided by the government since 1960s and deindustrialization since early 1990s. The effect of rapid deindustrialization can be seen in the changing industrial composition of employment. While the number of people employed consistently increased from 13.7 million in 1980 to 19 million in 1992, and then to 20.3 million in 1999, the number of people employed in mining or manufacturing industries increased from 3.1 million in 1980 to 5 million in 1992, but decreases to 4 million in 1999.

Figure 3. Number of Manufacturing Plants with Employees More Than 5 in Korea, 1981~99

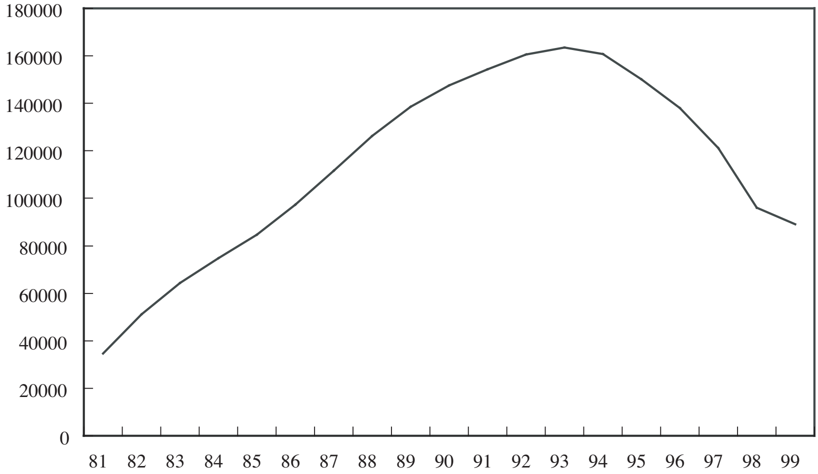


Figure 4. Number of Entries and Exits of Manufacturing Plants with Employees More Than 5 in Korea, 1981~99

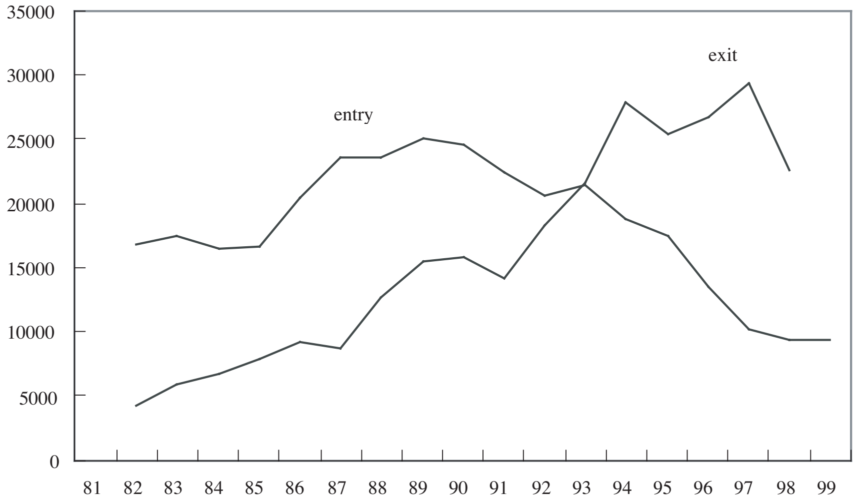


Figure 4 shows the number of entries and exits of mining and manufacturing plants by year. While the number of entries and exits show similar pattern of rise during the 1980s, entry and exit begin to move in opposite directions during the 1990s. The number of entries into mining and manufacturing continuously decrease from the peak of 25,041 in 1989 to 9,355 in 1999. The number of exits keeps increasing during the 1990s and reaches a peak of 29,380 in 1997. We can interpret the increasing exits and decreasing entries during the 1990s as reflecting the general trend of deindustrialization. The year of 1997, when the severe crisis hit Korean economy, shows the lowest level of entry into and the highest level of exit from mining and manufacturing industries.

Table 1 shows the distribution of inter-industry constraint measures by industry and year. Average level of constraint is 0.33 in 1980 and 0.31 in 1998 respectively. Highly constrained markets in 1980 include nonmetallic mineral mining (0.84) and grain and starch (0.89). In 1998, only grain and starch industry remain highly constrained (0.86). Industries enjoying high level of autonomy from other industries in 1980 include other chemical products (0.13), miscellaneous manufacturing (0.14), paper (0.14), rubber products (0.17), electronic and communication machinery (0.17), medical, measuring and control instruments (0.17), chemical (0.18) and nonferrous metal (0.18). In 1998, highly autonomous industries include miscellaneous manufacturing (0.12), fabric products (0.15), paper (0.15), electronic and communication machinery (0.16), transportation equipment (0.17), other chemical products (0.17), rubber products (0.17), general purpose machinery (0.18), electric machinery (0.18), pharmaceutical and cosmetics (0.19) and nonmetallic mineral product (0.19).

Table 2 shows the level of concentration by four plants by industry and year. Average level of concentration declined from 0.37 to 0.29 during 1981 and 1998. In 1981, highly concentrated industries included petroleum products (0.98), sugar (0.92), and synthetic fiber (0.85). In 1998, highly constrained industries include metal ore mining (1.00), tobacco (1.00), petroleum products (0.98), and coal product (0.92).

Table 3 presents the estimates from the event history models of plant exits. We use Gompertz model to test the age dependence in exit rates, and the age effect is positive but not significant. When we estimate model excluding size variables (number of employees and amount of capital), the result of which is not presented, the age effect is negative and significant (age effect = -0.005 with t = 14.5). This result is consistent with the findings of previous studies (Barron, West, and Hannan 1994; Ranger-Moore 1997) that negative age dependence in organizational mortality disappears after controlling for time-varying size of organizations. Having large amount of capital tends to lower the risk of exit, but having large number of employees tends to increase the risk.

The effect of four-firm concentration measure on exit rate is negative and significant. Plants in highly concentrated industries tend to face lower risk of exit. Predicted multiplier to exit rate for the completely concentrated industries (e.g. tobacco) is 44 percent of that for the least concentrated industries (e.g. miscellaneous manufacturing). If an industry is highly constrained by the network of transactions, plants in the industry face higher risk of exit. Predicted multiplier to exit rate for the most constrained industries (e.g. grain and starch) is 14 percent higher than that for the least constrained industries (e.g. paper or fabric products). These two opposite effects of concentration and constraint provide support for our hypothesis 1 that structural autonomy of an industry should lower the exit rate of plants in the industry.[2]

The effect of logged density is positive and significant. If a population's density is

Table 1. Market Constraints of 38 Industries, 1980~1998

	1980	1983	1985	1988	1990	1993	1995	1998
coal mining	0.52	0.39	0.41	0.44	0.56	0.65	0.63	0.61
metal ore mining	0.41	0.50	0.56	0.57	0.57	0.74	0.65	0.64
nonmetallic mineral mining	0.84	0.85	0.77	0.55	0.36	0.34	0.43	0.39
animal, dairy and fruit processing	0.57	0.53	0.55	0.49	0.51	0.46	0.48	0.52
seafood products	0.58	0.48	0.55	0.52	0.44	0.44	0.48	0.49
grain and starch	0.89	0.91	0.91	0.92	0.89	0.88	0.87	0.86
sugar	0.33	0.31	0.37	0.38	0.37	0.32	0.57	0.56
bakeries and noodles	0.34	0.31	0.31	0.29	0.30	0.31	0.29	0.30
other foods	0.59	0.63	0.62	0.56	0.53	0.48	0.27	0.30
beverage	0.22	0.19	0.23	0.24	0.21	0.19	0.21	0.22
tobacco	0.44	0.38	0.51	0.47	0.28	0.34	0.47	0.47
fabric mills	0.34	0.34	0.39	0.40	0.40	0.40	0.27	0.25
textile mills	0.49	0.51	0.47	0.46	0.43	0.39	0.21	0.22
fabric products	0.47	0.46	0.43	0.41	0.44	0.37	0.15	0.15
leather products	0.22	0.21	0.28	0.28	0.20	0.22	0.23	0.22
wood products	0.28	0.23	0.21	0.19	0.21	0.20	0.25	0.22
paper	0.14	0.16	0.14	0.14	0.15	0.14	0.17	0.15
printing	0.21	0.22	0.21	0.21	0.26	0.25	0.25	0.23
chemical	0.18	0.17	0.16	0.16	0.17	0.17	0.19	0.22
pesticide and fertilizer	0.44	0.45	0.39	0.40	0.39	0.39	0.40	0.37
pharmaceutical and cosmetics	0.25	0.21	0.20	0.20	0.18	0.19	0.19	0.19
plastics and rubber	0.17	0.15	0.20	0.20	0.30	0.32	0.35	0.35
synthetic fiber	0.40	0.40	0.44	0.44	0.42	0.40	0.40	0.36
other chemical products	0.13	0.13	0.13	0.14	0.14	0.14	0.17	0.17
petroleum products	0.24	0.26	0.26	0.21	0.22	0.21	0.22	0.25
coal product	0.36	0.38	0.41	0.40	0.50	0.49	0.52	0.58
rubber products	0.17	0.15	0.15	0.15	0.15	0.16	0.16	0.17
nonmetallic mineral product	0.27	0.22	0.22	0.21	0.25	0.21	0.21	0.19
primary metal	0.43	0.44	0.49	0.53	0.50	0.50	0.52	0.47
metal products	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
nonferrous metal	0.18	0.18	0.19	0.20	0.21	0.22	0.22	0.20
fabricated metal	0.21	0.22	0.23	0.20	0.23	0.22	0.23	0.21
general purpose machinery	0.19	0.20	0.22	0.20	0.19	0.19	0.19	0.18
electric machinery	0.19	0.17	0.16	0.17	0.21	0.21	0.19	0.18
electronic and communication machinery	0.17	0.16	0.16	0.16	0.27	0.26	0.16	0.16
transportation equipment	0.22	0.21	0.21	0.19	0.17	0.17	0.17	0.17
medical, measuring and control instruments	0.17	0.16	0.16	0.17	0.19	0.20	0.20	0.21
miscellaneous manufacturing	0.14	0.13	0.15	0.14	0.13	0.12	0.12	0.12

Table 2. Market Concentration by Four Plants for 38 Industries, 1981~1998

	1981	1983	1985	1988	1990	1993	1995	1998
coal mining	0.36	0.35	0.35	0.40	0.31	0.24	0.30	0.44
metal ore mining	0.81	0.66	0.51	0.83	0.99	1.00	1.00	1.00
nonmetallic mineral mining	0.20	0.15	0.12	0.07	0.06	0.07	0.08	0.10
animal, dairy and fruit processing	0.40	0.19	0.17	0.14	0.11	0.10	0.10	0.14
seafood products	0.20	0.15	0.13	0.10	0.11	0.13	0.13	0.13
grain and starch	0.39	0.38	0.34	0.25	0.23	0.15	0.13	0.14
sugar	0.92	0.69	0.68	0.67	0.70	0.70	0.63	0.58
bakeries and noodles	0.40	0.33	0.31	0.25	0.23	0.17	0.17	0.24
other foods	0.21	0.15	0.15	0.12	0.10	0.09	0.09	0.11
beverage	0.44	0.29	0.25	0.25	0.26	0.34	0.35	0.34
tobacco	0.45	0.39	0.38	0.43	0.69	1.00	1.00	1.00
fabric mills	0.19	0.11	0.10	0.08	0.08	0.07	0.07	0.10
textile mills	0.23	0.11	0.09	0.09	0.09	0.06	0.09	0.08
fabric products	0.19	0.19	0.18	0.16	0.17	0.18	0.07	0.11
leather products	0.19	0.08	0.07	0.05	0.04	0.05	0.05	0.07
wood products	0.24	0.13	0.11	0.12	0.11	0.10	0.10	0.15
paper	0.12	0.10	0.09	0.08	0.08	0.08	0.10	0.15
printing	0.43	0.24	0.23	0.14	0.12	0.10	0.11	0.13
chemical	0.46	0.37	0.36	0.25	0.25	0.19	0.23	0.24
pesticide and fertilizer	0.68	0.42	0.42	0.29	0.28	0.29	0.28	0.44
pharmaceutical and cosmetics	0.30	0.17	0.13	0.12	0.08	0.09	0.09	0.14
plastics and rubber	0.21	0.15	0.14	0.12	0.12	0.11	0.14	0.18
synthetic fiber	0.85	0.93	0.91	0.73	0.56	0.41	0.42	0.47
other chemical products	0.26	0.23	0.21	0.15	0.16	0.19	0.13	0.25
petroleum products	0.98	0.93	0.95	0.88	0.91	0.96	0.96	0.98
coal product	0.16	0.14	0.13	0.12	0.13	0.79	0.67	0.92
rubber products	0.36	0.22	0.19	0.13	0.10	0.19	0.25	0.23
nonmetallic mineral product	0.19	0.10	0.08	0.07	0.06	0.05	0.07	0.10
primary metal	0.57	0.40	0.38	0.36	0.33	0.35	0.37	0.39
metal products	0.24	0.15	0.20	0.12	0.10	0.10	0.14	0.15
nonferrous metal	0.47	0.50	0.45	0.31	0.30	0.28	0.23	0.16
fabricated metal	0.11	0.07	0.08	0.10	0.09	0.09	0.10	0.12
general purpose machinery	0.19	0.08	0.08	0.08	0.07	0.06	0.09	0.12
electric machinery	0.30	0.19	0.17	0.15	0.13	0.10	0.10	0.15
electronic and communication machinery	0.23	0.23	0.18	0.18	0.29	0.29	0.33	0.29
transportation equipment	0.61	0.37	0.36	0.32	0.33	0.33	0.34	0.39
medical, measuring and control instruments	0.33	0.23	0.18	0.12	0.12	0.16	0.21	0.18
miscellaneous manufacturing	0.10	0.06	0.05	0.08	0.08	0.05	0.06	0.07

Table 3. Estimates from Gompertz Model of Plant Exit Rate

	Estimated coefficients	Multiplicative effect	t-value
Age	0.0002		0.68
Capital in natural log	-0.0842	0.9192	-47.36
Number of employees	0.2433	1.2754	34.53
Producer concentration (O)	-0.8856	0.4124	-29.57
Constrained supplier-customer transactions (C)	0.1771	1.1938	9.85
Logged number of producers in industry (D)	0.2433	1.2754	85.42
Number of plant-year spells		1,828,338	
Number of plants		285,023	
Number of exits		212,665	
Log likelihood		-363,765.83	
χ^2		21,335.26	

multiplied by 10, multiplier to mortality rate increases by 75 percent. In the case of wood product industry, multiplier to mortality rate at the observed maximum of density (4096) is 30.8 percent higher than that at the observed minimum of density (1404). Thus density dependent competition received empirical support in this study. We are, however, more interested in whether the competitive effect of density is higher for the industries that are lacking autonomy.

The upper graph in Figure 5 is a scatter plot showing the relationship between the constraint imposed on an industry by other industries and the effect of logged density on mortality of plants in that industry. Market constraint and competitive effect of density are shown to have positive relationship. Density dependent competition is more intense in markets that are more tightly constrained by the inter-market network. The second hypothesis of this study is supported in the mortality analysis.

Table 4 presents the estimates from cross-sectional time-series model of plant growth rate. The effect of lagged dependent variable is highly significant showing the existence of serial autocorrelation. The coefficient of lagged dependent variable is smaller than 1, indicating that size has a negative effect on plant's growth.[3] It is consistent with empirical evidence from

[2] One reviewer raised the possibility that low exit rate in highly concentrated industry is an artifact coming from absence of organizational failure in some extremely highly concentrated industries such as tobaccos or sugar. We estimated the same model excluding such industries and the results are not substantially affected by that.

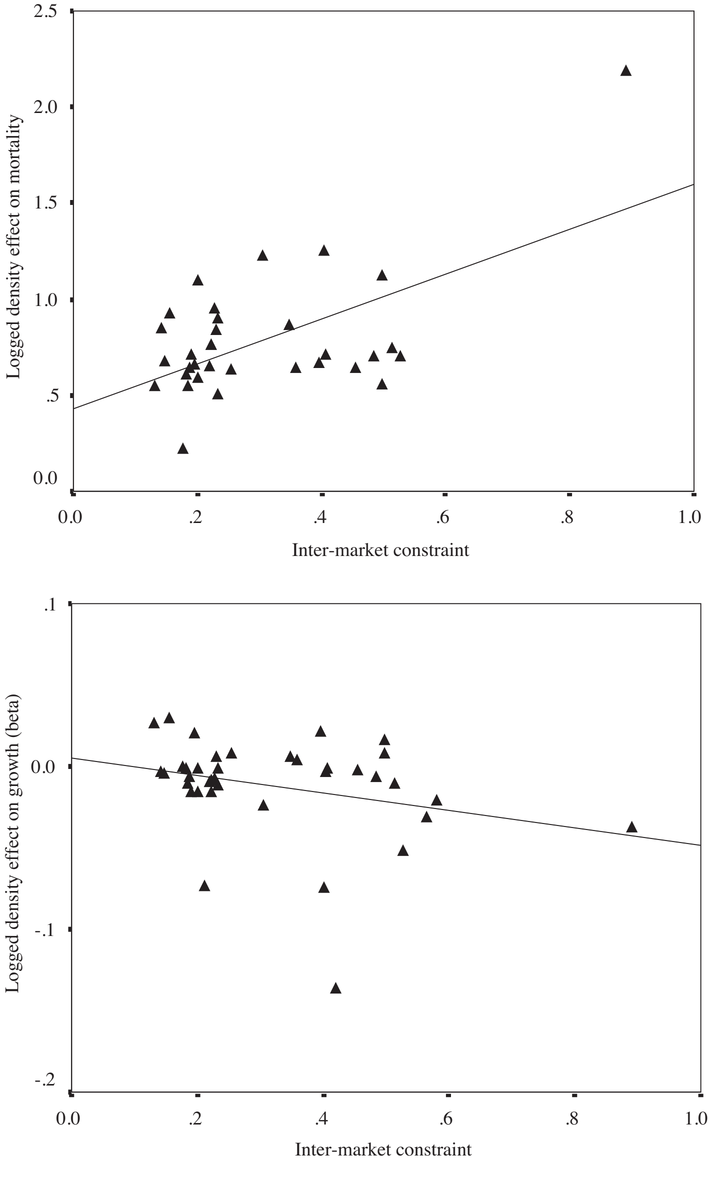
[3] We can test Gibrat's law of proportional growth by rearranging the regression equation as follows:

$$\log(S_{it}) - \log(S_{i,t-1}) = v\log(S_{i,t-1}) - \log(S_{i,t-1}) + \gamma_{i,t-1}$$

$$\log(\frac{S_{it}}{S_{i,t-1}}) = (v-1)\log(S_{it}) + \gamma_{i,t-1}$$

If Gibrat's law holds, the estimated value of v should be close to 1. A value of v smaller than 1 means that growth rate declines with size, while a value of v greater than 1 indicates that the growth rate increases with size.

Figure 5. Relationship Between Density Effect and Market Constraint at Industry Level



previous studies on the relationship between size and growth (Dunne, Roberts, and Smuelson 1989). Both age and number of employees have a positive and significant effect on growth.

The effect of four-firm concentration measure on growth rate is positive and significant. Plants in highly concentrated markets tend to grow at a faster rate than those in less concentrated markets. However the effect is not as strong as on mortality rate. Predicted

Table 4. Estimates from Cross-sectional Time-series Random-Effect Model of Plant Growth Rate

	Unstandardized coefficient	t-value
Lagged capital in natural log	0.9150	3052.1
Age	0.0046	70.417
Number of employees	0.0001	64.803
Producer concentration (O)	0.0882	17.746
Constrained supplier-customer transactions (C)	0.0477	14.723
Logged number of producers in industry (D)	-0.0027	-5.527
Number of plant-years	1,777,797	
R^2	0.852	

multiplier to growth rate for the completely concentrated industries (e.g. tobacco) is 8 percent bigger than that for the least concentrated industries (e.g. miscellaneous manufacturing). The effect of inter-market constraint measure on exit rate is positive and significant. If an industry is highly constrained by the network of transactions, plants in the industry tend to grow fast. This result is contrary to what we expect in our hypothesis. However the effect size is not big, and the predicted multiplier to growth rate for the most constrained industries (e.g. grain and starch) is 4 percent higher than that for the least constrained industries (e.g. paper or fabric products). The first hypothesis of this study is supported only for the effect of concentration in growth analysis.

The effect of logged density is negative and significant. The size of the density effect is not big. If a population's density is multiplied by 10, multiplier to growth rate decrease by less than one percent. In the case of wood product industry, multiplier to mortality rate at the observed maximum of density (4096) is 0.3 percent lower than that at the observed minimum of density (1404). Although density effect itself is statistically significant, we cannot accept that as strong evidence of plant growth hampered by density dependent competition. The lower graph in Figure 5 is a scatter plot showing the relationship between the constraint imposed on an industry by other industries and the effect of logged density on growth rate of plants in that industry. Negative effect of density on growth appears more in highly constrained industries. Density dependent competition is more intense in markets that are more tightly constrained by the inter-market network. The second hypothesis of this study is supported in the growth analysis.

DISCUSSION

We have attempted to integrate theory of structural holes and organizational ecology to develop general multi-level account of organizational competition. We have examined how structural autonomy of industries based on intra- and inter-industrial network influence competitive dynamics among organizations directly and indirectly. While density dependent competition constrains the survival and growth chances of individual organizations in populations, the strength of density dependence is further constrained by the level of structural autonomy enjoyed by each population from dependency on other interacting populations.

We believe looking at the interplay between structural autonomy across industry and density dependence within industry is a good starting point for a theoretical development toward community ecology. Concluding their most recent theoretical updates on organizational ecology, Caroll and Hannan stated that:

> An important next step in developing the demography of corporations and industries will be to design and conduct research on the communities of interacting populations of corporations and industries (Carroll and Hannan 2000: 451)

We have attempted to design and conduct research for contributing to the development of community ecology. Theory of structural holes has proven to be useful in providing parameters to compare populations interacting as community.

However the efforts of cross-fertilization between the two theories could be mutually beneficial. With their theoretical focus on evolutionary dynamics in populations and communities, organizational ecology provides general account on how organizational forms (Ruef 2000) appear, how population boundaries are segregated or blended (Hannan and Freeman 1989), and how organizational niche is partitioned and sub-populations emerge (Carroll and Hannan 2000).

Hitherto structural theories of market have more emphasized the stability of market boundaries (Burt 1988) or role structures in markets (White 1981). However, seen from a longer time perspective, it is an interesting question to ask where these structures come from. Ecological theories can be a good starting point in search of theory on how structural opportunities or role structures emerge from interactions among organizations or populations (for an interesting research in such direction, see Park and Podolny 2000; Podolny and Phillips 1996).

There are some unexpected and paradoxical results between mortality and growth models. For example, while inter-industry constraints increase the exit rate of organizations, the same variable lower the growth rate of at the same time. In addition, the number of employees has a positive effect on the organization’s exit rates, while the same variable has a positive effect on its growth rates. Further research should be conducted to take care of such anomalies.

APPENDIX

Figure 6-1. Change in the Number of Producers in Various Industries

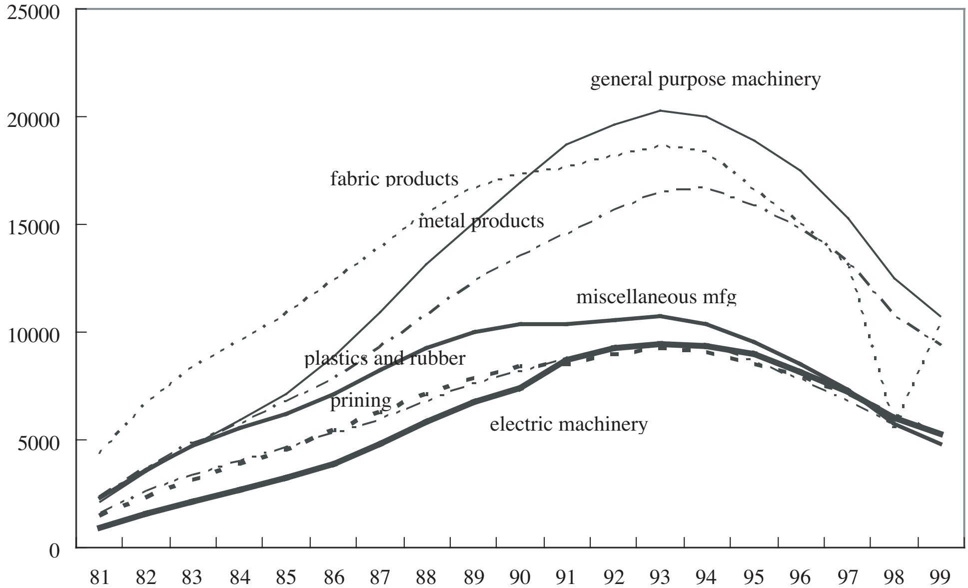


Figure 6-2. Change in the Number of Producers in Various Industries

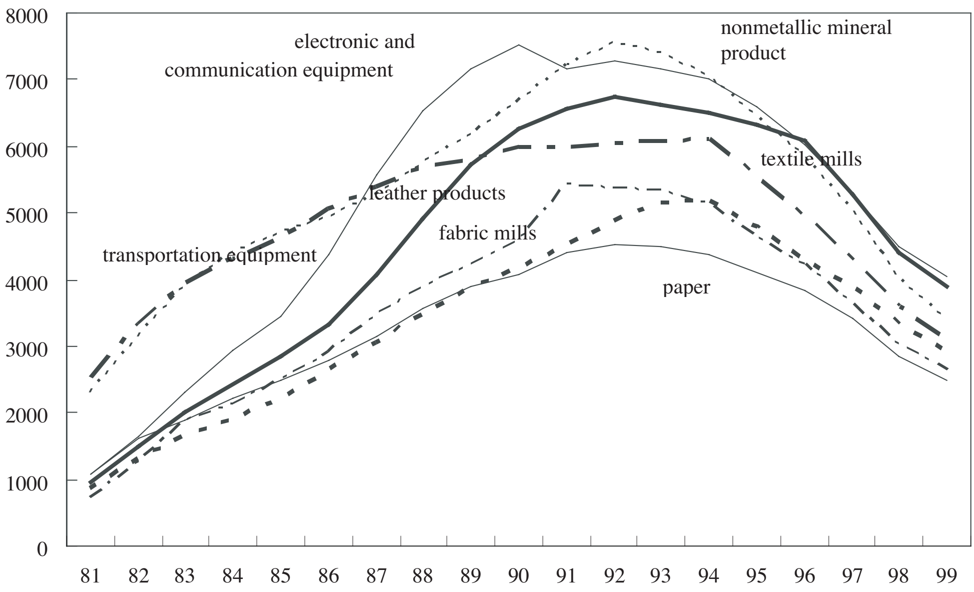


Figure 6-3. Change in the Number of Producers in Various Industries

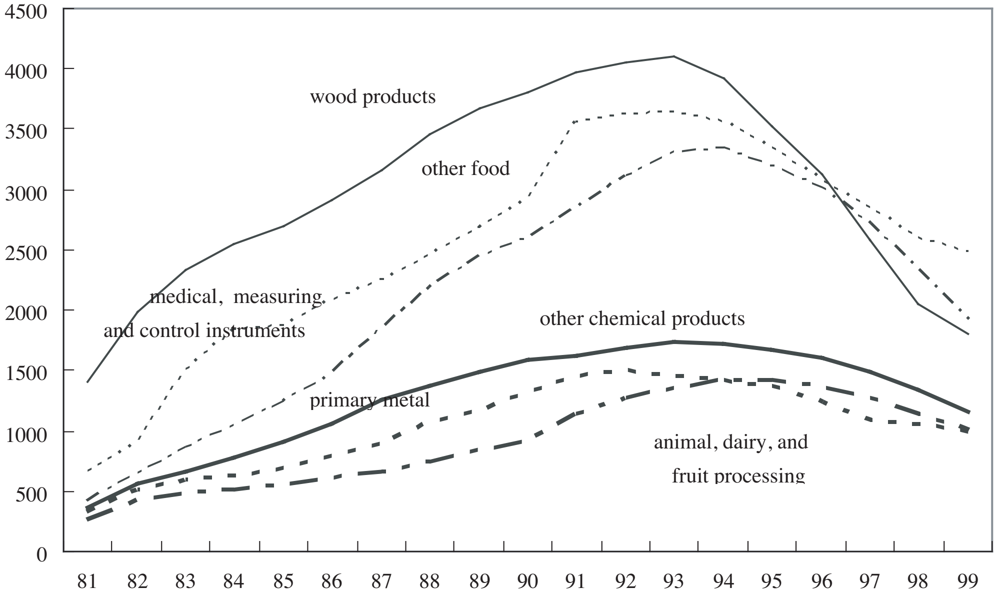


Figure 6-4. Change in the Number of Producers in Various Industries

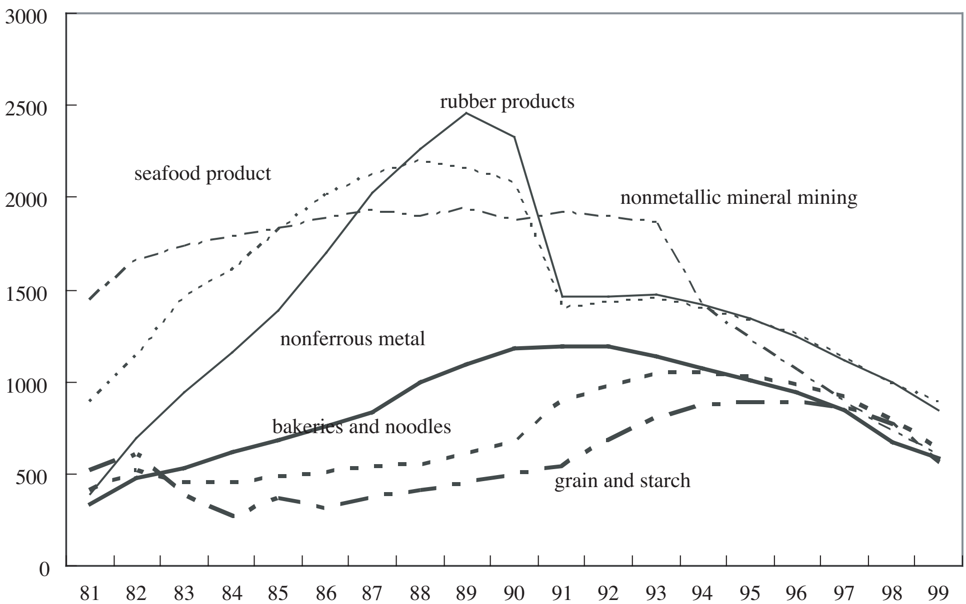


Figure 6-5. Change in the Number of Producers in Various Industries

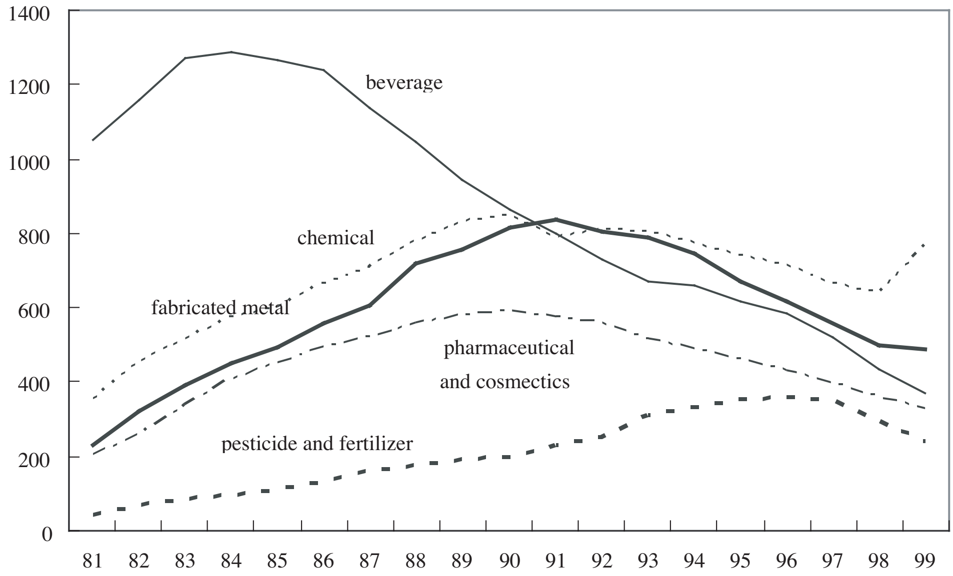
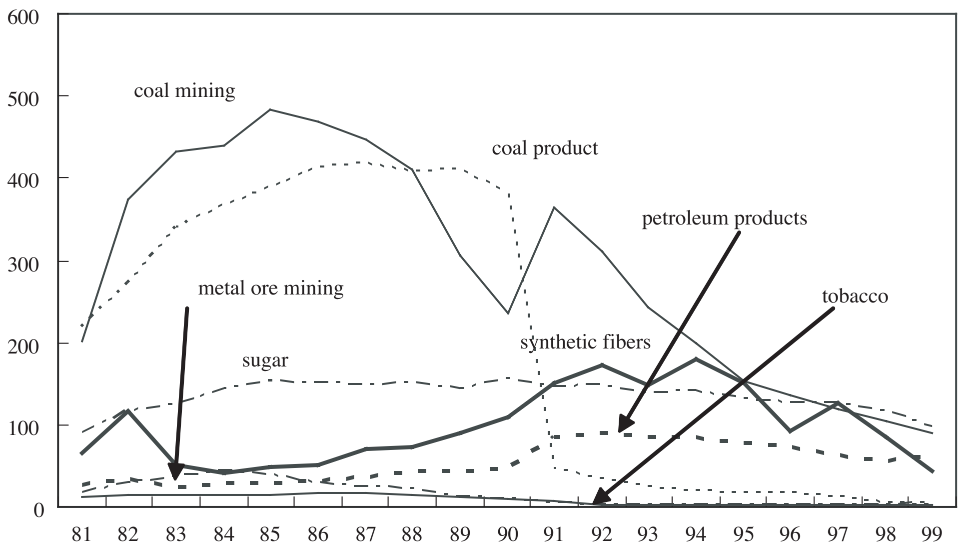


Figure 6-6. Change in the Number of Producers in Various Industries



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