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(Citation)
国民経済雑誌,223(2):15-35

(Issue Date)
2021-02-10

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(JaLCDOI)
https://doi.org/10.24546/E0042418

(URL)
https://hdl.handle.net/20.500.14094/E0042418

ISSN 0387-3129

国民経済雑誌

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The Kokumin-Keizai Zasshi（*Journal of Economics & Business Administration*）
Vol. 223, No. 2（February, 2021）

神戸大学経済経営学会

The Kokumin-Keizai Zasshi (*Journal of Economics & Business Administration*)
Vol. 223, No. 2 (February, 2021), 15-35

Natural Selection: A Review of Studies on Firms' Exit and Efficiency†

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In this study, we review the studies on the relation between firms' efficiency or profitability and their exit. Although we take it for granted that inefficient or unprofitable firms are more likely to exit, which we call the natural selection hypothesis, some theories predict that it is not necessarily the case. After reviewing these theories, we sort out a large amount of empirical studies that report direct and related evidence on the relation between efficiency or profitability and exit.

Keywords Natural selection, exit, efficiency, cleansing effect

1 Introduction

The aim of this study is to review the literature, both theoretical and empirical, on the relation between firms' efficiency (productivity) or profitability and their exit.[1)] At first glance, it is natural to predict that less efficient or less profitable firms are more likely to exit. We call this the *natural selection hypothesis*, and standard theoretical models indeed predict this hypothesis. However, there are also theories that do not. And there is a large amount of empirical studies that report direct and related evidence on the relation between efficiency or profitability and exit. We review these studies in this study.

The most significant contribution of this study is that it comprehensively reviews the related studies in two somewhat distinct but overlapping strands of the literature. The first is the literature on resource reallocation that examines whether and how resources are reallocated among existing, surviving, and entering firms, and how such reallocation affects the aggregate productivity. This literature focuses on exit as a source of resource reallocation among firms in an economy. The second is the literature on the dynamics of individual firms, or firm dynamics.

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This literature examines the evolution of a firm from its birth to death, and thus deals with exit as the terminal event in its life cycle.[2)]

Below, we first review the theoretical studies in Section 2. This section sorts out the studies in the two strands of the literature (reallocation and firm dynamics) into those focusing on efficiency only (Section 2.1) and financial constraints as well (Section 2.2), as the determinants of firm exit. Most studies model the firm's efficiency as the key determinant of its exit, and thus predict natural selection. However, there are also studies that focus on financial constraints as another important determinant, and these studies do not necessarily predict natural selection. We also discuss the difference between ex ante and ex post exit (Section 2.3).

In Section 3, we review the empirical studies. We first review the evidence on resource reallocation in studies that decompose the aggregate productivity growth into different components, with growth due to firms' exit as one of them (Section 3.1). These studies show whether exited firms are more or less efficient than surviving or entering firms. We then review the evidence in the studies that examine various determinants of exit and include the firms' efficiency as one of the determinants (Section 3.2). These studies directly show whether and how a firm's efficiency affects exit. Section 4 concludes the study and provides potential avenues for future research.

2 Theories on a firm's efficiency and exit

2. 1 Efficiency and exit

The theoretical models on exit, both in the literature on resource reallocation and firm dynamics, formalize firm exits as the violation of a participation constraint or a non-negativity constraint for its profit (e.g., Caballero and Hammour 1994 on reallocation, and Jovanovic 1982 and Hopenhayn 1992 on firm dynamics). Although many models assume homogeneity of firms' efficiency levels, this constraint indicates that if we introduce heterogeneity of the efficiency levels in the model, less profitable or less efficient firms are more likely to exit, because they find it preferable to stop their operations and seek alternative opportunities. As such, we can predict that firms' efficiency is one of the most important determinants of their exit, and the mechanism of exit should be one of *natural selection* where less efficient firms are more likely to exit.[3)]

This mechanism of firms' exit might be state-dependent, that is, it changes depending on aggregate shocks or the economic environment (e.g., Caballero and Hammour 1994 and Mortensen and Pissarides 1994 in the literature on reallocation and Hopenhayn 1992 in the literature

on firm dynamics[4]). Adverse (favorable) aggregate shocks increase (decrease) exits because they decrease (increase) profitability of firms, and promote natural selection because less (more) efficient firms are more (less) likely to violate participation constraint when an adverse shock occurs. This effect creates a counter-cyclical movement of exit, that is, more (less) exits in an economic downturn (boom).

The promotion of natural selection in an economic downturn is closely related to the so-called cleansing effect. The *cleansing effect* refers to the reallocation of resources when an adverse shock occurs from the destructed inefficient firms to more efficient ones (e.g., Caballero and Hammour 1994). Although the exit of inefficient firms is one of the key components of the cleansing effect, this effect more broadly refers to how resources of the exiting firms are reallocated to surviving and entering firms. Due to this broader focus, studies on resource reallocation examine not only exiting firms but also surviving and entering firms. Because this study is interested in the relation between a firm's exit and its efficiency, we do not focus on this whole mechanism of resource reallocation, and rather extract a part of the evidence on exiting firms.

2. 2 Financial constraint and exit

Efficiency or profitability is probably the key determinant of firms' exit, but it is not the only one. Another important factor highlighted in the literature is financial constraint. Some studies on reallocation demonstrate that even profitable firms might exit due to financial constraint.[5] In their model where entrepreneurs need to raise funds to stay in business, Caballero and Hammour (2005) show that relation-specificity of physical capital produces positive rents to entrepreneurs and makes it difficult to be committed to sufficient repayments. Due to this "hold-up problem," lenders do not provide funds when a production unit suffers from an adverse shock, and the unit might fail even if it is profitable. Caballero and Hammour (2005) refer to this effect as *spurious destruction*.[6]

Osotimehin and Pappada (2017) obtain similar results in their model on the moral hazard in financial contracting. In this model, some profitable firms fail if they have insufficient net worth and fail to raise funds. However, the effects that these studies demonstrate are that the financial constraint raises the exit threshold on the profitability axe, that is, the promotion of natural selection, and the less profitable firms are still more likely to exit.[7]

Barlevy (2003) is an exceptional study that demonstrates the possibility that more profitable firms are more likely to exit, that is, *unnatural selection*.[8] In his model, a firm can divert bor-

rowed funds, and so the lender does not provide funds unless the amount of expected repayment is greater than the amount of funds lent. Under the possibility of this kind of moral hazard, together with a critical assumption that the amount of resources needed increases with the profitability of the project, Barlevy (2003) shows that when facing adverse shocks, more profitable firms are more likely to fail to raise funds (of a larger amount) and to exit, while less profitable firms can raise funds (of a smaller amount) and continue.

Although these studies examine the effects of the promotion of exit due to tighter financial constraints, financial constraints might work in the other direction, that is, the loosening of the constraints might promote the survival of inefficient firms. Studies on the so-called *zombie firms* predict that undercapitalized banks provide evergreening loans to inefficient firms, which contributes to their survival (e.g., Peek and Rosengren 2005, Caballero, Hoshi and Kashyap 2008). This is because such banks are willing to decrease non-performing loans that reduce their regulatory capital ratios. To the extent that these effects are significant, the selection mechanism might not be natural, and/or the natural selection might not be intensified in the face of adverse shocks. Thus, on balance, whether the selection mechanism of firms is natural or not, and how it changes depending on different states, are empirical questions.

2. 3 Ex post and ex ante exits

Before proceeding to the empirical evidence, it is worthwhile to discuss the difference in the types of exit, the ex post and ex ante exits, in the theoretical models. From a theory point of view, the studies indicated earlier deal with ex ante exit, where firms exit due to the violation of their participation or financial constraints *before* they start their operation and/or fundraising. Empirically and practically, this type of exit can be captured by exit in the form of (voluntary) closure in which firms (voluntarily) decide to quit their operation without producing goods or services.

In practice, however, there is another form of exit, bankruptcy. This is a form of exit that an inability to meet debt obligations ignites *after* a firm raises funds and starts its operation. Theoretically, bankruptcy can be formalized as an ex post exit that occurs in a textbook model of financial contracting with uncertainty as an event at "bad" states where the firm's return from its production or operation is too small (or zero) to repay debt obligations. Different from the theories on ex ante exit, these theories produce no clear prediction on the relation between ex ante efficiency of firms and exit, or on the state dependence of the selection mechanism, because the bad state should take place due to bad luck even for efficient firms.

3 Evidence on firms' efficiency and exit

This section reviews the empirical literature on the selection mechanism of firms with different efficiency levels. We classify the studies into those that report evidence on productivity decomposition (Section 3.1), and those that examine the relation between firms' efficiency and exit by univariate or multivariate analyses (Section 3.2). This classification is based on differences in empirical approaches and not on whether the studies are in the literature on resource reallocation or firm dynamics. Although it is easy to distinguish theoretical studies on resource reallocation and those on firm dynamics, whether an empirical study is in the field of resource reallocation or firm dynamics is hard to tell, except for the studies on productivity decomposition in the literature on resource reallocation. In fact, there are some studies that report the results on productivity decomposition as well as on the productivity levels of surviving, entering, and exiting firms. Below, we refer to such studies in both Sections 3.1 and 3.2.

3. 1 Evidence from productivity decomposition

3. 1. 1 Evidence on net entry

In empirical studies on resource reallocation, there are many studies that decompose the growth of aggregate productivity, which is measured as a weighted average of firm- or establishment-level productivity, into different components. These studies examine the contribution of the entry-exit margin as one of the components that drives productivity growth.[9] Their results on the contribution of exit firms thus tell us whether firms that exit are more or less efficient than surviving or entering firms.[10]

Table 1 summarizes the evidence that studies in this area report. Studies that use data from the manufacturing sector find that within-firm productivity growth (i.e., the growth of productivity in individual firms that survive) is the main driving factor. However, they also find that the net entry component (i.e., difference in the productivity between entering and exiting establishments) makes a positive (although small) contribution (e.g., Griliches and Regev 1995 (labor productivity, Islael, 1979–1988), Foster, Haltiwanger and Krizan 2001 (labor and multifactor productivity, the US, 1977–1987), Bellone, Musso, Nesta and Quere 2006 (TFP, France, 1990–2002[11])). This finding means that inefficient firms exit, which is consistent with natural selection.

A study on a service sector (Foster, Haltiwanger and Krizan 2001 (labor productivity, auto repair shops in the US, 1987–1992)) also finds a positive contribution of the net entry compo-

Table 1 Evidence from productivity decomposition

Question	Sec.	Method	Paper	Efficiency measure	Country	Period/Year	Industry (firms/establishments)	Result	Answer (natural selection?)
Natural selection?	3.1.1	Contribution of net entry to productivity growth	Griliches and Regev (1995)	labor productivity	Islael	1979-1988	manufacturing	positive (although small) contribution	Yes
			Foster, Haltiwanger and Krizan. (2001)	labor and multifactor productivity	U.S.	1977-1987	manufacturing	positive (although small) contribution	Yes
			Bellone, Musso, Nesta and Quere (2006)	TFP	France	1990-2002	manufacturing	positive (although small) contribution	Yes
			Collard-Wexler and De Loecker (2015)	TFP	U.S.	1963-2002	manufacturing (steel mills)	positive contribution for vertically integrated plants only	Yes
			Foster, Haltiwanger and Krizan (2001)	labor productivity	U.S.	1987-1992	service sector (auto repair shops)	positive and relatively large	Yes
			Osotimehin (2019)	TFP	France	1991-2006	service sector	negative (but small)	No
	3.1.2	Contribution of exit to productivity growth	Baldwin and Gu (2006)	(labor-)productive firms	Canada	1973 to 1997	manufacturing	positive (but small)	Yes
			Lentz and Mortensen (2008)	labor productivity	Demark	1992-1997	privately-owned firms (not necessarily manufacturing)	positive	Yes
			Melitz and Polonec (2015)	labor productivity	Slovenia	1995-2000	manufacturing	positive (but smaller)	Yes
			Melitz and Polonec (2015)	TFP	Slovenia	1995-2000	manufacturing	mixed (but smaller)	Yes/No
			Scarpetta, Hemmings, Tressel, and Woo (2002)	labor or multi-factor productivity	10 OECD countries in Europe and the U.S.	1987-1992 and 1992-1997	manufacturing and service	positive (relatively large) but sometimes negative (although small)	Yes/No
			Nishimura, Nakajima, and Kiyota (2005)	TFP	Japan	1996-1997	mining, manufacturing, wholesale and retail, and restaurants	negative and large	No
			Fukao and Kwon (2006)	TFP	Japan	1994-2001	manufacturing	negative and sizable	No
			Kim, Kwon and Fukao (2007)	labor productivity and TFP	Japan	1981-2003	manufacturing	negative (but small, but large in latter half of 1990s)	No
			Kim, Kwon and Fukao (2007)	labor productivity	Japan	1997-1999	non-manufacturing	positive (but small, and negative for larger firms)	Yes (No for larger firms)
Question	Sec.	Method	Paper	Efficiency measure	Country	Period/Year	Industry (firms/establishments)	Result	Answer (state dependent?)
State dependent?	3.1.1	Cyclicality of contribution of net entry	Baily, Baltelsman and Haltiwanger (2001)	labor productivity	U.S.	1972-1989	service sector	counter-cyclicality (only modest)	Yes (only modestly)
			Foster, Haltiwanger and Krizan (2001)	labor and multifactor productivity	U.S.	1977-1992	service sector	mixed evidence	Yes/No
	3.1.2	Cyclicality of contribution of exit	Fukao and Kwon (2006)	TFP	Japan	1994-2001	manufacturing	no cyclicality	No

nent. They find that this contribution is larger than that of the within-firm productivity growth. However, using data from France over 1991 to 2006, Osotimehin (2019) finds that the contribution of net entry is negative, which is inconsistent with natural selection, but its magnitude is small as compared with the contribution of the within-firm component.[12)]

There are also studies that explicitly take into account the state dependence of the resource reallocation. These studies report only modest (Baily, Baltelsman and Haltiwanger 2001 (labor productivity, the US, 1972–1989)) or mixed (Foster, Haltiwanger and Krizan 2001 (labor and multifactor productivity, the US, 1977–1992)) evidence of the counter-cyclicality of the contribution of the net entry margin. On balance, the findings in the studies reviewed in this subsection indicate that although the selection mechanism is likely to be natural, there is little state dependence in the mechanism.

3. 1. 2 Evidence on Exit

Although the abovementioned studies all make important contributions to the literature on resource reallocation, their evidence is indirect when viewed from this study's perspective. This is because they focus on the contribution of the *net* entry component and thus do no separate the effects of entry and exit. There are some studies that distinguish these effects. As for evidence on manufacturing firms, Baldwin and Gu (2006) report that exit makes a positive contribution to the labor productivity of manufacturing plants in Canada for the period from 1973 to 1997, which means that less labor-productive firms exit. But they also report that within-firm productivity growth is far more significant. Lentz and Mortensen (2008, Table II) use data on approximately 4,900 privately owned firms in Demark with 20 or more employees (including non-manufacturing firms) for the period from 1992 to 1997, and report a positive contribution by the exit component. Melitz and Polonec (2015) use data for manufacturing firms in Slovenia over 1995 to 2000. Consistent with the abovementioned studies, they find that the contribution of the exit component to labor productivity growth is positive but smaller than the within-firm productivity growth. As to total factor productivity (TFP), the sign of the contribution by the exit component is mixed and sometimes negative depending on what decomposition method is used, but the magnitude of the contribution is smaller than that of the within-firm component.[13)]

On balance, this evidence indicates that the contribution of firm exit to productivity growth is mostly positive, and if negative, it is small, and is outweighed by the contribution of the within-firm component. Thus, we can at least reject the hypothesis that the selection mecha-

nism is unnatural.

However, studies in Japan report a negative and sizable contribution of firm exit, especially in the late 1990s. Using data for mining, manufacturing, wholesale and retail, and restaurants, Nishimura, Nakajima, and Kiyota (2005) find that the net exit component negatively and significantly contributes to the aggregate growth of the TFP for the period from 1996 to 1997, the banking crisis period in Japan. Fukao and Kwon (2006) report the results on the cyclicality in the contribution of the exit component for manufacturing firms in Japan over the period from 1994 to 2001. They find that firm exit makes a negative and sizable contribution to TFP growth, but they find no cyclicality in the sign and the extent of this negative contribution over this period.

Kim, Kwon and Fukao (2007) examine establishments in the manufacturing sector in Japan for the period from 1981 to 2003. They find that although the positive contribution of the within-firm component dominates in the other periods, the exit component contributes negatively to the aggregate productivity growth (both labor productivity and TFP), and its magnitude dominates in the crisis period of the latter half of 1990s. Kim, Kwon and Fukao (2007) also examine non-manufacturing firms and find that the growth rate of their aggregate labor productivity in the period from 1997 to 1999 is negative, and the exit component makes a small but positive contribution. However, they also find that the result changes when they separate the sample based on firm size.[14)]

3. 1. 3 Methodological issues

There is a methodological issue in the studies on the decomposition of productivity. In fact, the main purpose of Melitz and Polonec (2015) is to compare different methods of decomposing productivity. The most conventional approach in the literature is to decompose the growth in aggregate productivity into within, between, entry, and exit components, which follows Baily, Hulten and Campbell (1992), Foster, Haltiwanger and Krizan (2001), and Griliches and Regev (1995). However, there is also a static (cross-sectional) decomposition by Olley and Pakes (1996), and Melitz and Polonec (2015) propose a dynamic version of Olley and Pakes that takes into account the contributions of firms' entry and exit.[15)]

When we judge whether firms exit due to natural selection, we need to keep in mind that the results might differ depending on which of these methods to use. As mentioned earlier, Melitz and Polonec (2015) find that the direction of the contribution of exiting firms to the growth of TFP is mixed across these approaches.

Another methodological issue is how to define the aggregate productivity. The earlier mentioned studies all use the weighted average of productivity as the measure of aggregate productivity. In this case, the productivity growth represents an increase in technical efficiency. However, there is another measure of aggregate productivity growth called APG (aggregate productivity growth) that measures the change in aggregate output (final demand) minus the change in aggregate input (expenditures) (Basu and Felnald 2002, Petrin and Levinsohn 2012). In the most standard form, this APG is decomposed into (1) the technical efficiency term, (2) the reallocation term, and (3) the fixed costs term (Petrin and Levinsohn 2012). The first term (1) corresponds to the within-firm productivity growth measured in the earlier mentioned studies, because it captures increases in production given input levels due to technological improvement on the production side (represented by the production function). The decomposition of APG can include the "entry and exit" components by conducting the decomposition separately for entering, surviving, and exiting firms (Kwon, Narita, and Narita 2015, online Appendix B)[16].

However, these "entry and exit" components capture only the contribution of (2) (the reallocation term) for entering and exiting firms, and do not measure whether entering or exiting firms are efficient or not. Because we are interested in the evidence on the efficiency of exiting firms, we do not focus on this APG decomposition.[17]

3. 2 Evidence on efficiency levels of exiting firms

3. 2. 1 Evidence from univariate analysis

Different from the previous approach of decomposing productivity growth in studies on resource reallocation, many studies directly compare the productivity levels of surviving, entering, and exiting firms. The evidence in these studies is summarized in Table 2.

Earlier studies have used different efficiency measures and have focused on a small number of specific industries to conduct primitive univariate comparisons. They have reported mixed evidence. Bresnahan and Raff (1991) find that smaller and less productive plants are more likely to exit in the US motor vehicles industry for the period from 1929 to 1935. But Baden-Fuller (1989) do not find that less profitable firms are more likely to close in a declining industry (steel casting) in the UK for the period from 1979 to 1981.

Later studies explicitly compare the productivity levels of newly created, continuing, and exiting establishments. Some of the studies on the productivity decomposition reviewed above additionally report that the productivity of exiting plants is actually lower than that of continu-

Table 2 Evidence on efficiency levels of exiting firms

Question	Sec.	Method	Paper	Efficiency measure	Country	Period/Year	Industry (firms/establishments)	Result	Answer (natural selection?)
Natural selection?	3.2.1	Primitive comparison of efficiency measure between continuing and exit firms	Bresnahan and Raff (1991)	size and productivity	U.S.	1929–1935	motor vehicles industry	small/low for exiting firms	Yes
			Baden-Fuller (1989)	profitability	U.K.	1979–1981	declining industry (steel casting)	no difference	No
	3.2.2	Comparison of efficiency levels of newly created, continuing, and exiting establishments	Griliches and Regev (1995)	labor productivity	Islael	1979–1988	manufacturing	lower for exiting firms	Yes
			Foster, Haltiwanger and Krizan (2001)	labor and multifactor productivity	U.S.	1977–1987	manufacturing	lower for exiting firms	Yes
			Foster, Haltiwanger and Krizan (2001)	labor productivity	U.S.	1987–1992	service	lower for exiting firms	Yes
			Aw, Chung and Roberts (2003)	TFP	Korea	1983–1993	manufacturing	lower for exiting firms	Yes
			Aw, Chung and Roberts (2003)	TFP	Taiwan	1981–1991	manufacturing	lower for exiting firms	Yes
			Lee and Mukoyama (2015)	TFP	U.S.	1972–1997	manufacturing	lower for exiting firms	Yes
			Bellone, Musso, Nesta, and Quere (2006)	TFP and labor productivity	France	1990–2002	manufacturing	lower for exiting firms	Yes
			Baldwin and Rafiquzzaman (1995)	labor productivity	Canada	1971–1982	manufacturing (new plants only)	lower for exiting firms	Yes
			Nishimura, Nakajima, and Kiyota (2005)	TFP	Japan	1996–1997	mining, manufacturing, wholesale and retail, and restaurants	high for exiting firms	No
		Differences in productivity distributions	Fariñas and Ruano (2005)	TFP	Spain	1990–1997	manufacturing	stochastic dominance for continuing firms over exiting firms	Yes
	3.2.2	Firm exit regressions	Baily, Hulten and Campbell (1992)	TFP	U.S.	1972–1982	manufacturing	more productive plants/firms less likely to exit	Yes
			Olley and Pakes (1996)	TFP	U.S.	1974 and 1987	telecommunication equipment industry	more productive plants/firms less likely to exit	Yes
			Dwyer (1998)	TFP	U.S.	1972–1987	textile industry	more productive plants/firms less likely to exit	Yes
			Musso and Schiavo (2008)	TFP	France	1996–2004	manufacturing	more productive plants/firms less likely to exit	Yes
			Kiyota and Takizawa (2006)	TFP and its growth	Japan	1995–2002	several industries	more productive plants/firms less likely to exit	Yes
			Foster, Grim and Haltiwanger (2016)	TFP	U.S.	Crisis periods (including Great Recession)	manufacturing	more productive plants/firms less likely to exit	Yes
			Baldwin and Rafiquzzaman (1995)	labor productivity or its growth	Canada	1971–1982	newly created firms	more productive firms/plants not less likely to exit	No
			Collard-Wexler and De Loecker (2015)	TFP	U.S.	1963–2002	steel industry	no significant effect	No
			Kimura and Fujii (2003)	firm profitability	Japan	1994–1999	several industries	no significant effect	No
			Hall (1987)	Tobin's Q	U.S.	1979 and 1983	large manufacturing firms	negative on survival	Yes
Question	Sec.	Method	Paper	Efficiency measure	Country	Period/Year	Industry (firms/establishments)	Result	Answer (state dependent?)
State dependent?	3.2.1	Cyclicality of productivity levels of exiting firms	Griliches and Regev (1995)	labor productivity	Islael	1979–1988	manufacturing	no cyclicality of productivity levels of exiting firms over the business cycle	No
			Lee and Mukoyama (2015)	TFP	U.S.	1972–97	manufacturing	no cyclicality of productivity levels of exiting firms over the business cycle	No
	3.2.2	Cyclicality of effect of TFP on firm exit	Foster, Grim and Haltiwanger (2016)	TFP	U.S.	Crisis periods (including Great Recession)	manufacturing	negative effect condenses in recession periods (but less so in the Great Recession)	Yes

ing ones (Griliches and Regev 1995 (labor productivity, manufacturing establishments, Israel, 1979-1988) and Foster, Haltiwanger and Krizan 2001 (labor and multifactor productivity, manufacturing establishments in the US,1977-1987[18])). Foster, Haltiwanger and Krizan (2001) also more clearly find lower labor productivity for a service industry for the period from 1987 to 1992. Aw, Chung and Roberts (2003) also find lower productivity (in terms of TFP) for manufacturing plants or firms in Korea (1983-1993) and Taiwan (1981-1991[19]). Griliches and Regev (1995) and Lee and Mukoyama (2015) (TFP, the US, 1972-1997) go further to compare the productivity levels of exiting firms over the business cycle, and find no clear evidence of cyclicality.

Different from these studies that simply compare mean productivities, Fariñas and Ruano (2005) test the differences in productivity distributions between exiting and continuing firms. Using data from Spanish manufacturing firms over 1990-1997, they find stochastic dominance of the productivity distribution of continuing firms over that of exiting firms as well as the dominance of the distribution of continuing firms over that of failing firms in the same birth cohort. These findings are consistent with natural selection.

There is one study that disagrees with these studies and does not lend support to the natural selection hypothesis. Nishimura, Nakajima, and Kiyota (2005) find that the firm-level TFP for exiting firms is on average higher than that for surviving firms in Japan over 1996-1997. However, this finding is consistent with their finding on productivity decomposition that exit negatively contributes to productivity growth (see Section 3.1.1).

3. 2. 2 Evidence from regression analysis

To test natural selection, we can also run regressions on the determinants of firm/plant exit in which an indicator for exit is the dependent variable and firm efficiency is an independent variable. Many studies take this approach, although model specifications are often different depending on their research interests. There are also studies that estimate a survival model in the empirical literature on firm dynamics.

Consistent with natural selection, many studies find that more productive plants/firms are less likely to exit. Examples include Baily, Hulten and Campbell (1992) (TFP, the US manufacturing sector, 1972-1982), Olley and Pakes (1996) (TFP, the US telecommunication equipment industry, 1974, 1987), Dwyer (1998) (TFP, the US textile industry, 1972-1987), Musso and Schiavo (2008) (TFP, French manufacturing firms, 1996-2004), and Kiyota and Takizawa (2006) (TFP and its growth, Japanese firms in several industries, 1995-2002).

As for state dependence, Foster, Grim and Haltiwanger (2016) regress the firm exit on the TFP and compare this effect across recession periods, especially between the Great Recession in the late 2000s and the other periods. They find that the effect of the TFP on firm exit is negative, which is consistent with natural selection, and that the relevant effect condenses in recession periods, but less so in the Great Recession.

However, there are some studies that do not find that more productive firms/plants are less likely to exit. Baldwin and Rafiquzzaman (1995) use a regression analysis of the survival rate with sector-level data on newly created firms in Canada for the period from 1971 to1982. They find no significant effects of labor productivity or its growth on exit. Also, in the analysis on the effect of technology on firm exit in the US steel industry, Collard-Wexler and De Loecker (2015) find no significant effect of the TFP (as a control variable) on the likelihood of plant exit, although the number of observations in this analysis is small. Kimura and Fujii (2003) find no statistically significant effect of proxies for profitability on exit for Japanese firms in several industries for the period from 1994 to 1999.[20)]

On balance, most of the studies report evidence that inefficient firms are more likely to exit, but there are some studies that report the absence of such an effect. Although the results are mixed, the mixed results are not strong enough in the sense that we can at least conclude that there is no unnatural selection. Also, the fact that many studies report consistent evidence from the data of different samples (countries, years, and industries) indicates that natural selection is a relatively robust phenomenon. Nevertheless, paying more attention to the mixed results might be worthwhile, because they might be related to a methodological issue in the approach of these studies that we next discuss.

3. 2. 3 Methodological issues

Nonlinearity in the effect of firm efficiency

In this part, we discuss two methodological issues in existing studies on the effect of a firm's efficiency on its exit. The first issue pertains to the nonlinearity of the effect. Most of the studies introduced earlier use a continuous measure of efficiency and examine the sign of its coefficient. Although this is a simple and reasonable approach, it does not consider nonlinearity, that is, the differing effects of efficiency on firm's exit at the different efficiency levels. The actual probability of exit might not change linearly as the efficiency level changes, because the same marginal increase in the efficiency level might decrease the exit probability to a greater extent for extremely inefficient firms than for more efficient ones, for example. Thus, the mixed

evidence indicated earlier might be an artifact of picking firms at different efficiency levels.

As for this nonlinearity issue, Dwyer (1998) reports a result that take into account this issue. In a preliminary analysis, Dwyer (1998, Table II) splits the sample firms based on their productivity levels (10 deciles) and calculates the exit rate for each decile. The results indicate that the exit rate is higher for less productive firms, and the difference from the mean exit rate is statistically significant to a greater extent at lower and higher productivity deciles.[21)]

3. 2. 4 Other determinants of firm exit

The second methodological issue is the determinants of exit other than efficiency. Although we have reviewed evidence on the effect of efficiency on exit, studies on firm dynamics do not necessarily focus on efficiency. Especially, as motivated by theoretical studies such as Jovanovic (1982) and Hopenhayn (1992), there are many studies that run a regression for exit or survival in which the firm's age and size are the main independent variables.[22)]

More broadly speaking, this is an issue of a variable choice. Viewed from this perspective, different studies run regressions on exit that use different sets of independent variables. The choices of the variables are often ad hoc and lack theoretical justification. Regarding this issue, Thompson (2005) points out, as a criticism over studies focusing on firm age and firm size, that there are a number of competing explanations that can justify the use of firms' age and size as their proxy, and what really drives the effect of the age or size of the firm that they find is unclear. The choice of variables also matters because it might change the overall results.

In this study, we have focused on firm efficiency and not on other factors including age or size. This is a reasonable and theoretically well-founded approach, because the lack of efficiency is modeled as the most fundamental cause of firm exit. In fact, as explained above, even theoretical studies on firm dynamics that focus on its age and size (including Jovanovic 1982 and Hopenhayn 1992) model exit as the violation of the participation constraint, that is, the zero-profit condition, and firm's age and size are conditioning factors to the condition. To the best of our knowledge, the only other cause of firm exit that theoretical studies explicitly model is financial constraint (Section 2.2).

Strictly speaking, as far as we rely on these studies as a theoretical foundation, empirical studies do not need independent variables other than the proxies for firm efficiency and financial constraint (including firms' ages and sizes).[23)] Under these theories, other variables could never affect exit, unless they change the firms' efficiency levels or the extent of the financial constraint.

However, this argument does not mean that using other variables are entirely meaningless. Even if the fundamental cause for exit is the lack of efficiency or financial constraint, there is merit in running a *reduced form* regression (without variables for firm exit or financial constraint), because we can examine whether and how other factors (like age and size) affect the exit, probably through efficiency or financial constraint. Or, even a regression using other variables as well as firm efficiency and financial constraint might be meaningful. Such a regression would be a fact finding study that examines whether other factors directly affect firm exit *in a manner neglected by current theories*, because their indirect effects (through efficiency or financial constraint) are already controlled for. Ultimately, what is important is not what variables to use, but what research questions we want to address by using the variables.[24)]

4 Conclusion

In this study, we reviewed the literature on the relation between the firm's efficiency or profitability and its exit. Theoretical studies predict that less efficient or less profitable firms are more likely to exit, but some studies on financial constraint do not. So whether or not the selection mechanism is natural is an empirical question.

As for empirical evidence, we find that most studies that decompose productivity report results that firm exit increases productivity growth, which is consistent with natural selection. However, we also find that studies on Japan in the banking crisis period in the later 1990s report the opposite result. Most empirical studies on firm dynamics also find results that less efficient firms are more likely to exit, although some studies do not find such an effect. As for the state dependence of the selection mechanism, there are few studies, but their evidence does not strongly support the counter-cyclicality of the mechanism.

On balance, the evidence mostly lends support to the natural selection hypothesis. However, it is important to address the inconsistency in the results by examining whether it is merely due to differences in the sample (e.g., country, year, and industries). There are also countries, years, and industries that no study has examined yet. Also, it is important to address methodological issues like the nonlinear effect of firm efficiency and the choice of variables based on a proper theoretical foundation and on research questions. Together with the need for more studies on the state dependence of the selection mechanism, there are still many important issues remaining for future research.

Notes

† This study is a result of the Project on Corporate Finance and Firm Dynamics undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The author thanks Kaoru Hosono, Daisuke Miyakawa, Arito Ono, and Iichiro Uesugi for their comments. This study is financially supported by JSPS KAKENHI Grant Number JP16H02027.

1) Theoretically, we can express firms' *efficiency* (or *productivity*) as a parameter of the profit (or production or cost) function that changes the value of the function given the amount of inputs, while firms' *profitability* is expressed by the profit itself. For example, if we denote a firm's production function as f, the price of the product as p, the vector of inputs as X, and the vector of their prices as w, then efficiency can be expressed as a parameter ϕ for $f(X|\phi)$, and profitability can be expressed as the profit $pf(X|\phi)-wX$. Unless explicitly mentioned, we do not distinguish efficiency and profitability in this paper because theoretical predictions on their relation with exit are mostly the same, like more efficient (profitable) firms are less likely to exit.

2) In addition to these two strands of the literature, there have been many studies on the models to predict the default of debt claims since the seminal study by Altman (1968). However, these studies are interested in increasing the precision of predicting future default by changing empirical models and adding or dropping variables, and are not very interested in the mechanisms behind firms' exit. Also, default is not the only cause of firm exit (see Section 2.3). Due to these reasons, and because of the limited space, we do not deal with these studies in this paper.

3) Note that there are types of natural selection. Referring to studies in genetics, Okada and Horioka (2008) point out that there are at least three types: stabilizing, directional, and disruptive selection. The stabilizing selection eliminate phenotypes at both extremes of the distribution, the directional selection eliminates only one extreme of phenotypes, and the disruptive (diversifying) selection eliminate intermediate phenotypes. The natural selection in the literature we review focuses on a directional selection to eliminate inefficient or unprofitable firms.

4) Jovanovic (1982), an important theoretical contribution in the literature on firm dynamics, demonstrates that firm exit depends on the firm's age, and we can consider this relation as another form of state-dependence. However, in his learning model, firms that observe low output levels for consecutive periods of time learn that they are inefficient enough to violate their participation constraint, and thus exit. Thus, the basic cause of firm exit in his model is the lack of efficiency.

5) Studies to focus on the effect of financial constraint are also in the literature on firm dynamics (e.g., Albuquerque and Hopenhayn 2004, Clementi and Hopenhayn 2006).

6) Ramey and Watson (1997) demonstrate a similar mechanism in a model with relation-specific investment, but without financial friction. In their model, adverse shocks promote the separation of efficient firm-worker pairs by exacerbating the problem of prisoners' dilemma, and prevents profitable relation-specific investment.

7) There is also a study that demonstrates a decrease, not increase, in the exit threshold. In the model of Gomes, Greenwood and Rebelo (2001), adverse shocks reduce wealth of workers. To compensate for the resulting loss of income, workers do not abandon their jobs even if their jobs are

of low productivity (the *sullying effect*). Relatedly, Kehrig (2015) shows a decrease in the exit threshold due to mismeasurement. When firms need fixed overhead inputs that is unobservable by researchers, the exit threshold measured in terms of observable profitability might decrease.

8) Eslava, Galindo, Hofstetter, and Izquierdo (2015) later present a similar model, where irrespective of the level of productivity, a firm exits due to an inability to raise funds for production.

9) This approach first calculates the weighted average of productivity at the firm- or establishment-level, say Φ, where the market share of each firm or establishment is used as the weight. It then takes a time-difference in this average, that is, Φ_t minus Φ_{t-1}, to obtain the growth of aggregate productivity and decomposes this growth into the growth for surviving firms, negative of Φ_{t-1} for exited firms, and the positive of Φ_t for entered firms. It finally takes the difference in each term from a reference productivity level, and further decomposes the growth for surviving firms into within-firm (changes in the firms' productivity) and between-firm (changes in their share) components. See, for example, Melitz and Polanec (2015) for more information.

10) See Foster, Grim, and Haltiwanger (2016) for a review of broader pieces of evidence in this literature (i.e., not limited to exiting firms).

11) To examine the effect of technology change, Collard-Wexler and De Loecker (2015) compare the decomposition of the productivity growth between vertically integrated (old technology) and non-integrated (new technology) plants in the U.S. steel industry. They find that the positive and significant contribution of net entry for vertically integrated plants only.

12) The measure of aggregate productivity in Ostomehin (2019) is slightly different from that in the other studies. She also proposes a decomposition of productivity growth of incumbent firms into the contribution of the change in allocative and technical efficiency.

13) Scarpetta, Hemmings, Tressel, and Woo (2002) also distinguish the contribution of exit and entry when they compare the labor or multifactor productivity of manufacturing and service firms in 10 OECD countries in Europe and the US for the 1987–1992 and the 1992–1997 periods. They find that the contribution of exit firms is positive and relatively large, sometimes even comparable to the contribution of within-firm growth, but the contribution is sometimes negative (although small). However, we should also note that the number of observations for their analysis is small.

14) Specifically, Kim, Kwon and Fukao (2007) find that the contribution of the exit component over 1997 to 1999 is small and negative to large firms, while it is large and positive to small firms. They also find that the aggregate productivity growth over 2000 to 2002 is positive, but the exit component contributes negatively and significantly to large firms, while positively and significantly to smaller firms.

15) Olley and Pakes (1996) decompose cross-sectional aggregate (weighted average) productivity into the mean productivity and the covariance of the productivity levels of each firm and its market share. Melitz and Polonec (2015) use a time-difference in this decomposition, and also take into account the productivity changes due to firms' entry and exit.

16) In this decomposition, Kwon, Narita, and Narita (2015) do not consider the fixed costs term.

17) In a similar vein, we do not focus on a different criticism by Lentz and Mortensen (2008) on the

irrelevance of the between-firm component of the conventional method for productivity decomposition.

18) Lee and Mukoyama (2015) also find in the US manufacturing sector in 1972–1997 that the productivity of exiting firms is smaller than that of entering firms. Bellone, Musso, Nesta, and Quere (2006) report a similar result for French manufacturing firms in 1990–2002.

19) In the sample of Baldwin and Rafiquzzaman (1995) (the sector-level sample of manufacturing firms in Canada that enter a market by creating a new plant during the 1971–1982 period), surviving firms have higher labor productivity (value-added per employee) than exiting firms.

20) There is also a study using an efficiency measure other than productivity. In examining the determinants of firm growth (employment growth) to take into account sample selection bias, Hall (1987) estimates, as the first-stage regression, a probit model of survival in which she controls for firms' efficient use of assets by using Tobin's Q (market-to-book ratio and R&D stock / asset ratio). The result from using a sample of 1,753 large (Compustat) manufacturing firms shows that Tobin's Q positively contributes to the survival for the period from 1979 to 1983.

21) Although they do not run regressions, Fariñas and Ruano (2005) compare the distributions of continuing and existing firms. This approach also gives an idea of the nonlinear effect, but because they assume monotonicity of the distribution function and only test the stochastic dominance of the distributions between the two types of firms, they do not consider the possibility of a non-monotonic effect in the first place but consider a monotonic nonlinear effect only.

22) To name a few, such studies include Evans (1987a, b), Hall (1987), Dunne, Roberts and Samuelson (1988, 1989), Audretsch (1991), Mata and Portugal (1994), Wagner (1994), Audretsch and Mahmood (1995), Agarwal and Gort (2002), Disney, Haskel and Heden (2003), Persson (2004), Coad, Frankish, Roberts and Storey (2016), and Fackler, Schnabel and Wagner (2013).

23) There are many studies that explicitly focus on financial constraint (e.g., Holtz-Eakin, Joulfaian and Rosen 1994, Musso and Schiavo 2008, Huynh, Petrunia and Voia 2010, Cetorelli 2014, Eslava, Galindo, Hofstetter and Izquierdo 2015 and Byrne, Spaliara and Tsoukas 2016). Although the proxies for financial constraint used in these studies are diverse (like leverage, inheritance, financial deregulation, and other measures calculated using financial or survey information), they consistently find that a tighter financial constraint increases the likelihood of firm exit.

24) Examples of studies that indicate such research questions are Dixit (1989) who focuses on the effect of uncertain output prices, and Ghemawat and Nalebuff (1985, 1990) who focus on the effect of competition and a capacity choice in declining industries.

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