

Firm Dynamics in Korea's Export-leading Industries*

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This study investigates the impact of firm dynamics from entry, exit, and persevering incumbents on the productivity growth of Korea's export-leading industries by applying a stochastic frontier production function model to unbalanced firm-level panel dataset over 2006-2017. Empirical results verified that technical progress led productivity growth across industries, with market distortion, firm dynamics, and persevering incumbents also playing a considerable role on productivity growth. Consequently, resource reallocation from firms with declining productivity to firms with rising productivity occurred through market mechanisms favoring the latter; while rigid institutional frameworks and industrial features of the business environment hinder efficient resource reallocation.

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1. INTRODUCTION

In the past six decades, Korea's economic growth has been driven by targeted manufacturing industries, which have then occupied the top ranks of exports until now. These industries have distinct business transactions and different degrees of vertical integration in their industrial structure because Korea's export-driven growth is hinged on large conglomerates for transaction costs savings and efficiency promotion, which subcontract to small and medium-sized firms. Thus, there have consistently been reiterated policy issues concerning government support for the shared growth between large conglomerates and subcontracting firms.

In this study, firms with a certain number of business transactions with parent firms, subsidiaries, or associated firms are defined as vertically integrated with capital-share (VI) firms, and the other firms are defined as non-VI (NVI) firms. Bounded by this business environment, firm dynamics of entry and exit have been characterized by industrial features, and the accompanying productivity gain or loss determines productivity growth across manufacturing industries. Within the bounds of individual industrial structure, transactions exclusively in the VI structure may hinder fair trade and competition, which could ultimately lead to market distortion.

In the early literature, D'Aveni and Ravenscraft (1994) emphasized that prioritizing a secure supply chain can cause the principal-agent problem, which infringes upon fair trade and competition in the market, and eventually higher production costs caused by insulation from market competition and a lack of incentive to minimize input costs linked to vertical integration.

In the past decades, VI firms have faced substantial challenges from the agency dilemma in Korea and thus carried out strategies to strengthen their competitiveness by increasing efficiency, whereas NVI firms either have tried proactively to step into a VI structure to secure stable supply chains or to introduce new technologies to be competitive.

Foster *et al.* (1998) used an establishment-level dataset for US manufacturing and found that the effects of reallocating inputs and outputs

from less-productive to more-productive establishments have played a significant role in accounting for the aggregate productivity growth.

Likewise, as an initiative study about the microdynamics in Korean manufacturing industries, Hahn (2000) used a plant-level panel dataset from 1990 to 1998 for Korean manufacturing and found that the combined effect of the entry and exit and the market share reallocation explained the aggregate productivity growth in manufacturing.

However, these studies addressed the impact of plant dynamics on aggregate productivity growth without due consideration for the specific industrial features and business dealings in the individual industry.

Interestingly, Son and Lee (2017) shed light on how firm structure can determine the exit of plants in the Korean manufacturing sector, concluding that “multiplant firms are more likely to shut down plants in the event of more active resource allocation and restructuring within firms.”

A more recent study on the Korean manufacturing industries by Pai (2016a), using an establishment-level dataset of Korea's 37 growth-leading industries from 1995 to 2012, verified that technical progress led productivity growth in the targeted industries driven by the Korean government's “selection and concentration” policy.

With regard to specific industrial features and productivity growth, Pai (2016b) specified for firms to share growth with their counterparts and found that this resulted to either higher productivity or a larger export share in the global market.

Focusing on firm dynamics, Pai (2019) found that the Korean government's recent institutional push improved the productivity growth rates of NVI firms in Korea's electronics, automobile, and machinery industries reaching their highest levels in 2010.

Although Pai (2019) considered firm age, no previous studies have attempted to measure the impact of changes in business durations as persevering incumbent effect on the productivity growth of industries. Business durations are defined here as persistent participation in the production process of one industry.

Therefore, this study attempted to measure the extent to which VI firms and NVI firms contributed to the industry in the form of productivity gain or loss, when they enter or exit the industry and further when they persevere in business as incumbents.

As a consequence, these firm dynamics altered market share and resource reallocation between VI and NVI firms, not by market selection force alone but more substantially by market exogenous shocks such as the macroeconomic turbulence triggered by the 2008 global financial crisis.

In the end, this study investigates resource waste and inefficient resource reallocation between VI and NVI structures, which in turn will find a way to enhance the global competitiveness of the export-leading industries and eventually lead to the sustainable economic growth of Korea in the long run.

The remainder of this paper is presented as follows: Section II explains the estimation model, and section III describes the data used. Section IV discusses the empirical results, and section V presents the conclusions and intuitions.

2. MODEL

This study applies a Cobb-Douglas stochastic frontier production function (C-D SFPF) to an unbalanced firm-level panel dataset of Korea's 15 export-leading industries from 2006 to 2017. For the industry as a whole, the following are the C-D SFPF models, which includes variables of new VI entrants and NVI entrants, variables of exiting VI and NVI firms, and variables of the business durations of VI and NVI incumbents.

$$\begin{aligned} \ln VA_{it} = & \alpha_0 + \alpha_L \ln L_{it} + \alpha_K \ln K_{it} + \alpha_T t + \alpha_{TL} t \ln L_{it} + \alpha_{TK} t \ln K_{it} \\ & + \alpha_V \text{Entry}_{V_{it}} + \alpha_N \text{Entry}_{NV_{it}} + \beta_V \text{Exit}_{V_{it}} + \beta_N \text{Exit}_{NV_{it}} \\ & + \omega_{VD} BD_{V_{it}} + \omega_{ND} BD_{NV_{it}} + (v_{it} - u_{it}), \end{aligned} \quad (1)$$

where VA_{it} is the real value-added of the i th firm in the t th period ($i=1, \dots,$

N , $t=1, \dots, T$), t is a time trend index that serves as a proxy for technical change, and L_{it} and K_{it} are the input volumes of labor and capital, respectively, for the i th firm in the t th period.

$Entry_{V_{it}}$ and $Entry_{NVI_{it}}$ are the impact of new VI entrants and new NVI entrants, respectively: $Entry_{V_{it}} = 1$ if a firm is a new VI entrant; otherwise, $Entry_{V_{it}} = 0$. $Entry_{NVI_{it}} = 1$, if a firm is a new NVI entrant; otherwise, $Entry_{NVI_{it}} = 0$. $Exit_{V_{it}}$ and $Exit_{NVI_{it}}$ are the pre-exit impact of exiting VI firms and exiting NVI firms, respectively, from the industry one year prior to their actual exit: $Exit_{V_{it}} = 1$ if a firm is an exiting VI firm; otherwise, $Exit_{V_{it}} = 0$. $Exit_{NVI_{it}} = 1$ if a firm is an exiting NVI firm; otherwise, $Exit_{NVI_{it}} = 0$. $BD_{V_{it}}$ and $BD_{NVI_{it}}$ are the business durations of VI firms and NVI firms, respectively. Finally, α , β , and ω are unknown parameters.

Here, entry of firms are defined as entering the current industry for the first time, exit of firms are defined as exiting the designated industry for good, and business duration of firms are defined as persistent participation in the production process of one industry.

For a composed error term $(v_{it} - u_{it})$, v_{it} is a random disturbance assumed to distribute independently and identically as $N(0, \sigma_v^2)$ independent of u_{it} . u_{it} is output-oriented time-variant technical inefficiency (Battese and Coelli, 1992; Battese *et al.*, 1995).

$$u_{it} = \eta_{it} u_i = \exp(\eta(t - T)) u_i, u_i \geq 0, u_i \sim N(\mu, \sigma_u^2), \quad (2)$$

where the distribution of u_i is a more flexible nonnegative truncation of the normal distribution;

$$\gamma = \frac{\sigma_u^2}{\sigma^2}, \quad \sigma^2 = \sigma_u^2 + \sigma_v^2, \quad (3)$$

where γ is the ratio of the variance of technical inefficiency to the variance of a composed error, and $0 < \gamma < 1$. η is the parameter that represents the rate of catching-up toward frontier technology.

Finally, the program FRONTIER 4.1 by Coelli (1996) applies to the

unbalanced panel dataset of Korea's 15 export-leading industries from 2006 to 2017.

Next, Solow (1956) first introduced TFP growth (TFP) as output growth that is inexplicable by input growth. Eventually, Kumbhakar (2000) decomposed TFP into four components, the rates of technical progress (TP), changes in technical efficiency (TE), scale component (SC), and allocative efficiency (AE). Together, these four components and the impact of changes in firm entry, exit, and business durations of incumbents (ZC) (4) are estimated in this model (the derivation of the five components are available from the author upon request).

$$TFP = TP + TE + SC + AE + ZE, \quad (5)$$

where $ZC = V_{enter}, NV_{enter}, V_{exit}, NV_{exit}, V_{BD},$ and NV_{BD} are from (1).

3. DATA

The unbalanced panel dataset used in this study includes firms with 50 or more workers in Korea's 15 export-leading industries during the 2006-2017 period (from the *Survey of Business Activities* data issued by Statistics Korea). Appendix table A.1 presents Korea's 15 export-leading industries by Korean Standard Industrial Classification (KSIC) code according to export volume in 2018 shown in table A.2.

VI firms are those that perform a certain number of transactions with parent, subsidiary, and associated firms, where a parent firm owns more than 50% of a subsidiary firm's capital, while an associated firm owns 20-50% of another firm's capital. The transactions involve business activities of domestic sales, direct exports and imports, input purchases, and commissioned and fiduciary research and development. All other firms are defined as NVI firms.

Table 1 Summary Statistics for Korea's 15 Export-leading Industries and Their VI and NVI Structures from 2006 to 2017

IT manufacturing											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
201.2	445.3	31.7	482.6	939.9	165.2	107.1	235.1	18.2	0.700	0.685	0.711
(3,358.6)	(5,221.9)	(340.4)	(3,729.0)	(5,771.0)	(445.9)	(1,439.0)	(2,233.3)	(165.4)	(0.148)	(0.146)	(0.149)
Automobiles											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
83.5	184.3	24.8	399.4	833.4	146.5	70.4	158.3	19.1	0.701	0.709	0.696
(644.5)	(1,053.4)	(40.4)	(2,663.1)	(4,351.5)	(140.6)	(626.4)	(1,025.7)	(29.3)	(0.133)	(0.124)	(0.137)
Chemicals											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
125.3	202.4	50.9	299.3	460.5	143.9	112.0	186.7	40.0	0.690	0.670	0.710
(463.2)	(624.2)	(185.8)	(849.0)	(1,165.0)	(241.4)	(412.0)	(566.1)	(118.2)	(0.154)	(0.158)	(0.147)
Machinery											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
34.8	61.5	20.9	178.5	280.6	125.4	23.6	40.4	14.9	0.762	0.763	0.762
(99.7)	(159.8)	(35.4)	(314.0)	(493.5)	(122.2)	(69.0)	(110.9)	(25.1)	(0.122)	(0.124)	(0.121)
Coke, briquettes, and refined petroleum products											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
1,469.8	2,381.8	126.8	752.0	1,150.7	164.9	1,246.2	2,031.1	90.5	0.627	0.580	0.697
(4,799.4)	(6,027.5)	(759.7)	(1,200.8)	(1,352.7)	(547.1)	(2,472.6)	(2,932.2)	(492.4)	(0.188)	(0.200)	(0.144)
Basic metal products											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
125.3	275.4	41.3	280.1	534.2	138.0	160.2	386.2	33.8	0.653	0.621	0.670
(814.0)	(1,340.2)	(96.7)	(1,132.0)	(1,850.9)	(162.6)	(1,267.2)	(2,092.0)	(111.2)	(0.156)	(0.158)	(0.152)
Other transport equipment (shipbuilding)											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
269.4	799.7	55.5	737.3	2,121.7	178.8	216.0	639.1	45.3	0.705	0.673	0.718
(1,135.5)	(1,922.9)	(401.3)	(2,771.6)	(4,805.7)	(627.8)	(855.7)	(1,478.6)	(213.9)	(0.174)	(0.187)	(0.168)
Precision instruments											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
25.4	37.0	16.8	159.9	211.9	121.5	13.1	18.6	9.1	0.765	0.752	0.775
(47.6)	(67.2)	(20.9)	(212.7)	(300.0)	(93.7)	(22.2)	(30.5)	(11.3)	(0.122)	(0.127)	(0.117)
Electric equipment											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
64.0	131.0	24.0	239.8	413.4	136.4	36.7	74.5	14.2	0.753	0.737	0.762
(952.9)	(1,556.0)	(52.9)	(1,894.4)	(3,085.6)	(165.8)	(509.4)	(831.5)	(31.5)	(0.133)	(0.140)	(0.128)
Fabricated metal products											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
34.5	65.3	24.2	157.4	278.2	117.0	26.8	53.3	18.0	0.725	0.713	0.730
(92.1)	(165.9)	(40.8)	(310.4)	(565.5)	(122.2)	(103.3)	(193.9)	(36.5)	(0.146)	(0.145)	(0.147)
Textiles											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
32.2	103.0	13.2	146.3	310.8	102.2	25.7	81.0	10.9	0.756	0.706	0.770
(246.9)	(529.8)	(21.4)	(354.9)	(733.9)	(80.0)	(138.8)	(285.0)	(40.7)	(0.118)	(0.118)	(0.115)

Food products											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
54.6	125.4	26.4	285.5	585.4	166.2	41.5	99.9	18.2	0.736	0.704	0.749
(158.6)	(253.5)	(82.5)	(599.1)	(956.8)	(298.2)	(138.5)	(230.7)	(61.4)	(0.119)	(0.116)	(0.118)
Beverages											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
121.4	175.2	74.3	474.9	742.6	241.0	143.2	230.1	67.2	0.681	0.693	0.670
(240.9)	(290.9)	(173.9)	(912.4)	(1,213.2)	(399.3)	(364.1)	(473.8)	(200.9)	(0.131)	(0.120)	(0.139)
Pharmaceuticals											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
61.8	96.7	44.0	315.1	467.5	237.8	40.7	66.3	27.7	0.773	0.762	0.779
(90.5)	(118.9)	(65.1)	(351.9)	(462.2)	(246.4)	(81.0)	(95.5)	(69.0)	(0.116)	(0.127)	(0.109)
Clothing apparel											
Value -added			Labor			Capital			Labor share		
Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI	Industry	VI	NVI
740.1	121.7	47.8	212.1	297.2	165.3	190.1	32.5	11.6	0.730	0.704	0.744
(1,292.0)	(176.8)	(82.2)	(244.0)	(323.6)	(169.0)	(412.0)	(55.5)	(28.0)	(0.150)	(0.153)	(0.146)

Notes: 1) Value-added and capital are measured in billion KRW, Labor is measured in number of workers, and Labor share is a share of labor cost out of total cost, (capital cost+ labor cost).

2) All are mean values, and standard deviations are in parentheses.

The real value-added (VA), the real value of fixed assets (K), and the number of workers (L) are measured to estimate the C-D SFPF: Each industry's real value-added of firms is produced by value-added deflator issued by the Bank of Korea for 82 industrial sectors, and the real value of fixed assets including land and individual assets that are durable for at least one year is produced in terms of the producers' constant 2010 prices.

The selected time periods with entry, exit, and business duration of firms are: the 2008-2009 economic recession, the 2010-2011 economic upturn, the 2012-2014 mild economic downturn, and the 2015-2016 economic downturn. Table 1 verifies that the VI firms significantly overtook the NVI firms, in terms of real value-added, number of workers, and capital from 2006 to 2017. However, VI firms showed smaller labor share than NVI firms, whereas VI automobiles and VI beverages firms exhibited larger labor share.

4. RESULTS

Table 2 Firms' Survival in Korea's 15 Export-leading Industries from 2006 to 2017

	Stay in business for 12 years	Not stay in business for 12 years	Total number of firms (100%)	Total number of observations (100%)
IT manufacturing	211 (12.6%) 2,532 (28.0%)	1,457 (87.4%) 6,506 (72.0%)	1,668	9,038
Automobiles	302 (24.3%) 3,624 (43.1%)	943 (75.7%) 4,780 (56.9%)	1,245	8,404
Chemicals	173 (25.7%) 2,076 (47.8%)	501 (74.3%) 2,263 (52.2%)	674	4,339
Machinery	226 (16.4%) 2,712 (33.5%)	1,151 (83.6%) 5,377 (66.5%)	1,377	8,089
Coke and refined petroleum products	8 (20.5%) 96 (42.7%)	31 (79.5%) 129 (57.3%)	39	225
Basic metal products	133 (22.3%) 1,596 (39.9%)	464 (77.7%) 2,407 (60.1%)	597	4,003
Other transport equipment	28 (10.0%) 336 (22.6%)	253 (90.0%) 1,153 (77.4%)	281	1,489
Precision instruments	59 (13.4%) 708 (28.9%)	382 (86.6%) 1,746 (71.1%)	441	2,454
Electric equipment	103 (13.6%) 1,236 (29.6%)	657 (86.4%) 2,934 (70.4%)	760	4,170
Fabricated metal products	97 (11.3%) 1,164 (27.0%)	763 (88.7%) 3,149 (73.0%)	860	4,313
Textiles	109 (26.0%) 1,308 (48.2%)	310 (74.0%) 1,403 (51.8%)	419	2,711
Food products	177 (27.4%) 2,124 (46.2%)	470 (72.6%) 2,475 (53.8%)	647	4,599
Beverages	23 (36.5%) 276 (58.0%)	40 (63.5%) 200 (42.0%)	63	476
Pharmaceuticals	88 (33.7%) 1,056 (53.3%)	173 (66.3%) 924 (46.7%)	261	1,980
Clothing apparel	71 (20.8%) 852 (39.2%)	270 (79.2%) 1,324 (60.8%)	341	2,176

Note: Share of firms and observations are in parentheses.

Table 2 shows firm survival in Korea's export-leading industries from 2006 to 2017, where the total number of observations indicates the number of firms that took part at least once in the manufacturing processes during the sample period and the total number of firms refers to the number of unique firms for the 2006-2017 period.

Over the 12-year period, out of the total number of firms, the number and share of surviving firms are small for IT manufacturing with 211 (12.6%), machinery with 226 (16.4%), other transport equipment (mainly shipbuilding) with 28 (10.0%), precision instruments with 59 (13.4%), electric equipment with 103 (13.6%), and fabricated metal products with 97 (11.3%); large for beverages with 23 (36.5%), and pharmaceuticals with 88 (33.7%); and in between for automobiles with 302 (24.3%), chemicals with 173 (25.7%), coke, briquettes, and refined petroleum products with 8 (20.5%), basic metal products with 133 (22.3%), food products with 177 (27.4%), and clothing apparel with 71 (20.8%).

Among the core target industries, the share of surviving firms in the IT manufacturing, machinery, and other transport equipment (mainly shipbuilding) industries is above 10%, half that of the automobiles, chemicals, and basic metal products industries mainly due to the business environment and the product life cycle.

Table 3 Number of Firms' Entry to and Exit from the Industry in Korea's 15 Export-leading Industries from 2006 to 2017

	IT manufacturing		Automobiles		Chemicals		Machinery		Coke and refined petroleum products	
	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	13	47	8	31	10	3	4	29	1	0
2008	89	164	33	89	30	37	61	137	1	2
2009	10	24	3	5	2	7	8	13	2	0
2010	16	23	6	5	7	10	6	22	2	0

2011	21	133	17	99	14	40	20	101	2	0
2012	11	70	14	68	10	29	16	73	0	1
2013	9	27	9	33	7	12	7	19	0	1
2014	20	39	9	14	7	26	15	32	0	0
2015	3	6	2	7	2	6	4	11	0	0
2016	18	76	16	57	11	40	23	105	0	5
2017	7	15	7	19	9	18	8	29	1	0
Total	217	624	124	427	109	228	172	571	9	9
Exit	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	21	61	4	16	7	11	5	25	1	0
2008	65	113	26	82	12	20	43	87	1	2
2009	24	46	8	24	6	8	12	32	0	0
2010	25	32	12	21	5	14	7	26	2	0
2011	50	83	7	23	12	20	14	39	1	1
2012	21	53	7	27	7	13	13	38	0	0
2013	15	56	6	21	5	14	13	26	1	4
2014	42	66	11	26	11	16	19	42	1	0
2015	14	34	10	23	5	12	4	27	0	1
2016	52	77	45	85	16	28	43	80	1	1
2017	13	37	8	26	12	10	4	27	0	2
Total	342	658	144	374	98	166	177	449	8	11
	Basic metal products		Other transport equipment		Precision instruments		Electric equipment		Fabricated metal products	
Entry	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	3	14	1	16	5	20	3	11	5	7
2008	28	55	7	36	20	37	40	62	29	98
2009	2	8	4	4	5	5	7	4	2	10
2010	3	7	1	5	2	3	5	14	6	17
2011	8	41	4	31	12	22	6	49	8	55
2012	7	38	2	21	6	23	5	55	12	51

2013	1	9	4	11	2	12	5	8	3	11
2014	3	10	2	12	5	19	7	16	10	25
2015	1	4	0	2	1	10	1	5	0	7
2016	4	25	2	13	15	29	18	49	11	89
2017	2	15	0	2	2	4	6	11	6	26
Total	62	226	27	153	75	184	103	284	92	396
Exit	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	2	11	0	7	5	13	6	21	2	24
2008	11	38	1	16	20	22	31	58	25	79
2009	5	10	5	8	7	8	9	13	5	32
2010	3	5	7	9	6	4	10	11	6	20
2011	6	17	4	11	3	15	10	25	10	26
2012	5	19	2	10	5	9	7	21	7	18
2013	2	17	4	12	8	10	6	24	7	23
2014	5	21	1	22	8	12	16	38	8	41
2015	5	8	0	5	1	3	3	13	5	13
2016	9	24	7	19	7	18	30	34	22	51
2017	1	18	3	10	3	8	3	12	3	25
Total	54	188	34	129	73	122	131	270	100	352
	Textiles		Food products		Beverages		Pharmaceuticals		Clothing apparel	
Entry	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	0	15	5	7	0	2	0	1	3	4
2008	10	23	12	56	1	5	7	5	14	15
2009	1	2	3	4	0	1	1	4	7	3
2010	0	1	2	11	0	1	3	4	2	10
2011	4	19	3	77	2	0	1	20	1	20
2012	0	19	1	23	1	1	6	10	1	6
2013	1	6	1	11	0	0	4	8	0	1
2014	3	4	2	9	1	0	2	8	1	10

2015	1	3	0	6	1	0	2	2	2	4
2016	5	7	4	36	0	2	4	5	1	11
2017	1	3	2	4	0	1	2	7	3	2
Total	26	102	35	244	6	13	32	74	35	86
Exit	VI	NVI	VI	NVI	VI	NVI	VI	NVI	VI	NVI
2007	1	25	3	14	0	1	0	2	3	10
2008	8	48	13	26	2	2	4	8	13	23
2009	2	14	3	11	1	0	1	2	7	5
2010	3	9	6	21	2	3	4	5	2	9
2011	3	20	4	22	1	1	0	6	7	11
2012	1	14	3	22	2	3	1	2	2	22
2013	2	17	2	20	0	1	4	4	1	8
2014	4	16	6	18	0	2	2	8	5	23
2015	4	11	5	11	1	0	1	2	1	9
2016	8	7	4	17	1	1	6	7	7	12
2017	0	8	5	21	0	0	4	5	1	7
Total	36	189	54	203	10	14	27	51	49	139

Tables 3 shows that the frequency of firm entry to the industry soared sharply in 2008, 2011, and 2016 and plummeted in 2017, while firm exit rose fast in 2008 and rose again in 2011, 2014, and 2016, except for the textile, food product, beverage, pharmaceutical, and clothing apparel industries. These firm dynamics were triggered by the 2008 global financial crisis, the subsequent economic downturn, and the large-scale industrial restructuring that followed. The frequency of entry and exit of NVI firms was higher than that of VI firms, which indicates that NVI firms are more likely to act on firm dynamics than VI firms, due to their insecure status in the supply chain.

Table 4 presents the impacts of changes in new VI entrants (\dot{V}_{enter}) and new NVI entrants (\dot{NV}_{enter}) on the productivity growth of Korea's 15 export-

leading industries in the specified time periods, ranked by average values, from 2006 to 2017.

Throughout the selected time periods, \dot{NV}_{enter} varied across industries to a greater extent than \dot{V}_{enter} , and the impact of new NVI entrants on the productivity growth was more positive in the past decade. The impacts of new NVI entrants on the productivity growth varied the most extensively across industries during the 2008-2009 economic recession triggered by the 2008 global financial crisis, and the second most extensively across industries during the 2015-2016 economic downturn. However, they became close to zero across industries during the 2012-2014 mild economic downturn after the 2010-2011 economic upturn.

Table 4 \dot{V}_{enter} and \dot{NV}_{enter} in Korea's 15 Export-leading Industries, Ranked by Their Respective Average Values, from 2006 to 2017

	2008-2009	2010-2011	2012-2014	2015-2016	2008-2016
\dot{V}_{enter}					
Precision instruments	0.3	0.1	0.0	0.2	0.1
IT manufacturing	0.1	0.1	0.0	0.0	0.1
Textiles	0.1	0.0	0.0	0.0	0.0
Basic metal products	0.1	0.0	0.0	0.0	0.0
Other transport equipment (mainly shipbuilding)	0.1	0.0	0.0	0.0	0.0
Machinery	0.0	0.0	0.0	0.0	0.0
Fabricated metal products	0.0	0.0	0.0	0.0	0.0
Automobiles	0.0	0.0	0.0	0.0	0.0
Beverages	-0.1	0.0	0.0	0.0	0.0
Electric equipment	-0.1	0.0	0.0	0.0	0.0
Food products	-0.2	0.0	0.0	0.0	-0.1
Chemicals	-0.1	-0.1	0.0	-0.1	-0.1
Pharmaceuticals	-0.2	-0.1	-0.1	-0.1	-0.1
Clothing apparel	-0.5	-0.1	0.0	0.0	-0.1
Coke and refined petroleum products	-0.1	-1.6	0.0	0.0	-0.4
Average	0.0	-0.1	0.0	0.0	0.0
\dot{NV}_{enter}					
Electric equipment	6.9	0.0	0.0	6.6	3.0
Machinery	9.7	0.9	0.0	2.1	2.8
Automobiles	1.9	0.9	-0.1	2.4	1.1
IT manufacturing	3.0	0.2	0.0	1.5	1.1
Precision instruments	0.6	0.5	0.0	1.4	0.6

Basic metal products	0.5	0.1	0.0	0.1	0.1
Food products	0.5	0.1	0.0	0.0	0.1
Coke and refined petroleum products	-0.4	0.0	0.6	0.0	0.1
Beverages	0.0	0.0	0.0	0.1	0.0
Textiles	0.0	0.0	0.0	-0.1	0.0
Clothing apparel	-0.5	0.1	0.0	0.0	-0.1
Fabricated metal products	-0.3	0.0	0.0	0.0	-0.1
Pharmaceuticals	0.2	0.2	-1.0	-0.3	-0.3
Chemicals	-0.3	-0.3	0.0	-0.8	-0.3
Other transport equipment (mainly shipbuilding)	-2.1	-0.8	0.1	0.0	-0.6
Average	1.3	0.1	0.0	0.9	0.5

Note: TFP growth is expressed in percentage terms and the components are expressed in percentage points.

Throughout the selected time periods, new entrants mostly retained the trend with which they started, whether positive or negative. New NVI entrants had significant positive impacts on the productivity growth of the target industries of electric equipment (3.0%), machinery (2.8%), automobiles (1.1%), IT manufacturing (1.1%), and precision instruments (0.6%), but similarly significant negative impact on the productivity growth of other transport equipment (mainly shipbuilding) (-0.6%).

In the target industries of machinery, automobiles, and IT manufacturing, which retain a vertical integration in their industrial structure, new NVI entrants considerably contributed to the productivity growth. Furthermore, new VI and NVI entrants both had positive impacts on the productivity growth of the precision instruments and IT manufacturing industries.

Table 5 presents the impacts of changes in exiting VI firms (\dot{V}_{exit}) and exiting NVI firms (\dot{NV}_{exit}) on the productivity growth of Korea's 15 export-leading industries in the specified time periods, ranked by average values, from 2006 to 2017.

Throughout the selected time periods, \dot{NV}_{exit} , pre-exit impacts of exiting NVI firms on the productivity growth varied more extensively across industries and more significant negative than \dot{V}_{exit} , pre-exit impacts of exiting VI firms on the productivity growth, one year prior to the actual exit.

Table 5 \dot{V}_{exit} and $\dot{N}V_{\text{exit}}$ in Korea's 15 Export-leading Industries, Ranked by Their Respective Average Values, from 2006 to 2017

	2008-2009	2010-2011	2012-2014	2015-2016	2008-2016
\dot{V}_{exit}					
Other transport equipment (mainly shipbuilding)	1.6	0.1	-0.1	-0.5	0.2
Basic metal products	0.4	0.1	0.0	0.0	0.1
Fabricated metal products	0.1	0.2	0.0	-0.2	0.0
Beverages	0.0	0.0	0.0	0.0	0.0
Textiles	0.0	0.0	0.0	0.0	0.0
Food products	0.0	0.0	0.0	-0.1	0.0
Automobiles	0.0	-0.1	0.0	-0.1	0.0
Coke and refined petroleum products	-0.9	0.0	0.4	0.0	-0.1
Pharmaceuticals	0.1	0.0	-0.3	-0.1	-0.1
Machinery	-0.4	-0.1	0.0	0.0	-0.1
Chemicals	-0.1	-0.4	0.0	-0.3	-0.2
IT manufacturing	-0.7	-0.2	0.0	-0.2	-0.2
Precision instruments	-0.6	-0.7	0.2	-0.9	-0.4
Clothing apparel	-2.4	0.6	0.3	-0.8	-0.5
Electric equipment	-3.0	0.1	0.0	-0.6	-0.8
Average	-0.4	0.0	0.0	-0.2	-0.1
$\dot{N}V_{\text{exit}}$					
Beverages	0.6	0.8	0.4	0.0	0.4
Textiles	0.0	1.8	-0.1	0.1	0.4
Coke and refined petroleum products	0.0	0.0	0.5	0.0	0.2
Other transport equipment (mainly shipbuilding)	0.0	0.2	0.0	0.2	0.1
Pharmaceuticals	-0.3	-0.3	0.1	-0.1	-0.1
Precision instruments	-0.1	-1.5	0.1	-0.1	-0.3
Machinery	-0.5	-0.7	0.1	-0.7	-0.4
Basic metal products	-0.5	-1.5	0.2	-1.3	-0.7
Chemicals	-1.8	-1.1	0.0	-0.7	-0.8
Electric equipment	-0.8	-1.9	0.2	-1.1	-0.8
Fabricated metal products	-2.3	-0.4	0.1	-1.1	-0.8
Food products	-0.9	-2.5	0.3	-1.4	-1.0
Automobiles	-0.4	-5.3	0.3	-1.8	-1.6
IT manufacturing	-0.9	-2.9	0.4	-4.9	-1.8
Clothing apparel	-0.4	-2.8	-3.2	-0.4	-1.9
Average	-0.6	-1.2	-0.1	-0.9	-0.6

Note: TFP growth is expressed in percentage terms and the components are expressed in percentage points.

During the 2010-2011 economic upturn, exiting NVI firms had the most significant negative pre-exit impact of -1.2% on the productivity growth of Korea's 15 export-leading industries, despite the textiles industry having significant positive pre-exit impacts of 1.8% ; during the 2015-2016 economic downturn, exiting NVI firms had the second most significant negative pre-exit impact of -0.9% .

Eventually, exiting NVI firms had a significant negative pre-exit impact on automobiles, IT manufacturing, and clothing apparel, -1.6% , -1.8% , and -1.9% , respectively. Because of the "shadow of death," (Carreira and Teixeira, 2011), exiting NVI firms had negative impacts on the productivity growth of eleven industries, especially in industries with substantial vertical integration in their production process.

Taken together with the impacts of changes in new VI entrants and new NVI entrants on the productivity growth, and exiting VI firms and exiting NVI firms on the productivity growth from 2006 to 2017, resource reallocation from firms with declining productivity to firms with less declining or rising productivity occurred by the market force (J. Wagner, 2010), especially for NVI firms.

Throughout the selected time periods, the impacts of changes in exiting NVI firms on the productivity growth fluctuated across industries to a greater extent than their counterparts did, indicating that the bounds of institutional framework and industrial structure considerably worked on the productivity gain or loss of exiting NVI firms.

Table 6 presents the impacts of changes in business duration of VI firms (\dot{V}_{BD}) and business duration of NVI firms (\dot{NV}_{BD}) on the productivity growth of Korea's 15 export-leading industries in the specified time periods, ranked by average values, from 2006 to 2017.

\dot{V}_{BD} , the impact of persevering VI firms, similarly varied across industries during the 2008-2009 economic recession and the 2012-2014 mild economic downturn; they subsided during the 2010-2011 economic upturn and the 2015-2016 economic downturn. In contrast, \dot{NV}_{BD} , the impact of persevering NVI firms, varied extensively across industries throughout the

Table 6 \dot{V}_{BD} , \dot{NV}_{BD} and TFP in Korea's 15 Export-leading Industries, Ranked by Their Respective Average Values, from 2006 to 2017

*		2008- 2009	2010- 2011	2012- 2014	2015- 2016	2008- 2016
	\dot{V}_{BD}					
13	Beverages	6.2	2.7	5.9	-0.9	3.8
12	Food products	0.6	0.1	0.8	0.2	0.5
8	Precision instruments	0.4	0.1	0.3	0.2	0.2
2	Automobiles	0.5	0.0	0.3	0.1	0.2
7	Other transport equipment (mainly shipbuilding)	0.4	0.0	0.1	0.1	0.1
5	Coke and refined petroleum products	0.2	0.1	0.3	-0.1	0.1
4	Machinery	0.0	0.0	0.0	0.0	0.0
9	Electric equipment	-0.2	0.0	-0.2	0.0	-0.1
3	Chemicals	-0.5	0.0	-0.3	0.0	-0.2
6	Basic metal products	-0.6	0.0	-0.4	0.0	-0.2
10	Fabricated metal products	-0.7	0.0	-0.5	-0.4	-0.4
1	IT manufacturing	-0.9	-0.1	-0.8	-0.1	-0.5
14	Pharmaceuticals	-1.3	-0.4	-0.6	-0.7	-0.7
11	Textiles	-1.7	-0.3	-1.5	-0.8	-1.1
15	Clothing apparel	-2.2	-0.5	-2.7	-0.4	-1.6
	Average	0.0	0.1	0.0	-0.2	0.0
	\dot{NV}_{BD}					
13	Beverages	4.7	8.8	2.6	18.1	7.9
12	Food products	1.7	1.6	1.3	2.4	1.7
2	Automobiles	0.6	1.4	0.5	1.6	1.0
7	Other transport equipment (mainly shipbuilding)	0.3	0.5	0.3	0.3	0.3
3	Chemicals	0.1	0.4	0.1	0.4	0.2
8	Precision instruments	0.2	0.4	0.1	0.3	0.2
6	Basic metal products	0.0	0.1	0.0	0.1	0.0
4	Machinery	0.0	-0.1	0.0	-0.1	0.0
9	Electric equipment	-0.3	-0.6	-0.2	-0.5	-0.4
10	Fabricated metal products	-0.6	-1.0	-0.6	-0.3	-0.6
5	Coke and refined petroleum products	0.0	-0.9	0.0	-2.3	-0.7
1	IT manufacturing	-0.5	-1.2	-0.5	-1.2	-0.8
14	Pharmaceuticals	-1.0	-1.3	-0.8	-1.1	-1.1
15	Clothing apparel	-3.0	-3.2	-2.0	-4.7	-3.1
11	Textiles	-4.7	-5.1	-3.4	-5.3	-4.5
	Average	-0.2	0.0	-0.2	0.5	0.0

Note: Column * presents the ranking of export volume in 2018.

selected time periods.

Throughout the selected time periods, the impacts of both persevering VI firms and NVI firms consistently retained the trend with which they started. This result indicates that the binding conditions relevant to industrial structure and business dealings invariably acted on productivity gain or loss of both persevering VI firms and NVI firms in the past decade.

Consequently, the persistent NVI firms improved the productivity growth far greater than the persistent VI firms in the beverages (3.8%, 7.9%), food products (0.5%, 1.7%), and the most vertically integrated automobiles (0.2%, 1.0%) industries. In contrast, persevering NVI firms slowed the productivity growth more than the persevering VI firms in the vertically integrated clothing apparel (-1.6%, -3.1%) and textile (-1.1% and -4.5%), as well as pharmaceuticals (-0.7% and -1.1%), and the fast technology progressive and the vertically integrated IT manufacturing (-0.5%, -0.8%) industries.

Taken as a whole, TFP growth revealed a distinct trajectory when the impacts of changes in new VI and NVI entrants, exiting VI and NVI firms, as well as business duration of VI and NVI incumbents are included.

Table 7 TE in Korea's 15 Export-leading Industries, Ranked by Average TE, from 2006 to 2017

TE	2008-2009	2010-2011	2012-2014	2015-2016	2008-2016
Pharmaceuticals	57.4 (0.9)	59.2 (1.6)	59.3 (0.3)	60.0 (0.7)	59.0 (0.8)
Basic metal products	45.8 (-2.0)	45.7 (0.1)	44.3 (-1.5)	42.6 (-1.6)	44.6 (-1.3)
Automobiles	49.1 (-2.7)	46.2 (-3.4)	41.6 (-4.1)	36.9 (-5.5)	43.2 (-4.0)
Electric equipment	45.1 (-0.6)	44.5 (-1.0)	42.4 (-1.6)	40.2 (-3.0)	43.0 (-1.5)
Machinery	41.1 (0.3)	41.1 (-0.3)	40.2 (-1.0)	38.7 (-1.9)	40.3 (-0.8)
Precision instruments	41.2 (-2.0)	40.7 (0.2)	39.1 (-2.0)	37.9 (-1.2)	39.6 (-1.3)

Coke and refined petroleum products	38.2 (5.8)	38.4 (0.1)	37.7 (0.3)	35.2 (-9.1)	37.4 (-0.6)
Other transport equipment (mainly shipbuilding)	34.0 (-3.4)	34.2 (1.4)	35.0 (0.2)	34.6 (1.1)	34.5 (-0.1)
Fabricated metal products	33.9 (1.5)	34.4 (-0.3)	33.5 (-0.4)	33.2 (-1.1)	33.7 (-0.1)
IT manufacturing	35.6 (-0.9)	34.8 (-1.1)	32.9 (-2.5)	30.6 (-3.1)	33.4 (-2.0)
Textiles	31.2 (2.5)	32.1 (0.1)	32.2 (0.8)	32.9 (-0.5)	32.1 (0.8)
Food products	30.9 (-3.0)	30.6 (0.1)	29.3 (-2.1)	28.0 (-1.8)	29.6 (-1.8)
Beverages	29.7 (1.9)	30.9 (1.8)	28.3 (-3.5)	28.3 (1.1)	29.2 (-0.1)
Chemicals	29.4 (0.6)	29.1 (-2.3)	28.2 (-0.3)	27.9 (0.0)	28.6 (-0.5)
Clothing apparel	29.6 (0.8)	28.4 (-3.5)	27.4 (-1.3)	25.7 (-3.2)	27.7 (-1.7)
Average	38.1 (0.0)	38.0 (-0.4)	36.8 (-1.3)	35.5 (-1.9)	37.1 (-0.9)

Table 7 presents TE and average annual changing rate (\dot{TE}) are in percentage term in the specified time periods, ranked by average TE, from 2006 to 2017.

First of all, \dot{TE} fluctuated across industries and the largest TE losses occurred during the 2012-2014 mild economic downturn and significant TE losses occurred again during the 2015-2016 economic downturn. TE deteriorated continuously in three industries and worsened most in the automobiles, and their average TE and (\dot{TE}) were as follows: automobiles with 43.2 (-4.0), electric equipment with 43.0 (-1.5), and IT manufacturing with 33.4 (-2.0). On the contrary, TE improved continuously in the pharmaceutical industry and recorded the highest average TE and (\dot{TE}) of 59.0 (0.8).

Table 8 presents RTS in Korea's 15 export-leading industries, ranked by average RTS from 2006 to 2017.

t -test for the null hypothesis of CRS technology against the alternative hypotheses of non-CRS technology was conducted on the average estimates

Table 8 RTS in Korea's 15 Export-leading Industries, Ranked by Average RTS from 2006 to 2017

RTS	2008-2009	2010-2011	2012-2014	2015-2016	2008-2016	
Coke and refined petroleum products	1.178	1.157	1.130	1.103	1.140	(0.304)
Chemicals	1.096	1.090	1.083	1.076	1.086	(0.067)
Electric equipment	1.081	1.071	1.059	1.047	1.064	(0.067)
Basic metal products	1.017	1.036	1.060	1.085	1.051	(0.072)
IT manufacturing	1.018	1.017	1.014	1.012	1.015	(0.043)
Automobiles	1.017	1.014	1.009	1.005	1.011	(0.046)
Machinery	1.009	1.007	1.006	1.004	1.006	(0.046)
Beverages	0.958	0.975	0.997	1.018	0.988	(0.174)
Other transport equipment	0.953	0.970	0.991	1.012	0.982	(0.077)
Pharmaceuticals	0.962	0.972	0.985	0.998	0.980	(0.092)
Precision instruments	0.986	0.979	0.970	0.960	0.973	(0.085)
Fabricated metal products	0.960	0.962	0.965	0.967	0.964	(0.065)
Textiles	0.933	0.926	0.917	0.908	0.921	(0.082)
Food products	0.889	0.876	0.860	0.844	0.867	(0.055)
Clothing apparel	0.734	0.723	0.709	0.695	0.714	(0.071)

Note: Asymptotic standard errors are in parentheses.

of RTS of the 15 export-leading industries at 1% significance level.

As a result, the clothing apparel and food products industries exhibited DRS, while the remaining 13 export-leading industries exhibited CRS, given C-D SFPE.

Finally, table 9 presents TP, SC, AE, and *TFP* in Korea's 15 export-leading industries, ranked by the respective average values, from 2006 to 2017.

TP posted around 2% throughout the selected time periods; however, the earlier target industries of machinery, basic metal products, and chemicals posted relatively flagging TP, 0.6-1.2%, despite occupying high ranks in exports. Thus, they need to develop new frontier technologies to promote TP. For the worse, fabricated metal products (-0.6%), coke and refined petroleum products (-1.3%), food products (-1.4%), other transport equipment (mainly shipbuilding (-2.4%), and beverages (-7.6%) consistently recorded negative TP, exposing their technical retrogression.

Table 9 TP, SC, AE, and TFP in Korea's 15 Export-leading Industries, Ranked by the Respective Average Values, from 2006 to 2017

*		2008- 2009	2010- 2011	2012- 2014	2015- 2016	2008- 2016
TP						
15	Clothing apparel	10.3	10.2	10.1	10.1	10.2
1	IT manufacturing	8.7	8.7	8.7	8.6	8.7
8	Precision instruments	6.1	6.0	5.9	5.8	5.9
2	Automobiles	5.6	5.6	5.6	5.5	5.6
11	Textiles	5.3	5.2	5.1	5.0	5.1
9	Electric equipment	4.1	3.9	3.8	3.7	3.9
14	Pharmaceuticals	3.1	2.9	2.8	2.8	2.8
4	Machinery	1.4	1.3	1.1	0.9	1.2
6	Basic metal products	1.4	1.2	1.1	1.0	1.1
3	Chemicals	0.6	0.6	0.6	0.6	0.6
10	Fabricated metal products	-0.5	-0.6	-0.6	-0.7	-0.6
5	Coke and refined petroleum products	-0.9	-0.9	-1.6	-1.4	-1.3
12	Food products	-1.2	-1.3	-1.4	-1.6	-1.4
7	Other transport equipment (mainly shipbuilding)	-2.2	-2.4	-2.5	-2.5	-2.4
13	Beverages	-7.5	-7.5	-7.6	-7.7	-7.6
	Average	2.3	2.2	2.1	2.0	2.1
SC						
9	Electric equipment	7.6	-2.5	0.2	0.6	1.3
5	Coke and refined petroleum products	2.8	0.6	0.7	-1.0	0.8
3	Chemicals	0.3	0.5	0.4	-0.2	0.3
1	IT manufacturing	-0.2	0.6	0.0	0.0	0.1
6	Basic metal products	0.1	0.2	0.1	-0.2	0.1
2	Automobiles	0.1	0.0	0.0	0.0	0.0
4	Machinery	0.0	0.0	0.0	0.0	0.0
11	Textiles	-0.5	-0.3	0.5	-0.2	-0.1
7	Other transport equipment (mainly shipbuilding)	-0.4	0.0	0.0	-0.1	-0.1
14	Pharmaceuticals	-0.3	-0.1	0.0	-0.1	-0.1
13	Beverages	-0.4	0.0	-0.1	0.0	-0.1
8	Precision instruments	0.0	-0.1	-0.1	-0.3	-0.1
10	Fabricated metal products	-0.2	-0.2	-0.4	0.2	-0.2
12	Food products	-0.5	0.0	-0.6	-0.2	-0.4
15	Clothing apparel	-1.5	-1.2	-0.9	-0.1	-0.9
	Average	0.5	-0.2	0.0	-0.1	0.0
AE						
12	Food products	1.2	0.1	0.2	0.1	0.4
5	Coke and refined petroleum products	-0.5	0.1	-0.2	0.0	-0.1

15	Clothing apparel	-0.2	0.0	-0.2	-0.2	-0.2
8	Precision instruments	-0.2	-0.3	-0.2	0.0	-0.2
2	Automobiles	-0.5	-0.2	-0.2	-0.5	-0.4
14	Pharmaceuticals	-0.1	-0.5	-0.4	-0.4	-0.4
11	Textiles	-2.2	0.0	0.6	-1.1	-0.5
7	Other transport equipment (mainly shipbuilding)	-1.2	-0.6	0.2	-1.2	-0.6
4	Machinery	-1.9	0.2	-0.5	-0.3	-0.6
3	Chemicals	-1.4	-0.2	-1.2	0.4	-0.6
6	Basic metal products	-1.3	-0.7	-1.7	0.5	-0.9
10	Fabricated metal products	-1.7	-0.9	-1.1	-0.2	-1.0
1	IT manufacturing	0.8	-5.0	-1.1	-0.8	-1.5
13	Beverages	-5.3	-5.2	1.7	-2.0	-2.2
9	Electric equipment	-12.8	1.0	-0.3	-2.1	-3.2
	Average	-1.8	-0.8	-0.3	-0.5	-0.8
	<i>TFP</i>					
8	Precision instruments	4.7	4.5	4.3	5.5	4.7
1	IT manufacturing	8.6	-0.9	4.1	-0.2	3.0
4	Machinery	8.8	1.3	-0.3	0.1	2.1
13	Beverages	0.1	1.2	-0.5	8.7	2.1
2	Automobiles	5.1	-1.1	2.2	1.8	2.0
9	Electric equipment	0.8	-0.9	1.8	3.6	1.4
14	Pharmaceuticals	1.1	2.0	0.1	0.8	0.8
11	Textiles	-1.2	1.6	2.1	-2.9	0.5
15	Clothing apparel	0.2	-0.1	0.1	0.4	0.1
3	Chemicals	-2.4	-3.0	-0.6	-0.5	-1.5
6	Basic metal products	-1.8	-0.4	-2.2	-1.5	-1.6
12	Food products	-1.8	-1.9	-1.6	-2.5	-1.9
5	Coke and refined petroleum products	6.0	-2.6	1.0	-14.0	-2.0
7	Other transport equipment (mainly shipbuilding)	-7.1	-1.7	-1.7	-2.5	-3.1
10	Fabricated metal products	-4.7	-3.3	-3.5	-3.7	-3.8
	Average	1.1	-0.4	0.4	-0.5	0.2

Note: Column * presents the ranking of export volume in 2018.

SC largely tapered off across industries; however, significant scale economies appeared in the electric equipment (7.6%) and coke and refined petroleum products (2.8%), but scale diseconomies appeared in clothing apparel (-1.5%) during the 2008-2009 economic recession.

AE were negative across industries over the selected time periods, and the worst AE appeared during the 2008-2009 economic recession, notably in the industries of machinery (-1.9%), chemicals (-1.4%), basic metal products

(-1.3%), electric equipment (-12.8%), beverages (-5.3%), fabricated metal products (-1.7%), textile (-2.2%), and other transport equipment (mainly shipbuilding) (-1.2%), and IT manufacturing showed -5.0% during the economic recovery in 2010-2011. This indicates that allocative efficiency losses, i.e., market distortions prevailed across industries and time periods, especially in the aftermath of the 2008 global financial crisis.

Eventually, *TFP* fluctuated across industries throughout the selected time periods, and posted a significant positive value (1.1%) only during the 2008-2009 economic recession. *TFP* of the precision instruments (4.7%) and IT manufacturing (3.0%) industries overtook that of the earlier target industries of machinery (2.1%), automobile (2.0%), chemicals (-1.5%), basic metal products (-1.6%), and other transport equipment (mainly shipbuilding) (-3.1%) industries.

Taken together, technical efficiency and allocative efficiency considerably deteriorated during the economic downturn and the economic recession, respectively. Therefore, the government should be restrained from the baseless intervention in the labor market and the capital market, and let them be flexible by the market force to raise efficiency of resource allocation, especially under the market exogenous shock.

TP were relatively poor for the earlier target industries, and even significant technical retrogression came up in other transport equipment (mainly shipbuilding) industry, and thus they should develop new frontier technologies to promote TP. The alarming *TFP* retrogression of the earlier target industries led them to lose global competitiveness.

5. CONCLUSION

This study identified distinct characteristics of firm dynamics bound by industrial structures featured by capital share among firms in the business environment, especially due to macroeconomic fluctuations triggered by market exogenous shocks.

Throughout the selected time periods, the entry, exit, and business duration of firms continued the trend with which they started, whether positive or negative, implying that the business environment being bound by institutional inertia and industrial structure played a significant role in their productivity gain or loss, despite economic recession or economic recovery.

NVI firms are more likely to act on firm dynamics than VI firms due to their insecure status in the supply chain. Thus, the number of NVI firms decreased in the aftermath of the 2008 global financial crisis but increased in the economic recovery and upturns. Eventually, the share of NVI firms is greater than that of VI firms across industries except in the coke and refined petroleum products industry.

Throughout the selected time periods, the impact of new NVI entrants on the productivity growth varied across industries to a greater extent than that of VI firms, and finally, the impact of new NVI entrants was more positive. New NVI entrants contributed considerably to the productivity growth especially in the target industries of automobiles, IT manufacturing, and machinery which retain a substantial vertical integration in their industrial structure, while for the IT manufacturing, new VI and NVI entrants together raised its productivity growth.

On the other hand, exiting firms slowed the productivity growth in most industries, especially those with substantial vertical integration in their production process: exiting NVI firms in automobiles, IT manufacturing and clothing apparel significantly reduced the productivity growth.

Consequently, resource reallocation from firms with declining productivity to firms with less declining or rising productivity occurred by the market force, especially for NVI firms.

In the past decade, the impacts of persevering VI firms on the productivity growth similarly varied across industries during the 2008-2009 economic recession and the 2012-2014 mild economic downturn, whereas their counterparts consistently varied across industries throughout the selected time periods.

Eventually, the persevering NVI firms played a greater role in promoting

productivity growth than their counterparts in the beverages, food products, and automobiles sectors. However, persevering NVI firms reduced the productivity growth more than their counterparts in the clothing apparel, textile, pharmaceuticals, and IT manufacturing industries.

Taken together, TFP growth revealed a distinct trajectory across industries mainly by the rate of TP, the degree of market distortion, the impacts of firm dynamics, and persevering VI and NVI incumbents.

Furthermore, efficient resource reallocation is hindered by the chronic business environment being bound by the rigid institutional system and the vertical integration in their industrial structure. Especially, the government should refrain from unnecessary intervention in the labor and capital market, in order to let these markets work to improve efficiency of resource allocation, and let the earlier target industries develop new cutting-edge technologies to raise TFP growth and retain global competitiveness.

In the end, the empirical results in this study are contingent on the 15 export-leading industries of Korea, which should be interpreted with reservation for further study.

Specifically, further study must elaborate on the role of redistribution of sustainable firms through changes in the composition of plants in Korea.

APPENDIX

Table A.1 15 Manufacturing Industries under the KSIC (Korean Standard Industrial Classification) System

Industry	Subsectors
1. IT manufacturing	Manufacture of electronic components, computer, radio, television, and communication equipment and apparatuses (KSIC 26)
IT parts and components	Manufacture of semiconductors (KSIC 261) Manufacture of flat display boards (KSIC 2621) Manufacture of electronic components (KSIC 262)
IT products	Manufacture of computers and peripheral equipment (KSIC 263) Manufacture of telecommunications and broadcasting

	equipment (KSIC 264) Manufacture of electronic video and audio equipment (KSIC 265)
2. Automobiles	Manufacture of motor vehicles, trailers and semitrailers (KSIC 30) Manufacture of motor vehicles and engines for motor vehicles (KSIC 301) Manufacture of bodies for motor vehicles; manufacture of trailers and semitrailers (KSIC 302) Manufacture of parts and accessories for motor vehicles and engines (KSIC 303/KSIC 30400)
3. Chemicals	Manufacture of chemicals and chemical products except pharmaceuticals and medicinal chemicals (KSIC 20)
Petrochemicals	Manufacture of basic chemicals (KSIC 201) Manufacture of synthetic rubber and plastics in primary forms (KSIC 202)
Fine chemicals	Manufacture of fertilizer and nitrogen compounds (KSIC 203) Manufacture of other chemical products (KSIC 204)
4. Machinery	Manufacture of other machinery and equipment (KSIC 29) Manufacture of general-purpose machinery (KSIC 291) Manufacture of special-purpose machinery (KSIC 292)
5. Coke, briquettes, and refined petroleum products	Manufacture of coke, hard-coal and lignite fuel briquettes, and refined petroleum products (KSIC 19)
6. Basic metal products	Manufacture of Basic metal products (KSIC 24) Manufacture of basic iron and steel (KSIC 241) Manufacture of basic precious and non-ferrous metals (KSIC 242) Cast of metals ((KSIC 243)
7. Other transport equipment	Manufacture of other transport equipment (KSIC 31) Building of ships and boats (KSIC 311) Manufacture of railway and tramway locomotives and rolling stock (KSIC 312) Manufacture of aircraft, spacecraft, and its parts (KSIC 313)
8. Precision instruments	Manufacture of medical, precision and optical instruments, watches and clocks (KSIC 27)
9. Electric equipment	Manufacture of electrical equipment (KSIC 28)
10. Fabricated metal products	Manufacture of fabricated metal products, except machinery and furniture (KSIC 25)
11. Textiles	Manufacture of textiles, except for apparel (KSIC 13)
12. Food products	Manufacture of food products (KSIC 10)
13. Beverages	Manufacture of beverages (KSIC 11)
14. Pharmaceuticals	Manufacture of pharmaceuticals, medical chemicals, and botanical products (KSIC 21)
15. Clothing apparel	Manufacture of clothing apparel, clothing accessories, and fur articles (KSIC 14)

Table A.2 Export Volume by Industry in 2018

		Exports (US\$million)	Share (%)
Entire industries		604,860	100
Manufacturing industries		596,093	98.6
Industry	Sub sectors		
Manufacturing industries		596,093	100
1. IT manufacturing (KSIC 26)		183,091	30.7
IT parts and components	Semiconductors	127,838	21.4
	Flat display boards	11,871	2.0
	Other electronic components	7,379	1.2
IT products	Telecommunication apparatus	15,230	2.6
	Electronic and electric home appliances	13,545	2.3
	Computers	7,228	1.2
2. Automobile (KSIC 30)		64,998	10.9
3. Chemicals (KSIC 20)		73,383	12.3
	Petrochemicals	57,822	9.7
	Fine chemicals	15,561	2.6
4. Machinery (KSIC 29)		55,614	9.3
	Special purpose machinery	31,069	5.2
	General purpose machinery	24,545	4.1
5. Coke, briquettes, and refined petroleum products (KSIC 19)		48,020	8.1
6. Basic metal products (KSIC 24)		39,698	6.7
	Basic iron and steel	27,108	4.5
	Non-ferrous metals	11,913	2.0
	Metal casting	677	0.1
7. Other transport equipment (KSIC 31)		23,662	4.0
	Shipbuilding	20,334	3.4
	Railway	188	0.03
	Aircraft and spacecraft	3,140	0.5
8. Precision instruments (KSIC 27)	Precision instruments and medical devices	16,471	2.8
9. Electric equipment (KSIC 28)		15,565	2.6
10. Fabricated metal products (KSIC 25)		14,964	2.5
11. Textiles (KSIC 13)		11,658	2.0
12. Food and Beverages (KSIC 10 and 11)		6,495	1.1
13. Pharmaceuticals (KSIC 21)		4,314	0.7

14. Clothing apparel (KSIC 14)		2,091	0.4
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Source: Industrial Statistics Analysis System (ISTANS) (original source: Korea Customs Service, Korea Institute of Science & Technology Evaluation and Planning (KISTEP)).

Tables A.3 presents the results of hypothesis testing for the functional form C-D SFPF with a time-varying truncated normal distribution for inefficiency effects in Korea's 15 export-leading industries from 2006 to 2017. The null hypothesis indicating no technical inefficiency effects, $H_0 = \gamma = \mu = \eta = 0$, is rejected at the 1% significance level for the entire export-leading industries.

Table A.3 Results of Hypothesis Testing for the C-D FE SFPF with FC (firms' business duration, entry and exit) in Korea's 15 export-leading Industries from 2006 to 2017

Industry	$\hat{\gamma}$ (<i>t</i> ratio)	$\hat{\mu}$ (<i>t</i> ratio)	$\hat{\eta}$ (<i>t</i> ratio)	Null hypothesis $H_0 = \gamma = \mu = \eta = 0$			Outcome
				Log-likelihood function	Test statistics	Critical Value	
IT manufacturing	0.557 (38.41)	1.406 (15.74)	-0.022 (-6.07)	-9,875.0	2,252.3	10.50	Reject H_0
Automobile	0.533 (36.92)	1.196 (17.08)	-0.054 (-9.54)	-8,007.9	1,689.7	10.50	Reject H_0
Chemicals	0.635 (40.28)	1.449 (13.19)	-0.003 (-0.70)	-4,312.3	1,712.7	10.50	Reject H_0
Machinery	0.501 (36.57)	1.047 (17.62)	-0.011 (-3.45)	-7,275.6	1,885.3	10.50	Reject H_0
Coke and refined petroleum products	0.595 (8.90)	1.295 (3.85)	-0.020 (-0.82)	-213.6	82.8	10.50	Reject H_0
Basic metal products	0.357 (14.75)	0.936 (11.66)	-0.016 (-1.87)	-4,185.8	526.3	10.50	Reject H_0
Other transport equipment	0.514 (13.08)	1.115 (7.46)	0.006 (0.76)	-1,445.7	430.8	10.50	Reject H_0
Precision instruments	0.546 (26.32)	1.060 (10.04)	-0.016 (-2.02)	-2,089.6	655.9	10.50	Reject H_0
Electric equipment	0.441 (16.70)	1.015 (11.04)	-0.019 (-2.35)	-4,110.9	810.2	10.50	Reject H_0
Fabricated metal products	0.619 (41.17)	1.191 (15.74)	0.000 (-0.06)	-3,815.3	1,334.0	10.50	Reject H_0
Textiles	0.681 (35.18)	1.271 (12.30)	0.001 (0.17)	-2,107.3	1,012.0	10.50	Reject H_0
Food products	0.657 (56.71)	1.443 (17.03)	-0.019 (-2.88)	-4,238.1	1,573.6	10.50	Reject H_0
Beverages	0.705 (18.48)	1.297 (5.16)	-0.001 (-0.06)	-343.8	261.1	10.50	Reject H_0
Pharmaceuticals	0.892 (10.46)	-1.846 (-0.62)	0.022 (1.48)	-1,614.6	685.5	10.50	Reject H_0

Clothing apparel	0.829 (40.95)	1.869 (8.77)	-0.029 (-5.38)	-1,997.7	1,589.5	10.50	Reject H_0
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Note: The critical value=10.50 for this testing is imported from Kodd and Palm (1986).

Table A. 4 Average Impacts of Firms' Entry, Exit, and Business Duration of Incumbents on TFP Growth of 15 Export-leading Korea's Industries from 2006 to 2017 and Coefficients with t -values in Their SFPP

	Entry	impact	Pre-exit	impact	Incumbent	effect
Industry	New VI entrants	New NVI entrants	Exiting VI firms	Exiting NVI firms	Business duration of VI firms	Business duration of NVI firms
Coefficients (t -value)	$\hat{\alpha}_V$	$\hat{\alpha}_N$	$\hat{\beta}_{VX}$	$\hat{\beta}_{NX}$	$\hat{\omega}_{VD}$	$\hat{\omega}_{ND}$
IT manufacturing	0.108 (2.17)	0.055 (1.77)	-0.100 (-2.42)	-0.180 (-5.62)	-0.017 (-2.96)	-0.015 (-2.66)
Average impact	0.1	1.1	-0.2	-1.8	-0.5	-0.8
Automobiles	-0.033 (-0.57)	0.083 (2.51)	-0.040 (-0.75)	-0.165 (-4.77)	0.007 (1.15)	0.015 (2.67)
Average impact	0.0	1.1	0.0	-1.6	0.2	1.0
Chemicals	-0.131 (-1.95)	-0.036 (-0.73)	-0.068 (-0.96)	-0.164 (-2.88)	-0.006 (-0.84)	0.004 (0.55)
Average impact	-0.1	-0.3	-0.2	-0.8	-0.2	0.2
Machinery	0.033 (0.72)	0.066 (2.40)	-0.035 (-0.74)	-0.066 (-2.08)	0.001 (0.11)	-0.001 (-0.18)
Average impact	0.0	2.8	-0.1	-0.4	0.0	0.0
Coke and refined petroleum products	-0.401 (-1.76)	-0.357 (-1.49)	-0.227 (-0.95)	-0.244 (-1.17)	0.002 (0.06)	-0.014 (-0.41)
Average impact	-0.4	0.1	-0.1	0.2	0.1	-0.7
Basic metal products	0.097 (1.08)	0.008 (0.14)	0.069 (0.66)	-0.123 (-2.29)	-0.008 (-0.98)	0.001 (0.08)
Average impact	0.0	0.1	0.1	-0.7	-0.2	0.0
Other transport equipment	0.079 (0.64)	-0.032 (-0.56)	0.188 (1.76)	0.013 (0.20)	0.008 (0.56)	0.006 (0.50)
Average impact	0.0	-0.6	0.2	0.1	0.1	0.3
Precision instruments	0.172 (2.41)	0.020 (0.46)	-0.141 (-1.98)	-0.138 (-2.41)	0.008 (1.00)	0.004 (0.49)
Average impact	0.1	0.6	-0.4	-0.3	0.2	0.2
Electric equipment	-0.057 (-0.86)	0.059 (1.42)	-0.188 (-3.01)	-0.107 (-2.51)	-0.005 (-0.62)	-0.007 (-1.05)
Average impact	0.0	3.0	-0.8	-0.8	-0.1	-0.4

Fabricated metal products	-0.021 (-0.33)	-0.005 (-0.15)	0.055 (0.92)	-0.042 (-1.11)	-0.017 (-2.46)	-0.013 (-2.15)
Average impact	0.0	-0.1	0.0	-0.8	-0.4	-0.6
Textiles	0.141 (1.27)	-0.015 (-0.28)	-0.004 (-0.05)	0.034 (0.80)	-0.057 (-5.42)	-0.054 (-5.49)
Average impact	0.0	0.0	0.0	0.4	-1.1	-4.5
Food products	-0.273 (-2.46)	0.053 (1.13)	0.097 (1.13)	-0.127 (-2.74)	0.016 (1.76)	0.025 (2.84)
Average impact	-0.1	0.1	0.0	-1.0	0.5	1.7
Beverages	-0.154 (-0.82)	-0.022 (-0.15)	-0.011 (-0.08)	-0.219 (-1.59)	0.088 (3.81)	0.102 (4.25)
Average impact	0.0	0.0	0.0	0.4	3.8	7.9
Pharmaceuticals	-0.186 (-1.90)	-0.130 (-1.94)	-0.092 (-0.89)	-0.132 (-1.67)	-0.022 (-2.12)	-0.016 (-1.61)
Average impact	-0.1	-0.3	-0.1	-0.1	-0.7	-1.1
Clothing apparel	-0.293 (-3.02)	-0.033 (-0.49)	-0.361 (-4.23)	-0.219 (-4.01)	-0.048 (-3.38)	-0.048 (-3.49)
Average impact	-0.1	-0.1	-0.5	-1.9	-1.6	-3.1

Note: All impacts are expressed in percentage points.

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