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Industry Dynamics and Productivity Research

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Industry Dynamics and Productivity Research[1]

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Abstract

Firms experience birth (entry), growth and death (exit) as all living things do in any biological system. However, not all firms will show the same rate of growth and the same hazard rate of exit. Industry dynamics is a field of research that analyzes the dynamic patterns of entry, growth and exit of firms, and investigates the sources of those changes. On the other hand, productivity research has focused on the performance measurement of individual economic entities—such as firm, industry and country—and also on the examination of the sources. This paper reviews the past contribution of productivity research on industry dynamics and tries to specify the important future research areas that connect the two fields of research. For the past contribution, the paper emphasizes the following three issues: productivity as a measure of heterogeneity of firm population; productivity as an important source of the event in industry dynamics; source decomposition of industry-level productivity change. For the future work, the paper suggests the three areas of research: theoretical modeling that associates productivity with industry dynamics; accommodation of recent methodological developments of productivity analysis; rigorous study on the causal relationships among factors that affect the productivity change and industry dynamics. It is expected to better understand the logic behind pervasive yet complex behaviors of firms and industries, if the two research areas—productivity analysis and industry dynamics—interact more intensively.

Keywords: Industry Dynamics; Entry and Exit; Productivity; Survival Analysis; Firm Population

JEL Classification Numbers: D21; D24; L60; O30; C61

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1. Introduction

Industry dynamics is a field of research that describes the birth (entry), growth and death (exit) of firms in industries, regions and countries. Considering the object of the analysis, industry dynamics lies in the middle between the industry-level and firm-level analysis. While the former considers the target industry as a single unified decision-making unit, the latter regards the firm as an independent economic entity. Another distinctive feature of the industry dynamics research can be found in the characteristics of variables used for analysis. The key indicators are typically the ratio of the number of events to the total number of population—i.e., entry rate and exit rate, etc. Under the premise that the industries and firms are homogenous units by themselves, industry-level analysis and firm-level analysis utilize industry or firm-specific variables which represent their performances and characteristics. In terms of data, industry dynamics research also takes position between the industry and firm level analyses in that it makes use of industry population data. Considering all these aspects of objects, key variables and data in the analysis, it is clear that the industry dynamics research can be called as meso-level analysis between industry and firm level analyses.

On the other hand, productivity research has focused on measuring the performance of various economic entities and tried to investigate the reason why the performance changes across units and over time. The performance analysis accepts the objects unit such as firm, industry, or country as an independent decision-making unit. It is assumed that the automobile industry, for example, makes an economic decision for the optimization of that industry. There have been several studies showing the distribution of productivity-related indicators across the sample, but the event of industry dynamics, such as entry and exit, has not been discussed.

The two research streams of industry dynamics and productivity research are different in terms of key variables, data, methodologies and implications, and have been developed independently. However, we may argue that the productivity research has contributed much to the industry dynamics analysis in many ways. This paper will review the past contributions in terms of the following three areas: (i) productivity as one of the key indicators to describe the heterogeneity of firm's population; (ii) productivity as an important source of the event on industry dynamics; (iii) decomposition of industry productivity growth.

To extend the past contribution for the future, this paper argues that the following three areas of study should be taken into account: (i) theoretical modeling on the relationship between productivity and the event of industry dynamics; (ii) accommodation of recently developed methodologies of productivity analysis; (iii) rigorous investigation on the causal relationship among key factors that affect the productivity and industry dynamics. All those efforts will contribute to give better understanding of industry dynamics through the window of productivity performance.

The paper consists of four sections. The second section reviews the past contribution of productivity research on industry dynamics. The third section presents the areas of future study that connects those two fields of research more closely. The last section contains brief concluding remarks.

2. Contributions of productivity research on industry dynamics analysis

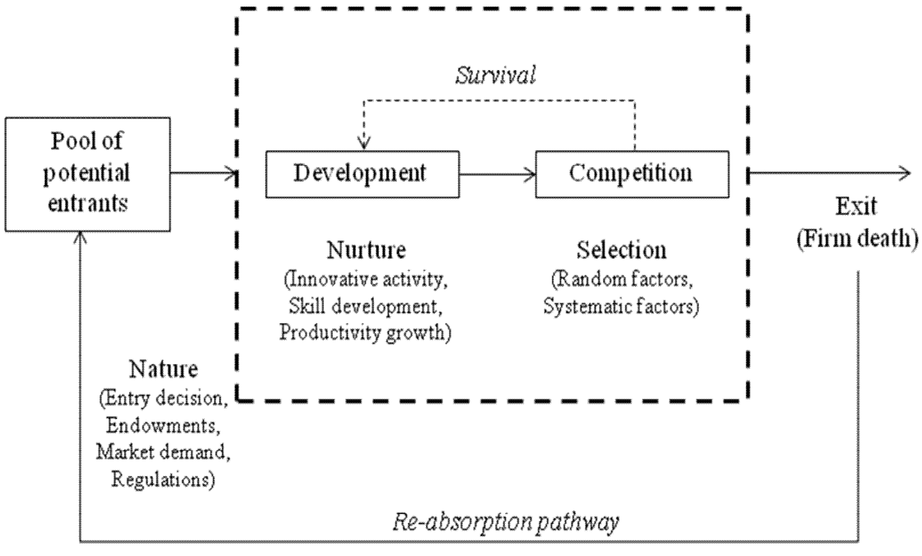
Even though industry dynamics research has more than a century of history, it has become popular since 1980s, and its topics and application targets have been significantly extended up to now. This rush of industry dynamics research coincides with better accessibility of micro (firm) level longitudinal databases and improvement of computing power that can handle large scale data (Jensen and McGuckin, 1997). Several relevant fields of research have contributed to develop industry dynamics research, which includes the firm theory in economics, organizational theory, management science, evolutionary theory in biology, to name a few. Demographics and statistics have provided methodological tools.

Especially the biological perspective provides the different framework to view the dynamic process of firm's entry and exit with conventional economic way of thinking, which assumes that a representative agent reflects the average behavior of whole population. Instead, industry dynamics research is based on the picture of population consisting of heterogeneous firms. In this regard, innovation theory adopting the evolutionary perspective also has relevance with industry dynamics research. (Malerba, 2007)

Industry dynamics has mainly dealt with dynamic events of birth (entry), growth and death (exit) of firm in an industry. All these events may correspond to those in biological system that constitutes the process of metabolism. (Haveman, 1995) The following diagram depicts the conceptual linkages across events of industry dynamics.

From the perspective of metabolism, a healthy industry can be characterized by the entry of productive firms, resource reallocation among incumbents and the exit of less productive firms. For making healthier industry, the new entrants are also required to absorb the released resources from exited firms. If the metabolism works efficiently, the industry becomes more competitive over time. The industry dynamics research, therefore, provides the framework to monitor the vitality of an industry, since its primary focus lies in entry, growth and exit rates. All the evidence of industry dynamics will provide important strategic information for private entrepreneurs and policy prescription for public decision makers.

[Figure 1] Conceptual framework of industrial evolution



Source: Webster, Budelmeyer and Jensen (2007)

Productivity research has largely contributed to the industry dynamics analysis with its focus on the measurement of individual economic entity. In the following subsections, the three main contributions are recognized. In the discussion, stylized facts on industry dynamics will be presented, and the cases for the Korean manufacturing industries will also be appended.

2.1. Productivity level as an index of heterogeneity

Industry dynamics research rests on the presumption that an industry consists of heterogeneous firms in terms of background, capability, behavior and performance, etc. The heterogeneity across firms will give rise to the different response patterns against environmental changes, to the different performance results, and finally to the diverse patterns of entry, growth and exit. In other words, some firms grow or survive and others exit due to the heterogeneity across firms. The heterogeneity, in that sense, is the conceptual background upon which the metabolism of variety creation-selection works. The heterogeneity observed in a specific time unveils one of the important characteristics of the industry and also insinuates future patterns of industry dynamics.[2]

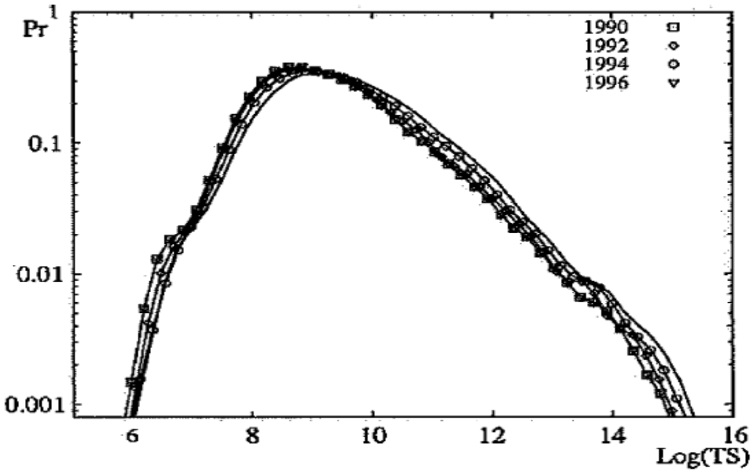
The analysis on the shape and changes in distribution of key indicators is the typical framework adopted for the analysis of heterogeneity in industry dynamics. Key indicators for describing the variety among firm's population include firm's characteristics (size, years of operation, etc.) and innovative activities (number of patents per firm, R&D expenditure, etc.) and their performances (profitability, rate on investment, etc.).

Previous researches posed a stylized fact that almost all key indicators take log-normal distributions across population. (Dosi, 2005) If we take the example of size, the log-normal distribution implies that the population is a mix of very small number of large firms and large number of small and medium-sized firms. This observation corresponds to a kind of 'Power Law' that appears in many social and natural populations.[3] The heterogeneity will appear again even if we divide the whole population into sub-samples, which implicates that this heterogeneity is not a phenomenon in a specific level of aggregation, but an intrinsic characteristic of any firm's population. In the followings, two diagrams show the distribution of firm size in the Italian and Korean manufacturing industries and we can confirm that the samples have log-normal distribution.

[2] The concept of heterogeneity on firm population contrasts with the concept of representative firm in neoclassical economics. In neoclassical production theory, we believe that the representative firm can depict the average behavior or production function of firm population, and the deviation around the production function is regarded as unsystematic error, which has been called as white noise. Thus, the conceptual difference between industry dynamics and neoclassical production theory lies on whether the heterogeneity is accommodated and provided with meaningful interpretation or not.

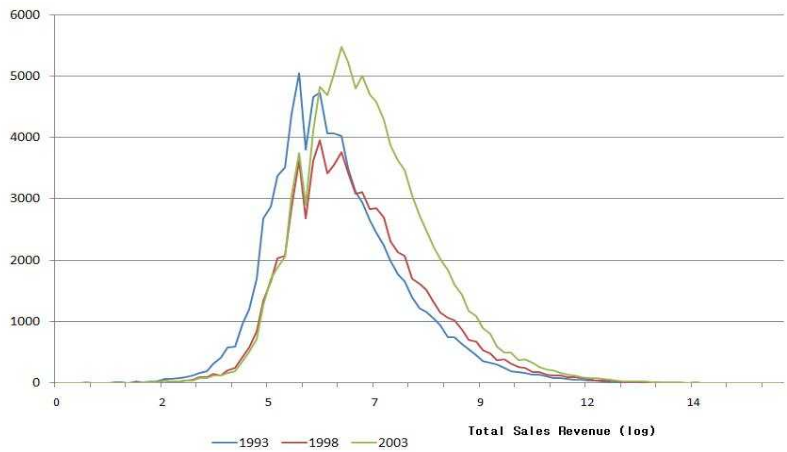
[3] Newman (2005) indicates that the 'Power Law' which implies the log-normal distribution of an indicator of population can be found in many instances, for example, physics, biology, earth and planetary sciences, economics, finance, computer science, demography and all kinds of social sciences.

[Figure 2] Distribution of firm size (sales) in Italian manufacturing industry[4]



Source: Bottazzi, Cefis, Dosi and Secchi (2007)

[Figure 3] Distribution of firm size (sales) in the Korean manufacturing industry[5]



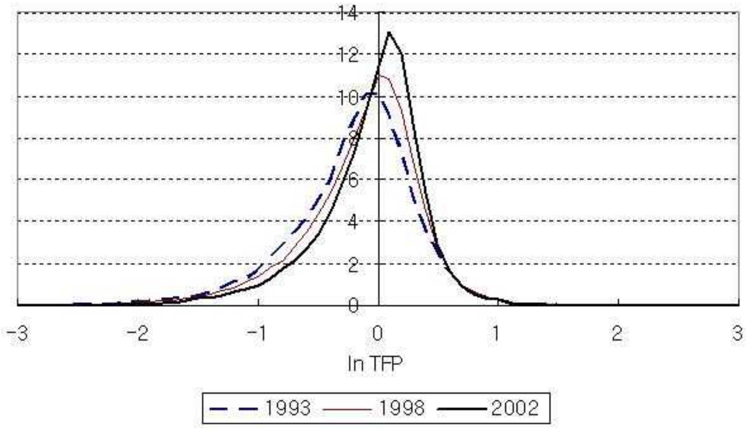
Source: Author's calculation

Productivity level as a representative measure of competitiveness is not an exception from this 'Power Law', which is evident from the following figure.

[4] The figure shows the Kernel density estimation of log (sales) in different years for firms with more than 20 employees.

[5] The data is based on the plant-level census for manufacturing industry of Korea covering all plants with more than 5 employees.

[Figure 4] Distribution of TFP level of the Korean manufacturing industry



Source: Author's calculation

The above figure on productivity distribution tells us that typical industry can be characterized by a few numbers of highly productive firms, which lead the industry, and a large number of laggard firms. If we resort to the familiar concept of efficiency, then it implicates that any firm's population is a mix of small number of highly efficient firms and a large number of poorly efficient firms, and the efficiency distribution is skewed downward with low median level of efficiency.[6]

Several policy implications can be derived from these observations on heterogeneity in terms of productivity.[7] If the productivity distribution is skewed to low median value, for example, the best practice of a small number of high performers should be transplanted into low ones. Another important implication can be obtained by investigating the changes of distribution over time. For example, we suspect that there is revolving door effect when a large number of low performers enter and exit with preserving high spread of productivity level. (Audretsch, 1995)

2.2. Productivity as an explanatory variable for the event of industry dynamics

Birth (entry), growth and death (exit) are the typical cases of events of industry dynamics. While M&A, inter-industry and/or regional transformations have been also discussed in some literatures, 'entry' and 'exit' have maintained the focal position in most of the previous research. (Carroll and Hannan, 2000) Events of industry dynamics can be represented by ratio variables such as entry rate—the ratio of the number of entrants to the total number of firms in an industry.

The factors that affect the industry dynamics events range from firm-, industry- to country-level characteristics, and include technological, socio-cultural and market-related attributes (Klepper, 1997). Previous literatures adopted regression analysis as the main tool to investigate the impact of potential sources of industry dynamics, which takes event ratio as a dependent variable and other potential factors as independent variables. Alternatively, the probability of

[6] This construct may contradict with the traditional assumption on the efficiency distribution in Stochastic Frontier Analysis (SFA), which assumes upwardly skewed efficiency distribution, for example, for the case of half-normal distribution.

[7] Example of policy research based on the productivity distribution can be found in DTI (2004) for the case of UK manufacturing industry.

individual event can be modeled with explanatory variables (co-variates), and probit analysis for the event itself or Heckman two-stage type regression that links an event and its ex post performance can be used. (Harris, Segel and Wright, 2005)

Productivity has long been cited as one of the main sources of industry dynamics events. A typical question tackled in the previous research was 'whether highly productive firms can survive longer?'[8] (Almus, 2004) Since productivity level has been considered as an important indicator of competitiveness, higher productivity is expected to be strongly correlated with survival rate. However, empirical evidence confirms that higher productivity may not guarantee higher survival rate. Selection bias can explain this unexpected result; surviving firms turn to be more productive, which does not mean that the productive firms will finally survive. Moreover, other factors which might be correlated with productivity performance will affect more, and obscure the impact of productivity on the survival rate. To my knowledge, there is no universal theoretical solution for the seemingly unexpected results.

The following table shows the Cox regression results for the case of the Korean manufacturing industry. Since the dependent variable is hazard rate of exit, the positive sign of estimate should be interpreted as the negative impact of the factor on survival, and vice versa. The table confirms that GDP growth rate, R&D activity and exporting activity affect positively (but negative sign of estimates) on the survival of firms. Productivity level, the main focus in this section, turns out to be statistically significant across all samples. However, the direction of impact of productivity on survival differs from sample to sample. For example, positive relationship appears only for the case of large scale firms.

[Table 1] Cox regression results for the Korean manufacturing firms (1993-2002)[9]

Categories of covariates	Variable	Samples		
		For all firms	Large sized firms	Small and medium sized firms
Externals	Sectoral growth rate (%)	0.00783***	-0.01086	0.00792***
	GDP growth rate (%)	-0.02896***	-0.02508	-0.02912***
Internals	R&D (Dummy)	-0.54996***	-0.70341**	-0.53318***
	Exporting (Dummy)	-0.57606***	-1.28657***	-0.55545***
	Multi-plant (Dummy)	-0.10940***	0.27058	-0.08803***
	Number of employees (Number)	-0.00403***	0.00012	-0.00682***
	Total Factor Productivity level	0.05994***	-0.95695***	0.06444***

Note: *** and ** denote estimates are significant at 1% and 5% significance level

Source: Lee, Oh and Heshmati (2008)

If survival can be considered as one of the ultimate objectives of firms, and if the productivity

[8] Griliches and Regev (1995) used the term of 'shadow of death' to describe the slowdown of productivity growth several years before the exit.

[9] Small and medium sized firms refer to those with less than 300 employees.

can be regarded as one of the key indicators of competitiveness, then the negative relationship between productivity level and survival, as presented in the above table, poses contradiction with our conceptual framework. In this regard, more elaborate approach should be made in terms of theoretical modeling and empirical analysis to derive more plausible explanation.

2.3. Decomposition of industry productivity growth

An industry as a pool of heterogeneous firms can improve its productivity level with entry of high productivity firms (entry effect), exit of low productivity firms (exit effect), resource allocation toward higher productivity incumbent firms (between effect) and productivity growth of individual firms (within effect).[10] According to Foster, Haltiwanger and Krizan (1998), the industry-level total factor productivity (TFP) growth between year t-τ and t is defined as followings.

$$\ln TFP_t - \ln TFP_{t-\tau} = \sum_f \theta_{f,t} \ln TFP_{f,t} - \sum_f \theta_{f,t-\tau} \ln TFP_{f,t-\tau}$$

where $\theta_{f,t}$ denotes establishment f 's sales share in year t. The above industry level TFP growth can be decomposed into the following terms:

(i) Within effect: $\sum_{f \in C} \theta_{f,t} \cdot \Delta \ln TFP_{f,t}$

(ii) Between effect: $\sum_{f \in C} \Delta\theta_{f,t} \cdot (\Delta \ln TFP_{f,t-\tau} - \overline{\ln TFP_{f,t-\tau}})$

(iii) Covariance effect: $\sum_{f \in C} \Delta\theta_{f,t} \cdot \Delta \ln TFP_{f,t}$

(iv) Entry effect: $\sum_{f \in N} \theta_{f,t} \cdot (\ln TFP_{f,t} - \overline{\ln TFP_{f,t-\tau}})$

(v) Exit effect: $\sum_{f \in X} \theta_{f,t-\tau} \cdot (\overline{\ln TFP_{f,t-\tau}} - \ln TFP_{f,t-\tau})$

where S is the set of firms that stayed in that industry from year t-τ to year t, N is the set of firms that newly entered and X is the set of firms that exited. TFP with an upper bar denotes the industry-average TFP level.

Decomposition of industry productivity growth rests on the conceptual framework that there are constant flows of firms with different productivity levels. All dynamic processes of creating new firms, competing among incumbents, and withdrawing the unproductive businesses will determine the productivity level of an industry. By decomposing the industry productivity growth, we can figure out why some industries and/or countries become more competitive than others. Furthermore, important policy implication can also be gleaned based on this source decomposition. In the case of big negative entry effect, for instance, it seems that there need specific public services preparing the potential entrepreneurs and letting them start with average productivity at least.

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[10] There are multiple ways to decompose the industry level productivity growth into sub components. For detailed review, see Ahn (2001).

Industry productivity decomposition has been heavily applied in many industries and countries.[11] The following table shows some of the main results of recent studies.

[Table 2] Cases of decomposition of industry productivity growth

Studies	Country	Period	Within Effect	Between Effect	Covariance Effect	Net Entry Effect (Entry Effect-Exit Effect)
Fukao, et al. (2006)	Japan	1981-1990	+	-	+	+
		1990-2003	+	-	+	+
Ahn, et al. (2005)	Korea	1990-1998	+	-	+	+
Foster, et al. (2001)	US	1977-1987	+	-	+	+
		1977-1992	-	-	+	+
Disney, et al. (2003)	UK	1980-1992	+	+	+	+
		1982-1987	+	-	+	+

One example of decomposition study on the Korean manufacturing industry is presented in the following table. The results show that there are some changes in the sources of industry productivity growth during the Asian Financial Crisis (1997-1999). During this kind of crisis characterized mostly by short-term liquidity problems, even productive firms may hardly sustain their competitiveness.

[Table 3] Productivity decomposition of the Korean manufacturing industry

Period			Sub-periods			
			1993-1995 (Pre-financial crisis period)	1997-1999 (Financial crisis period)	2000-2002 (Post-financial Crisis period)	1993-2002 (Entire Period)
Industry-wide TFP growth rate (%)			3.539	-3.155	2.036	1.925
			(100%)	(100%)	(100%)	(100%)
Composition of contributing effects (% to industry-wide growth rate)	Within (LSE)	LSE → LSE	90.888	42.622	77.982	31.025
		LSE → SME	4.097	0.663	6.075	5.858
	Within (SME)	SME → SME	36.829	42.696	-11.944	14.66
		SME → LSE	-1.165	4.656	-1.266	2.127
	Share (LSE)	LSE → LSE	-16.246	3.772	16.988	2.978
		LSE → SME	1.39	-2.065	3.128	-12.617
	Share (SME)	SME → SME	-15.459	-0.137	0.322	0.033
		SME → LSEE	-0.943	0.335	0.044	-3.723

[11] For more detailed review, see Bartelsman and Doms (2000), Ahn (2001), Bartelsman, Scarpetta and Schivardi (2005), and Lopez-Garcia and Puente (2006).

	Entry (Enter as LSE)	-7.671	5.716	10.162	13.805
	Entry (Enter as SME)	11.476	-17.965	23.487	19.629
	Exit (Exit as LSE)	5.349	-3.806	-0.225	19.308
	Exit (Exit as SME)	-8.544	23.513	-24.751	6.916

Note: LSE and SME imply large sized firms and small and medium sized firms, respectively.

Source: Lee, Oh and Heshmati (2008)

Even though the empirical results of industry productivity decomposition are interesting enough, there remain some debatable issues especially in terms of empirical application, which includes, for example, setting appropriate range of the study period, defining 'entry' and 'exit', and classifying industries, etc.[12] In addition, explaining the sources of individual effects poses another challenges. Given the above example of the Korean manufacturing industry, we suggest short-term liquidity problem as one of the sources for the negative exit effect. In this regard, precarious design of research framework is needed to investigate the reasons behind individual sources of industry productivity growth.

3. Challenges

Productivity research has provided conceptual foundation and empirical tools for industry dynamics analysis. This section suggests some of the future research areas that are expected to bring more close linkage between the two research streams.

3.1. Modeling the relationship between productivity and event on industry dynamics

The theoretical models of industry dynamics have been mainly proposed in industrial organization research. The most popular models are the passive learning model by Jovanovic (1982) and the active learning model by Ericson and Pakes (1995).[13] Even though both models assume that potential entrepreneurs do not know their capabilities before the entry, they adopt different perspectives on the post entry behaviors. In the passive learning model, the entrant will learn about its relative capability based on the noisy information of revealed performance results, which will dictate the decision on stay, growth or exit. The parameters that characterize the entrant's potential will not change, and thus, the firm will behave passively. On the other hand, in the active learning model, the entrant can change the intrinsic parameters after entry depending on the revealed performance and reaction of competitors. A large number of empirical researches have tested which model between the two fits better to the statistical data.[14]

Even though the above two models show the linkage between the performance (productivity) and the industry dynamics behavior, we can identify three main areas that need future research efforts. Firstly, theoretical model should accommodate innovative activities as well as productivity levels for better description of the industry dynamics, since innovation has been

[12] Longer study period, broader definition of entry and exit accommodating M&A and inter-industry transformation, and/or narrower definition of industry will result in larger entry and exit effect.
[13] Alternative models have also been proposed with the name of bounded rational model and history friendly model. See Malerba (2007) for more detailed description of each model.
[14] See Pakes and Ericson (1998) as example of empirical testing.

regarded as one of the important sources of firm performance, entry and exit. (Malerba, 2005)[15]

Secondly, it is legitimate to accommodate recent theoretical development of industrial organization. Specifically the high-tech industry, compared to the traditional industry, consists of handful number of firms, and the firms' decisions are strongly interrelated. Therefore, the industry dynamics model should admit the possibility of strategic behaviors. Examples can be found in Lambertini (2006) which embraces the Stackelberg game structure to model the industry dynamics.

Thirdly, simulation techniques have much potential to illustrate the theoretical underpinnings of industry dynamics. Although simulation cannot prove the theorem itself, it can provide important insights regarding the causal relationship among key factors and dynamic patterns of evolution. Especially agent-based simulation can model the system of agents (firms, organizations, etc.) with consideration of intrinsic heterogeneity. Recently, the simulation technique has been widely applied to the studies of innovation and industry dynamics; for example, see Haag and Liedl (2001) and Talyor and Morone (2005). If the simulation setting takes into account the productivity difference among agents, we may get better understanding of the impact of productivity on industry dynamics, including entry and exit behaviors, patterns of agglomeration and linkages, etc.

3.2. Implementation of recently developed methodologies in productivity research

Productivity research has focused mainly on the correct measurement of productivity level of an individual economic entity. The concept of efficiency has been developed, and the tools for empirical analysis, such as DEA and SFA, have been correspondingly refined. (In)efficiency concept allows the possible optimization-failure of firm's behaviors, which might be regarded as one of the main conceptual advances from the traditional framework assuming fully optimal behaviors. We can still notice new methodological developments appear in many journals.

Industry dynamics research will benefit once it adopts the recent methodological advancements and/or includes the empirical concepts of productivity analysis that has not been widely utilized for the analysis of industry dynamics. The examples may include the scheme of Malmquist productivity decomposition, aggregation of efficiency measures (Färe and Grosskopf, 2004) and dynamic efficiency index (Sengupta, 1999), to name a few.

All the concepts of industry dynamics can also be applied to the product dynamics, which highlights the launch, growth and exit of a specific product, not a firm. In this regard, the concept of product efficiency provides important supporting evidences for the analysis of product dynamics. (Lee, Hwang, and Kim, 2005)

3.3. Addressing the role of innovation for both of productivity growth and industry dynamics

Except for productivity, the concept of innovation has long been cited as the main source of industry dynamics. Audretsch (1995), for example, indicated that firms' characteristics related to innovation—such as technological regime of the industry, product life cycle, depth and width of innovative activities, and so on—will strongly affect the pattern of industry dynamics across industrial sectors.

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[15] Recently Kaniovski (2006) showed the model for the evolution of efficiency classes by considering individual firms' innovative activities.

From the perspective of innovation studies, industry dynamics has been one of the important research areas. Malerba (2007) recently reviews the past contribution of innovation studies and summarizes the following stylized facts of industry dynamics: (i) high within-industry heterogeneity in innovativeness; (ii) inter-sectoral differences in the rate of technical change, the market structure and the organization of innovative activities; (iii) major contributors to technological change in industries such as universities, venture capitals and other non-profit institutes. All these observations render us to view the industry dynamics with the help of innovation concept.

Innovation also has significant implications for productivity performance at the firm level. Several previous studies conclude that innovation will positively affect the firm performance in spite of some time lag (Crepon, Duguet and Mairesse, 1998; Lööf and Heshmati, 2006). Recent studies investigate the conditions under which higher returns can be generated with given innovative activities.

Admitting the importance of the three keywords—productivity, innovation and industry dynamics, we can conjecture that there must be some intricate relationship among them. (Sornn-Friese, 2000) According to considerable previous literatures, mutually causal relationships might exist among them: Innovation causes productivity improvement, higher productivity can render higher survival probability, and the survival will give opportunity to innovative further. In order to understand the complicated linkages among them, more detailed analysis is required. Structural equation modeling approach, for example, may be considered to test the causal relationships among the above three key concepts.

4. Concluding remarks

The two research streams of productivity and industry dynamics analyses have independently developed until now. However, both of the two fields commonly investigate the performance of firms, even though the methodologies, data, and target indicators that they rely on are different from each other. We can recognize that the past productivity research have notably contributed to the industry dynamics analysis. This paper reviews those past contributions in terms of (i) productivity as an index of heterogeneity across firm population, (ii) productivity as an important determining factor on industry dynamics, and (iii) decomposition of industry productivity growth.

This study suggests future research areas that help fill the gap between the fields of studies, such as, (i) theoretical modeling which links productivity and industry dynamics, (ii) adoption of recently developed methodologies for productivity and efficiency analysis, and (iii) investigation of causal relationship among productivity, innovation and industry dynamics.

The more common keywords the two fields of research share, the richer implications they might have.

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