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Structural Features and Firm Dynamics in Korea's IT Manufacturing Industry*

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This study investigates firm dynamics and productivity growth within IT manufacturing industry-specific features. The extensive business duration of vertically integrated with capital-share (VI) firms in their VI structure, despite agency costs, due to synergies from stable supply chains and lower transaction costs; new entrants in the industry and the structures; the strategic shifts that occurred in the non-VI (NVI) structure through self-selection, significantly contributed to productivity growth. The entry and exit impacts of VI firms in the industry and the structure were more pronounced than did NVI counterparts. TFP growth has been led mainly by technical progress and new entrants.

JEL Classification: D21, D24, C23, L63, O40
Keywords: structural features, firm dynamics, agency cost, self-selection, Korea's IT manufacturing industry

1. INTRODUCTION

Korea's information and communication technology (IT) manufacturing industry has been the backbone of the country's export-led economic growth, with key drivers coming out of the automobile electrical and electronics, and robotics industries. The IT manufacturing industry's structure tends toward hierarchies of vertical integration, involving original equipment manufacturers (OEM) partnering with small and medium-sized suppliers as subcontractors to promote efficiency and global price competitiveness. Vertically integrated with capital-share (VI) firms have advantages over non-VI (NVI) firms due to secure supply chains and lower transaction costs. However, secure supply chains can create principal–agent problems and hinder fair trade and competition in the market, resulting in higher production costs and a lack of incentive to minimize input costs due to insulation from market competition. This has led to vigorous debates in Korea about whether or not intra-VI structure transactions distort the market.

VI firms within the IT manufacturing industry attempt to resolve the agency dilemma by

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implementing strategies to eliminate inefficiency, promote productivity, and strengthen their global competitiveness; while NVI firms aim to secure stable supply chains by entry into VI structures or develop new products and technologies to remain competitive as NVI firms. As a result, the dynamics of entry into and exit from the industry, as well as strategic shifts between VI and NVI structures, directly impact productivity growth, market share, and resource reallocation between the VI and NVI structures, as well as the overall business duration of firms in the IT manufacturing industry.

Pai's studies (2019, 2021a, 2021b, 2021c) have shown how firms' strategic shifts impact the productivity growth of the industry and its VI and NVI structures, as well as the impact of exogenous market shocks. Pai (2016a) showed that 37 Korean manufacturing industries mainly led by technical progress, and they fared well in transitioning through the developmental phases. Pai (2016b) focused on three growth-leading industries (IT manufacturing, automobiles, and general machinery) to demonstrate the impact of firms' strategic choices on productivity growth. Pai (2019) measured the impact of the exogenous market shock of the 2008 global financial crisis on firm dynamics, firm age, and productivity growth in Korea's IT manufacturing, automobiles, and general machinery industries. Pai (2021a) showed that IT manufacturing firms retained greater competitiveness and resilience than automobile firms did under the adverse global value chain conditions since 2012; Pai (2021b) looked at 15 key manufacturing industries in Korea and verified that resource reallocation from firms with declining productivity to firms with rising productivity occurred through market selection forces; and Pai (2021c) evidenced that despite the most recent regulations on resource allocation, growth-leading industries along the developmental phase fared far better than expected.

This study aims to investigate how deeply firm dynamics and business duration can impact productivity growth in the IT manufacturing industry and its structures, as well as examine the resilience of firms in the face of market selection forces and exogenous market shocks. Ultimately, this study seeks to identify future directions for customized policy designs that enhance the global competitiveness of Korea's primary export-leading IT manufacturing industry for sustainable long-run economic growth.

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

2. MODEL

A Cobb-Douglas stochastic frontier production function (C-D SFPF) model is applied to an unbalanced firm-level panel dataset of Korea's IT manufacturing industry and its VI and NVI structures from 2006 to 2020.

For the industry as a whole, the C-D SFPF model is constructed as follows.

$$\ln VA_{it} = a_0 + \alpha_L \ln L_{it} + \alpha_K \ln K_{it} + \alpha_T t + \alpha_{TK} t \ln K_{it} + \alpha_{TL} t \ln L_{it} + \alpha_V BD_{V_{it}} + \alpha_N BD_{NV_{it}} + \alpha_{VE} Entry_{V_{it}} + \alpha_{NE} Entry_{NV_{it}} + \alpha_{VX} Exit_{V_{it}} + \alpha_{NX} Exit_{NV_{it}} + (v_{it} - u_{it}), \quad (1)$$

where VA_{it} is the real value-added of the ith firm in the tth period $(i = 1, \ldots N,\ t = 1, \ldots T)$, t is a time trend index that serves as a proxy for technical change, and respective L_{it} and K_{it} are the input volumes of labor and capital for the ith firm in the tth period. $BD_{V_{it}}$ and $BD_{NV_{it}}$ are the business durations of VI firms and NVI firms, respectively. Business duration of firms are defined as persistent participation in the production process of IT manufacturing industry. $Entry_{V_{it}}$ and $Entry_{NV_{it}}$ are the impact of new VI entrants and new NVI entrants, respectively; $Entry_{V_{it}} = 1$ if a firm is a new VI entrant, $Entry_{NV_{it}} = 1$, if a firm is a new NVI entrant. $Exit_{V_{it}}$ and $Exit_{NV_{it}}$ 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, and $Exit_{NV_{it}} = 1$ if a firm is an exiting NVI firm. Entry of firms are defined as entering the IT manufacturing industry for the first time and exit of firms are defined as exiting the IT manufacturing industry for good. Finally, α are unknown parameters.

For the VI structure, the following C-D SFPF model is built as follows.

$$\ln VA_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_T t + \beta_{TK} t \ln K_{it} + \beta_{TL} t \ln L_{it} + \beta_V BD_{V_{it}} + \beta_{VE} entry_{V_{it}} + \beta_{SE} shift_{(NVI \to VI)_{it}} + \beta_{VX} exit_{V_{it}} + \beta_{SX} shift_{(VI \to NVI)_{it}} + (v_{it} - u_{it}), \quad (2)$$

where VA_{it}, t, L_{it}, and K_{it} are defined as in (1), BD_{Vit} stands for the business durations of VI firms; $entry_{V_{it}} = 1$ if a firm is a new VI entrant, and $shift_{(NVI \to VI)_{it}} = 1$ if a firm is shifting from a NVI to a VI structure; $exit_{V_{it}} = 1$ if a firm is exiting a VI structure and the industry for good, and $shift_{(VI \to NVI)_{it}} = 1$ if a firm is shifting from a VI to a NVI structure. And β are unknown parameters.

Finally, for the NVI structure, C-D SFPF models is built as follows.

$$\ln VA_{it} = \omega_0 + \omega_L \ln L_{it} + \omega_K \ln K_{it} + \omega_T t + \omega_{TK} t \ln K_{it} + \omega_{TL} t \ln L_{it} + \omega_N BD_{NV_{it}} + \omega_{NE} entry_{NV_{it}} + \omega_{SE} shift_{(VI \to NVI)_{it}} + \omega_{NX} exit_{NV_{it}} + \omega_{SX} shift_{(NVI \to VI)_{it}} + (v_{it} - u_{it}), \quad (3)$$

where VA_{it}, t, L_{it}, and K_{it} are defined as in (1) and (2), $BD_{NV_{it}}$ represents the business duration of NVI firms; $entry_{NV_{it}} = 1$ if a firm is a new NVI entrant, and $shift_{(VI \to NVI)_{it}} = 1$ if a firm is shifting from a VI to an NVI structure. $exit_{NV_{it}} = 1$ if a firm is exiting a NVI structure and the industry permanently, and $shift_{(NVI \to VI)_{it}} = 1$ if a firm is shifting from a NVI to a VI structure. Finally, ω are unknown parameters.

In (1), (2), and (3), 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 real value-added-oriented time-variant technical inefficiency (Battese and Coelli, 1992; Battese *et*

al. , 1995).

$u_{it} = \eta_{it} u_i = \exp\left(-\eta(t-T)\right) u_i,\ u_{it} \geq 0,\ u_{it} \sim N\left(\mu, \sigma_u^2\right)$, where the distribution of u_i is a more flexible nonnegative truncation of the normal distribution; $\gamma = \sigma_u^2 / \sigma^2,\ \sigma^2 = \sigma_u^2 + \sigma_v^2$, 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. Thus, $u_{it} = \exp\left(-\eta(t-T)\right) u_i$ is adequate for tracing the changes in the average technical efficiency of the industry because each individual firm has an equivalent time-varying pattern, $\exp\left(-\eta(t-T)\right)$, for its technical inefficiency, u_i, indicating that the average technical inefficiency of the firms in the sample has the same time-varying pattern $\exp\left(-\eta(t-T)\right)$ (Lee, 2014).

Finally, the program FRONTIER 4.1 by Coelli (1996) is applied to the unbalanced panel dataset of Korea's IT manufacturing industry from 2006 to 2020 because the dataset has a long time-series for large cross-sectional firms.

Next, Solow (1956) first introduced TFP growth ($\dot{TFP}$) as output growth that is inexplicable by input growth. Eventually, Kumbhakar (2000) decomposed $\dot{TFP}$ into four components, the rates of technical progress (TP), changes in technical efficiency ($\dot{TE}$), scale component (SC), and allocative efficiency (AE). Together, these four components and the impact of changes in business durations of incumbents, firm entry, and exit are estimated for the industry as a whole, and the impact of changes in business durations of incumbents, firm entry, exit, and strategic shift are estimated for the VI and NVI structures (FC) in this model. These components are derived as follows. (The derivation of the components are available from the Appendix).

Eventually, for the industry as a whole,

$$\dot{TFP} = TP + \dot{TE} + SC + AE + \dot{V}_{BD} + \dot{NV}_{BD} + \dot{V}_{enter} + \dot{NV}_{enter} + \dot{V}_{exit} + \dot{NV}_{exit}\ , \tag{4}$$

where $\dot{V}_{BD}$ is an impact of changes in business durations of *VI* incumbents and $\dot{NV}_{BD}$ is an impact of changes in business durations of *NVI* incumbents, $\dot{V}_{enter}$ is an impact of changes in new *VI* entrants and $\dot{NV}_{enter}$ is an impact of changes in new NVI entrants, $\dot{V}_{exit}$ is an impact of changes in exiting VI firms and $\dot{NV}_{exit}$ is an impact of changes in exiting NVI firms.

For the VI structure,

$$\dot{TFP} = TP + \dot{TE} + SC + AE + \dot{BD}_V + \dot{eV} + \dot{S}_{NV \to V} + \dot{exV} + \dot{S}_{V \to NV}\ , \tag{5}$$

where $\dot{BD}_V$ is an impact of changes in business durations of VI incumbents, $\dot{eV}$ is an impact of changes in new firms to VI structure and $\dot{S}_{NV \to V}$ is an impact of changes in firms shifting from NVI to VI structure, $\dot{exV}$ is an pre-exit impact of changes in exiting firms from VI structure and industry and $\dot{S}_{V \to NV}$ is an pre-exit impact of changes in firms shifting from VI to NVI structure.

For the NVI structure,

$$\dot{TFP} = TP + \dot{TE} + SC + AE + \dot{BD}_{NV} + \dot{eNV} + \dot{S}_{V \to NV} + \dot{exNV} + \dot{S}_{NV \to V} \ . \quad (6)$$

Where $\dot{BD}_{NV}$ is an impact of changes in business durations of incumbents, $\dot{eNV}$ is an impact of changes in new firms to NVI structure and $\dot{S}_{V \to NV}$ is an impact of changes in firms shifting from VI to NVI structure, $\dot{exNV}$ is an pre-exit impact of changes in exiting firms from NVI structure and industry, and $\dot{S}_{NV \to V}$ is a pre-exit impact of changes in shifting from NVI to VI structure.

3. DATA

A micro-level unbalanced panel dataset of firms with 50 or more workers in Korea's IT manufacturing industry from 2006 to 2020 was selected, from the *Survey of Business Activities* issued by *Statistics Korea*. Korean Standard Industrial Classification (KSIC 26) in appendix table A.1 elaborates the sub-sectors of the IT manufacturing industry.

VI firms are those that complete a positive number of transactions with affiliated firms, such as parent, subsidiary, and associated firms. A parent firm owns more than 50% of a subsidiary firm's capital, and an associated firm owns 20-50% of another firm's capital. The transactions include business activities such as domestic sales, direct exports and imports, input purchases, and commissioned and fiduciary research and development (R&D). All other firms are defined as NVI firms.

For the estimation of C-D SFPF, the real value of fixed assets (*K*), the number of workers (*L*), and the real value-added (VA) are measured. The real value of fixed assets are composed of land and individual assets such as buildings, structures, machinery, equipment, vehicles, ships, and delivery equipment that are durable for at least one year, in terms of producers' constant 2015 prices. The real value-added of IT manufacturing firms is calculated using the value-added deflator for 24 manufacturing industrial sectors issued by the *Bank of Korea*.

4. RESULTS

4.1. Industrial Structure and TFP Growth

Table 1 presents the TFP growth $(\dot{TFP})$ of the IT manufacturing industry and its components: $TP, \dot{TE}, SC, AE,$ the incumbent effects of business duration of VI firms $(\dot{V}_{BD})$ and NVI firms $(\dot{NV}_{BD})$, the entry impact of VI entrants $(\dot{V}_{enter})$ and NVI entrants $(\dot{NV}_{enter})$, and the pre-exit

impact of exiting VI firms ($\dot{V}_{exit}$) and NVI firms ($\dot{NV}_{exit}$) in the industry from 2006 to 2020.

Table 1 $\dot{TFP}$ of the IT Manufacturing Industry and Its Components, TP, $\dot{TE}$, SC, AE, $\dot{V}_{BD}$, $\dot{NV}_{BD}$, $\dot{V}_{enter}$, $\dot{NV}_{enter}$, $\dot{V}_{exit}$, $\dot{NV}_{exit}$, from 2006 to 2020

	TP	$\dot{TE}$	SC	AE	$\dot{V}_{BD}$	$\dot{NV}_{BD}$	$\dot{V}_{enter}$	$\dot{NV}_{enter}$	$\dot{V}_{exit}$	$\dot{NV}_{exit}$	$\dot{TFP}$
2008	5.9	1.8	0.5	1.9	−0.4	−0.2	6.5	1.2	0.2	0.7	18.2
2009	6.0	−1.2	−0.1	0.6	−1.1	−0.4	−0.1	−0.1	0.0	0.2	3.6
2010	5.9	0.6	−0.6	−9.7	0.2	−1.4	0.2	0.0	−0.9	−3.4	−9.1
2011	5.9	−1.2	−0.1	−1.1	−0.4	−0.1	0.1	2.0	0.2	0.5	6.0
2012	5.9	−2.1	0.0	−1.1	−0.4	−0.4	−0.1	−0.1	0.1	−0.1	1.9
2013	5.9	−0.5	0.0	0.2	−1.0	−0.3	0.0	−0.1	−1.2	−0.2	2.8
2014	5.9	−2.6	0.0	−0.5	−0.8	−0.2	0.4	0.1	0.1	0.4	2.8
2015	5.9	−1.3	0.0	−0.5	−1.3	−0.2	0.0	0.0	−3.1	−2.5	−3.1
2016	5.9	−2.9	0.0	−1.6	1.2	−1.4	1.6	3.1	0.2	0.5	6.7
2017	5.9	−1.6	0.1	−2.6	−4.7	0.8	-0.1	0.0	−0.6	−0.1	−2.9
2018	5.9	−1.8	0.1	−1.7	−1.3	0.1	0.0	0.1	−0.5	−0.6	0.2
2019	5.9	−0.5	0.0	0.1	0.6	−0.8	0.4	0.1	0.2	0.2	6.3
2020	5.9	−3.2	−0.1	−0.7	0.8	−1.3	0.0	0.0	N.A.	N.A.	1.4
Average	5.9	−1.3	0.0	−1.3	−0.7	−0.4	0.7	0.5	−0.4	−0.4	2.7

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

First, except for a few instances of significant positive impact - namely, $\dot{V}_{BD}$ in 2016 (1.2%), $\dot{V}_{BD}$ in the 2020 economic depression induced by government policy failures and exacerbated by the pandemic (0.8%), and $\dot{NV}_{BD}$ in 2017 (0.8%), both $\dot{V}_{BD}$ and $\dot{NV}_{BD}$ dampened the TFP growth (productivity growth) of the industry throughout the period. Most significantly, $\dot{V}_{BD}$ in 2017 (−4.7%) dragged down TFP growth (−2.9%). In the end, $\dot{V}_{BD}$ (−0.7%) and $\dot{NV}_{BD}$ (−0.4%) averaged out, implying that firms with extensive business durations had a notable slowdown effect on productivity growth of the industry, particularly, VI firms had a greater slowdown effect on productivity growth of the industry, largely influenced by escalating agency cost. This can be attributed to the industry's short product life cycles and fast technological progress.

Second, $\dot{V}_{enter}$ (6.5%) and $\dot{NV}_{enter}$ (1.2%) in the 2008 economic downturn, $\dot{V}_{enter}$ (1.6%) and $\dot{NV}_{enter}$ (3.1%) in 2016, and $\dot{NV}_{enter}$ (2.0%) in 2011, were all significantly positive. Averaged out, $\dot{V}_{enter}$ (0.7%) and $\dot{NV}_{enter}$ (0.5%) show that both new VI and NVI entrants promoted the productivity growth of the industry, with new VI entrants contributing more through secure supply chains and lower transaction costs.

Third, significantly negative pre-exit impact on productivity growth strongly indicates a "shadow of death" effect, which reinforces the market selection mechanism of resource reallocation from firms with declining productivity to firms with stable or increasing productivity. $\dot{V}_{exit}$ (−3.1%) and $\dot{NV}_{exit}$ (−2.5%) in 2015, dampened productivity growth to (−3.1%); $\dot{V}_{exit}$ (−0.9%) and $\dot{NV}_{exit}$ (−3.4%) in the 2010 economic bounce-back dragged down productivity growth to (−9.1%); with another significantly negative $\dot{V}_{exit}$ (−1.2%) in 2013, averaged $\dot{V}_{exit}$

(−0.4%) and $\dot{NV}_{exit}$ (−0.4%) show that both exiting VI and NVI firms dampened the productivity growth of the industry one year prior to their actual exit.

Fourth and finally, TP remained steady at 5.9%, however $\dot{TE}$ and $\dot{AE}$, except during the 2008 economic recession, were negative throughout the years, and $\dot{SC}$ tapered off. As a result, $\dot{TFP}$ growth fluctuated extensively, ranging from a low of (−9.1%) due to poor $\dot{AE}$ (−9.7%), $\dot{NV}_{BD}$ (−1.4%), and $\dot{NV}_{exit}$ (−3.4 %), to a high of (18.2%) due to $\dot{TE}$ (1.8%), $\dot{AE}$ (1.9%), $\dot{V}_{enter}$ (6.5%), and $\dot{NV}_{enter}$ (1.2%), which eventually averaged out at 2.7%.

In summary, productivity growth of the IT manufacturing industry was mainly led by TP, $\dot{V}_{enter}$, and $\dot{NV}_{enter}$; while $\dot{TE}$, $\dot{AE}$, $\dot{V}_{BD}$, $\dot{NV}_{BD}$, $\dot{V}_{exit}$, and $\dot{NV}_{exit}$ dampened productivity growth.

4.2. Structural Shift and TFP Growth

Table 2 presents the TFP growth of the VI structure and its components: $\dot{TP}$, $\dot{TE}$, SC, AE, the incumbent effects of VI firms' business durations $(\dot{BD}_V)$, the entry impact of new firms to a VI structure $(\dot{eV})$ and firms shifting from a NVI to a VI structure $(\dot{S}_{NV\to V})$, and the pre-exit impact of firms exiting from a VI structure $(\dot{exV})$ and firms shifting from a VI to a NVI structure $(\dot{S}_{V\to NV})$ from 2006 to 2020.

Table 2 $\dot{TFP}$ of the VI Structure and Its Components, $\dot{TP}$, $\dot{TE}$, SC, AE, $\dot{BD}_V$, $\dot{eV}$, $\dot{S}_{NV\to V}$, $\dot{exV}$, $\dot{S}_{V\to NV}$ from 2006 to 2020

	TP	$\dot{TE}$	SC	AE	$\dot{BD}_V$	$\dot{eV}$	$\dot{S}_{NV\to V}$	$\dot{exV}$	$\dot{S}_{V\to NV}$	$\dot{TFP}$
2008	4.7	−1.8	0.4	1.5	0.5	13.2	−0.2	0.7	0.0	19.0
2009	4.7	−2.2	0.0	0.7	1.0	−0.3	0.1	0.0	−0.3	3.8
2010	4.8	2.6	−0.6	−12.9	0.9	0.8	0.0	−4.9	0.0	−9.3
2011	4.7	1.1	0.0	−1.0	0.5	0.2	0.0	0.7	0.0	6.1
2012	4.7	−3.8	0.0	0.0	0.4	−0.2	0.1	0.3	0.0	1.4
2013	4.6	0.8	0.0	−1.0	0.8	−0.1	−0.1	−2.9	0.0	2.2
2014	4.6	−3.0	0.0	−0.4	0.2	0.8	0.1	0.4	−0.4	2.2
2015	4.5	−3.4	−0.1	−0.4	0.3	−0.1	0.1	−6.6	0.0	−5.5
2016	4.7	−1.5	0.7	−4.1	0.7	7.7	−0.1	0.5	0.0	8.6
2017	4.6	−3.0	−0.6	−1.7	-0.2	−0.2	0.4	−0.4	0.0	−1.1
2018	4.5	−1.9	0.0	−2.0	0.6	0.0	−0.1	−1.0	0.0	0.0
2019	4.6	−2.9	0.3	−0.2	1.1	1.0	−0.1	0.3	−0.5	3.6
2020	4.6	0.7	−0.1	−2.8	0.5	0.0	0.4	n.a.	n.a.	3.3
Average	4.6	−1.4	0.0	−1.9	0.6	1.8	0.0	−1.1	−0.1	2.6

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

Table 3 presents the TFP growth of the NVI structure and its components: $\dot{TP}$, $\dot{TE}$, SC, AE the incumbent effects of NVI firms' business durations $(\dot{BD}_{NV})$, the entry impact of new firms to a NVI structure $(\dot{eNV})$ and firms shifting from a VI to a NVI structure $(\dot{S}_{V\to NV})$, and the pre-exit impact of firms exiting from a NVI structure $(\dot{exNV})$ and firms shifting from a NVI to a VI structure $(\dot{S}_{NV\to V})$ from 2006 to 2020.

First, $\dot{BD}_V$ was positive with the exception of a slight decrease in 2017 (–0.2%), while $\dot{BD}_{NV}$

was marginally negative except for a slight increase in 2016 (0.2), illustrating that VI firms with extensive business durations increased the productivity growth of their VI structure, however, NVI firms with extensive business durations slightly decreased the productivity growth of their NVI structure.

Table 3 $\dot{TFP}$ of the NVI Structure and Its Components, TP, $\dot{TE}$, SC, AE, $\dot{BD}_{NV}$, $\dot{eNV}$, $\dot{S}_{V\to NV}$, $\dot{exNV}$, $\dot{S}_{NV\to V}$ from 2006 to 2020

	TP	$\dot{TE}$	SC	AE	$\dot{BD}_{NV}$	$\dot{eNV}$	$\dot{S}_{V\to NV}$	$\dot{eNV}$	$\dot{S}_{NV\to V}$	$\dot{TFP}$
2008	5.0	4.8	−0.2	−2.6	−0.1	4.3	0.1	1.1	0.0	12.5
2009	5.0	−0.9	−0.5	−0.2	−0.4	−0.2	−0.2	0.3	0.0	2.8
2010	4.9	4.6	−0.7	−4.5	−0.1	0.0	16.6	−3.5	0.6	17.9
2011	4.9	−2.1	−0.3	−1.9	−0.1	6.0	−0.6	0.8	0.0	6.5
2012	4.9	−1.1	−2.9	−16.8	−0.2	−0.3	−0.2	−0.1	−0.1	−16.9
2013	4.8	−1.1	1.4	5.1	−0.3	−0.2	−0.1	−0.5	0.1	9.2
2014	4.8	−3.8	0.2	0.3	−0.2	0.2	0.0	0.6	0.2	2.4
2015	4.8	−3.8	0.1	0.2	−0.2	−0.1	0.3	−5.4	−0.1	−4.2
2016	4.8	4.4	−0.1	−0.3	0.2	6.6	0.1	0.8	3.8	20.3
2017	4.8	−7.9	0.2	0.4	−0.5	−0.2	−0.1	−1.0	−0.2	−4.4
2018	4.8	−2.3	−0.3	−1.7	−0.1	0.6	0.2	−1.7	−0.1	−0.6
2019	4.8	6.4	0.0	0.8	0.0	0.3	−0.1	0.6	2.3	15.2
2020	4.8	−1.6	−6.3	−11.0	0.0	−0.2	4.4	n.a.	n.a.	−9.8
Average	4.8	−0.3	−0.7	−2.5	−0.1	1.3	1.6	−0.7	0.5	3.9

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

Therefore, it is clear that extensive business durations of VI firms contribute more to the productivity growth of their structure supposedly due to gains from stable supply chains and reduced transaction costs despite the existence of agency costs. In contrast, extensive business durations of NVI firms led to slight productivity losses within their structure.

Second, ($\dot{eV}$, $\dot{eNV}$) in 2008 (13.2%, 4.3%) and in 2016 (7.7%, 6.6%) highlights that both new VI and NVI entrants remarkably boosted the productivity growth of their structures in 2008 and 2016, during the aftermath of market exogenous shocks: As a result, the productivity growth of the VI structure reached a record high in 2008 (19.0%) and the NVI structure hit a record high in 2016 (20.3%). Moreover, supposedly due to a stronger institutional push of shared growth through a large-scale restructuring in the aftermath of the 2008 global financial crisis, $\dot{eNV}$ in 2011 (6.0%) was a main contributor to productivity growth of their NVI structure (6.5%).

Third, $\dot{S}_{NV\to V}$ was negligible throughout the years, demonstrating that the entry impact of firms shifting from a NVI to a VI structure on the productivity growth of the VI structure was trivial. This finding implies that NVI firms achieved technological progress to secure stable supply chains in a VI structure, but only managed to have trivial impact on productivity of VI structure.

In contrast, $\dot{S}_{V\to NV}$ was remarkably significant in the 2010 economic bounce-back (16.6%) and in the 2020 economic depression (4.4%), underscoring that those “self-selecting” competitive

firms shifting from a VI to a NVI structure alarmingly boosted the productivity growth of the NVI structure in the repercussions of market exogenous shocks.

Especially, $\dot{S}_{V\to NV}$ in 2010 indicates that competitive VI firms shifting to a NVI structure exceptionally raised the productivity growth of the NVI structure when supported by an institutional push for shared growth between OEM and NVI subcontractors. On the other hand, $\dot{S}_{V\to NV}$ in 2020 demonstrates that competitive VI firms transitioning to a NVI structure under the economic depression induced by government policy failures and exacerbated by the pandemic, boosted the productivity growth of the NVI structure.

Fourth, ($\dot{exV}$, $\dot{exNV}$) in 2010 (−4.9%, −3.5%), in 2015 (−6.6%, −5.4%), and in 2018 (−1.0%, −1.7%); additionally, $\dot{exV}$ in 2013 (−2.9%) and $\dot{exNV}$ in 2017 (−1.0%), indicates that exiting VI and NVI firms both substantially dampened the productivity growth of their respective structures during market fluctuations one year prior to the actual exit, with exiting VI firms causing greater productivity loss than exiting NVI firms did. Should firms in a VI structure fail to keep abreast of rapid technological progress in their structure, their productivity loss leads to an eventual market exit.

Fifth, $\dot{S}_{V\to NV}$ was negligible, however, $\dot{S}_{NV\to V}$ in 2016 (3.8%) and in 2019 (2.3%) were significantly positive. Therefore, firms shifting from a VI to a NVI structure had a negligible pre-exit impact on the productivity growth of the VI structure, however, firms shifting from a NVI to a VI structure significantly boosted the productivity growth of the NVI structure in 2016 and 2019, one year prior to actual exits in 2017 and 2020. This is due to those "self-selecting" independent exporting NVI firms, who tend to seek out stable supply chains by achieving faster technological progress in order to enter a VI structure.

Finally, the TP of the VI structure (4.6%) has remained steady and slightly lower than that of the NVI structure (4.8%). $\dot{TE}$ of the VI structure fluctuated, but was mostly significantly negative, averaging out to (−1.4%); the $\dot{TE}$ of the NVI structure fluctuated more extensively, averaging out to (−0.3%). AE fluctuated far more than $\dot{TE}$ in both structures: for the VI structure, AE in 2010 (−12.9%) led to a record low TFP growth in 2010 (−9.3%); for the NVI structure, AE in 2012 (−16.8%) caused a record low TFP growth in 2012 (−16.9%), and AE in 2020 (−11.0%) led to the second lowest TFP growth in 2012 (−9.8%). Overall, AE caused less productivity loss in the VI structure (−1.9%) than in the NVI structure (−2.5%).

SC tapered off in the VI structure, while SC was significantly negative in the NVI structure (−0.7%). As a result, TFP growth of the VI structure declined to (2.6%), which was lower than that of the NVI structure (3.9%).

To summarize, in the VI structure, TFP growth fluctuated extensively, ranging from a low of (−9.3%) in the 2010 economic bounce-back due to poor AE (−12.9%) and $\dot{exV}$ (−4.9%) to a high of (19.0%) in the 2008 global financial crisis due to significantly positive AE (1.5%) and $\dot{eV}$ (13.2%). It is clear that the productivity growth of the VI structure has dominated that of the industry, however the productivity growth of the NVI structure has revealed a compelling trend across the selected time period: (17.9%) in 2010 driven by the entry impact of $\dot{S}_{V\to NV}$ (16.6%)

and $\dot{TE}$ (4.6%); (−16.9%) in 2012 dragged down by AE (−16.8%) and SC (−2.9%); (9.2%) in 2013 supported by AE (5.1%) and SC (1.4%); (20.3%) in 2016 driven by $\dot{eNV}$ (6.6%), $\dot{TE}$ (4.4%), and $\dot{S}_{NV\to V}$ (3.8%); (15.2%) in 2019 driven by $\dot{TE}$ (6.4%) and the pre-exit impact of $\dot{S}_{NV\to V}$ (2.3%); and (−9.8%) in 2020 by AE (−11.0%), SC (−6.3%), and $\dot{TE}$ (−1.6%).

4.3. Industry and its structures

Overall, table 4 and figures 1-2 reveal that TFP growth in the industry is primarily driven by TP, and $\dot{TE}$, SC, and AE were similar to those of VI structure writ large; Table 5 and figure 3 shows that the TFP growth trajectory of the VI structure folded into that of the industry.

In table 4, only VI firms with extensive business durations contributed to the productivity growth of their VI structure. All new entrants raised the productivity growth of their respective structures and, to a lesser extent, the industry as a whole. The entry impact of firms shifting from a VI to a NVI structure significantly raised the productivity growth of the NVI structure, while all exiting firms lowered the productivity growth of their structures and the industry as a whole one year prior to an actual exit; Firms shifting from a NVI to a VI structure promoted the productivity growth of the NVI structure one year prior to an actual exit.

Table 4 Average TFP Growth and Its Components for the IT Manufacturing Industry and VI and NVI structures from 2006 to 2020

					BD		Entry		Exit		
Industry	TP	$\dot{TE}$	SC	AE	$\dot{V}_{BD}$	$\dot{NV}_{BD}$	$\dot{V}_{enter}$	$\dot{NV}_{enter}$	$\dot{V}_{exit}$	$\dot{NV}_{exit}$	$\dot{TFP}$
Average	5.9	−1.3	0.0	−1.3	−0.7	−0.4	0.7	0.5	−0.4	−0.4	2.7
VI					$\dot{BD}_V$		$\dot{eV}$	$\dot{S}_{NV\to V}$	$\dot{exV}$	$\dot{S}_{V\to NV}$	
Average	4.6	−1.4	0.0	−1.9	0.6		1.8	0.0	−1.1	−0.1	2.6
NVI						$\dot{BD}_{NV}$	$\dot{eNV}$	$\dot{S}_{V\to NV}$	$\dot{exNV}$	$\dot{S}_{NV\to V}$	
Average	4.8	−0.3	−0.7	−2.5		−0.1	1.3	1.6	−0.7	0.5	3.9

Figure 1 Average *TP*, $\dot{TE}$, *SC*, *AE*, and TFP Growth for the IT Manufacturing Industry, VI and NVI Structures from 2006 to 2020

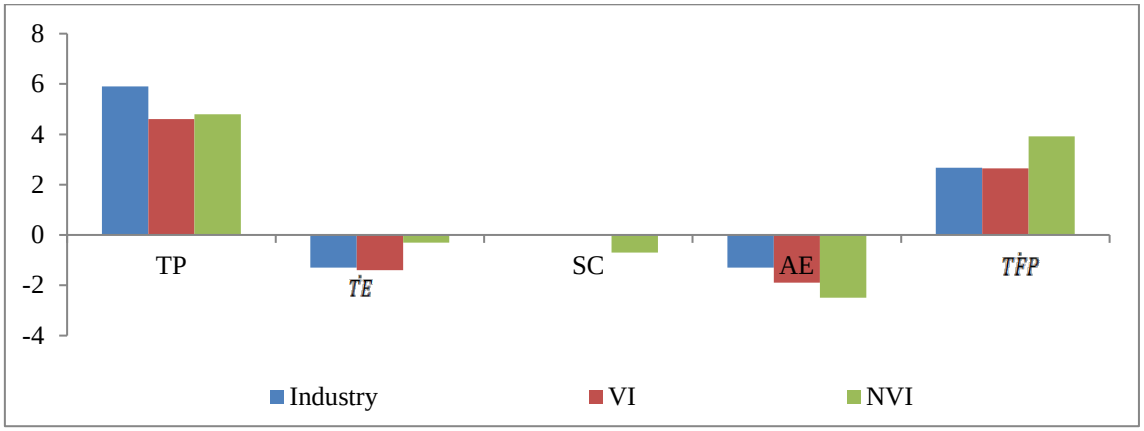


Figure 2 Average Impacts of Entry, Exit, and Strategic Shifts for the IT Manufacturing Industry, VI and NVI Structures from 2006 to 2020

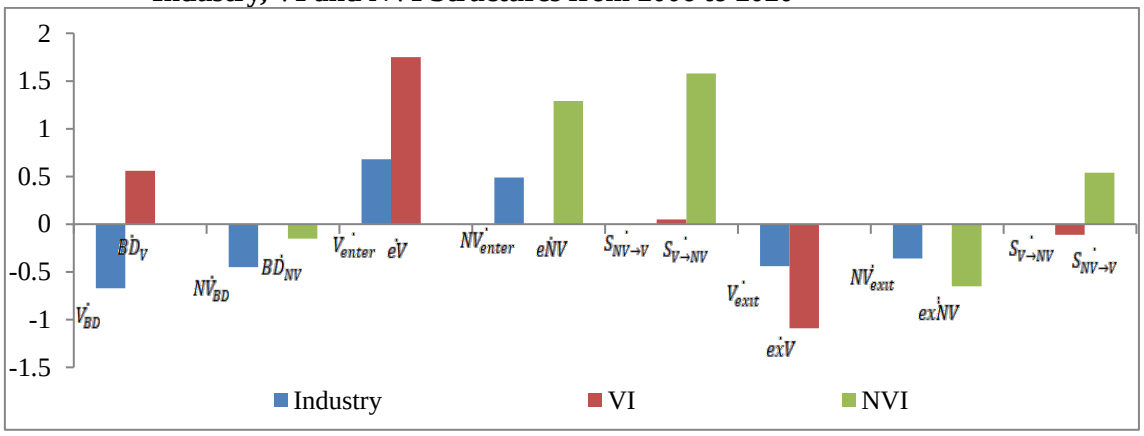
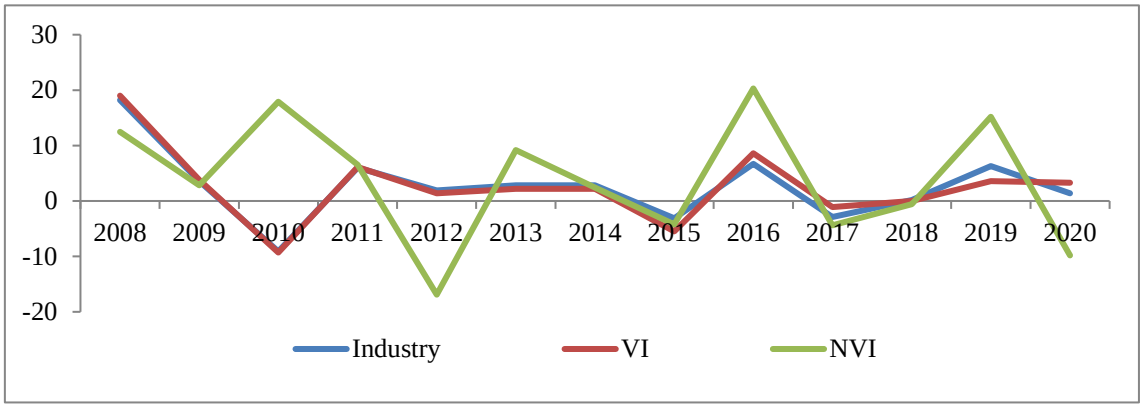


Table 5 TFP growth for IT manufacturing industry, VI and NVI structures from 2006 to 2020

$T\dot{F}P$	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	average
Industry	18.2	3.6	−9.1	6	1.9	2.8	2.8	−3.1	6.7	−2.9	0.2	6.3	1.4	2.7
VI	19.0	3.8	−9.3	6.1	1.4	2.2	2.2	−5.5	8.6	−1.1	0.0	3.6	3.3	2.6
NVI	12.5	2.8	17.9	6.5	−16.9	9.2	2.4	−4.2	20.3	−4.4	−0.6	15.2	−9.8	3.9

Figure 3 TFP Growth Trajectory for Industry, VI and NVI Structures from 2006 to 2020



5. CONCLUSION

This study investigates IT manufacturing industry-specific features and seeks out a future direction for the competitive and sustainable growth of IT manufacturing in Korea. What follows are the main findings of this study. First, as the findings show, firm dynamics were mostly triggered by market selection forces, the exogenous market shocks of the 2008 global financial crisis and the 2020 economic depression induced by government policy failures and exacerbated by the pandemic, and institutional pushes in the aftermath. Especially, NVI firms

are more likely to act on firm dynamics than their VI counterparts.

Second, both VI and NVI firms with extensive business durations in the industry and NVI firms with extensive business durations in the NVI structure dampened the productivity growth of the industry and their NVI structure, respectively. Only VI firms with extensive business durations significantly raised the productivity growth of their VI structure despite agency costs due to synergies from stable supply chains and lower transaction costs.

Third, in terms of impact from firm entry, all new entrants raised the productivity growth of the industry and their structures, however to different degrees: they raised productivity growth considerably for the structures, and most significantly for the VI structure, and firms transitioning from a VI to a NVI structure significantly raised productivity growth of the NVI structure due to their competitiveness as a NVI firm.

Fourth, all exiting firms dampened the productivity growth of the industry and their structures, most significantly in the VI structure one year prior to an actual exit; however, firms transitioning from a NVI to a VI structure promoted the productivity growth of the NVI structure one year prior to an actual exit due to their competitiveness via technological upgrades in order to enter a VI structure.

Taken as a whole, only VI firms with extensive business durations significantly raised the productivity growth of their VI structure, indicating that synergies from stable supply chains and lower transaction costs worked, despite the existence of agency costs, however, the impact from strategic transitioning that occurred in the VI structure were negligible due to their lack of competitiveness. Furthermore, the entry and exit impact by VI firms in the industry and in the VI structure were greater in magnitude than those by NVI firms in the industry and in the NVI structure. However, the impact from strategic transitioning that occurred in the NVI structure was far more significantly positive due to their competitiveness.

Even though the vertical integration in the industrial structures of the IT manufacturing industry could risk agency costs, the entry and exit of VI firms had greater impact on the productivity of the IT manufacturing industry and their VI structure, especially under market exogenous shocks and thereafter.

In terms of productivity growth, the extensive business durations of VI firms in their VI structure, the new entrants in the industry and the structures, and the strategic shifts that occurred in the NVI structure, contributed to greater competitiveness and resilience. On the other hand, TFP growth has been led mainly through technical progress, while deteriorating technical and allocative efficiency under market fluctuations considerably dragged TFP growth down for both the industry and its VI and NVI structures. On average, changes in technical and allocative efficiency, as well as scale effects of the VI structure, dominated those of the industry, and eventually, the TFP growth trajectory of the VI structure folded into the TFP growth of the industry.

The results of this study show that firms accommodating fast technological progress can contribute to the productivity growth of the industry and its structures, which can lead in turn to significant competitiveness of the vertically integrated IT manufacturing industry of Korea.

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Appendix

A.1. TFP Growth and Its Components

Solow (1956) first introduced TFP growth ($\dot{TFP}$) as output growth which is not dependent on input growth, and Kumbhakar (2000) decomposed $\dot{TFP}$ into four components, the rates of technical progress (TP), changes in technical efficiency ($\dot{TE}$), scale component (SC), and allocative efficiency (AE). These four components, as well as the impact from change in business durations of incumbents, firm entry, exit, strategic shift (FC) are estimated in this model. The five components are derived as follows.

According to Kumbhakar (2000), the logarithm of *VA* in (1)-(3) is differentiated for time *t*. In what follows, F_{it} represents the variables for the business durations of incumbents, firm dynamics of entry, exit, and strategic shifts. The subscript is omitted for simplicity.

$$\begin{aligned}\frac{d\ln VA}{dt} = \dot{VA} &= \frac{d\ln f(L,K,t,F)}{dt} - \frac{du}{dt} \\ &= \frac{\partial \ln f(L,K,t,F)}{\partial t} + \frac{\partial \ln f(L,K,t,F)}{\partial L}\frac{dL}{dt} + \frac{\partial \ln f(L,K,t,F)}{\partial K}\frac{dK}{dt} \\ &\quad + \frac{\partial \ln f(L,K,t,F)}{\partial F}\frac{dF}{dt} - \frac{du}{dt},\end{aligned}$$

where $\partial \ln f(L,K,t,F)/\partial t$ reflects a change in the real value-added frontier caused by an exogenous change in technical progress (TP), which raises the real value-added frontier for a given input level.

$$\frac{\partial \ln f(L,K,t,F)}{\partial L}\frac{dL}{dt} + \frac{\partial \ln f(L,K,t,F)}{\partial K}\frac{dK}{dt} = (\varepsilon_L \dot{L} + \varepsilon_K \dot{K}),$$

where $\varepsilon_L = \left(\partial \ln f(L,K,t,F)\right)/\left(\partial \ln L\right)$ and $\varepsilon_K = \left(\partial \ln f(L,K,t,F)\right)/\left(\partial \ln K\right)$ are the real value-added elasticities with respect to inputs *L* and *K*, respectively, which indicates a change in the real value-added frontier caused by input changes in labor and capital.

TE is the technical efficiency level for production unit *i* at time *t* and defined as the ratio of the actual real value-added $f(L_{it},K_{it},t,F_{it})\exp(-u_{it})$ to the potential real value-added $f(L_{it},K_{it},t,F_{it})$. Then, $TE_{it} = f(L_{it},K_{it},t,F_{it})\exp(-u_{it}) / f(L_{it},K_{it},t,F_{it}) = \exp(-u_{it})$. Should the subscript be omitted, $\left(du\right)/\left(dt\right) = \left(d\ln TE\right)/\left(dt\right) = \dot{TE}$.

The change in TE $(\dot{TE})$ shows how fast the maximum real value-added located on the real value-added frontier will be attained under the current technology. As a result, the real value-added change $(\dot{VA})$ comes from technical progress (TP), changes in the two inputs $(\varepsilon_L \dot{L} + \varepsilon_K \dot{K})$, changes in TE $(\dot{TE})$, and the change in impact from firms' business durations of incumbents, entry, exit, and strategic shift (FC),

$$FC = \dot{\varepsilon_F} F = \frac{\partial \ln f}{\partial \ln F} \dot{F} = \Phi F \dot{F}, \text{ where } \Phi = \alpha, \beta, \omega.$$

Eventually,

$$\dot{VA} = TP + \varepsilon_L \dot{L} + \varepsilon_K \dot{K} + \dot{TE} + \varepsilon_F \dot{F}.$$

$$\begin{aligned} \dot{TFP} &= \dot{VA} - (s_L \dot{L} + s_K \dot{K}) = TP + \varepsilon_L \dot{L} + \varepsilon_K \dot{K} + \dot{TE} + \varepsilon_F \dot{F} - (s_L \dot{L} + s_K \dot{K}) \\ &= TP + \dot{TE} + (\varepsilon_L - s_L) \dot{L} + (\varepsilon_K - s_K) \dot{K} + \varepsilon_F \dot{F} \\ &= TP + \dot{TE} + (RTS - 1)(\varphi_L \dot{L} + \varphi_K \dot{K}) + (\varphi_L - s_L) \dot{L} + (\varphi_K - s_K) \dot{K} + \varepsilon_F \dot{F} \\ &= TP + \dot{TE} + SC + AE + FC, \end{aligned}$$

where S_L and S_K are the shares of labor and capital costs in total costs, respectively, and $RTS = \left(\partial \ln f\left(L, K, t, F\right)\right) / \left(\partial \ln L\right) + \left(\partial \ln f\left(L, K, t, F\right)\right) / \left(\partial \ln K\right) = \varepsilon_L + \varepsilon_K$ is the estimated returns to scale; φ_L and φ_K represent the shares of the output elasticity of *L* and *K* in total elasticity, respectively,

$$\varphi_L = \frac{\varepsilon_L}{\varepsilon_L + \varepsilon_K} = \frac{\varepsilon_L}{RTS}, \text{ and } \varphi_K = \frac{\varepsilon_K}{\varepsilon_L + \varepsilon_K} = \frac{\varepsilon_K}{RTS}.$$

In consequence, SC represents scale effect, such that $SC = (RTS - 1)(\varphi_L \dot{L} + \varphi_K \dot{K})$, reflecting the effect of input growth on output growth: if RTS= increasing returns to scale (IRS), then SC >0; if RTS= constant returns to scale (CRS), then SC =0; and if RTS= decreasing returns to scale (DRS), then SC < 0.

AE is the change in allocative efficiency, such that $AE = (\varphi_L - s_L) \dot{L} + (\varphi_K - s_K) \dot{K}$, which measures the inefficiency of resource allocation caused by any deviation in factor prices from their marginal products.

Finally, FC represents the change in impact from firms' business durations, entry, exit, and strategic shift.

A.2. Supplementary Tables

Table A.1 specifies IT manufacturing industry under the KSIC (Korean Standard Industrial Classification) system.

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

Industry	Subsectors
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)

Table A.2 shows that VI firms surpassed NVI firms, in terms of value-added, number of workers, and capital from 2006 to 2020, while VI firms posted smaller labor share (0.691) than NVI firms (0.718).

Table A.2 Summary Statistics for Korea's IT Manufacturing Industry and Their VI and NVI Structures from 2006 to 2020

	Industry	VI	NVI
Number of firms	1,810	979	1,522
Number of observations	10,982	4,586	6,396
Value -added	198.8 (3,253.4)	435.0 (5,015.0)	29.4 (274.3)
Labor	500.4 (3,933.5)	956.5 (6,011.0)	173.5 (637.6)
Capital	148.1 (2,041.9)	322.3 (3,133.7)	23.3 (285.2)
Labor share	0.707 (0.147)	0.691 (0.146)	0.718 (0.147)

Note: 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 cast, (capital cost+ labor cost).
2). All are mean values, and standard deviations are in parentheses.

Table A.3 Results of Hypothesis Testing for the C-D SFPF for IT Manufacturing Industry and Its VI and NVI Structures from 2006 to 2020

Industry				Null hypothesis $H_0 = \gamma = \mu = \eta = 0$			
	$(\hat{\gamma})$ (t ratio)	$(\hat{\mu})$ (t ratio)	$(\hat{\eta})$ (t ratio)	Log-likelihood function	Test statistic $(\hat{\lambda})$	Critical Value	Outcome
Industry	0.566 (48.86)	1.383 (18.68)	−0.014 (-5.98)	−11,565.4	2,961.0	10.50	Reject H_0
VI structure	0.515 (23.94)	1.279 (10.19)	−0.018 (−3.52)	−4,933.2	1,062.4	10.50	Reject H_0
NVI structure	0.558 (35.41)	1.304 (13.04)	−0.007 (−1.86)	−6,732.4	1,591.3	10.50	Reject H_0

Note: Critical value=10.50 is obtained from Kodd and Palm (1986).

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 IT manufacturing industry

and its VI and NVI structures in Korea from 2006 to 2020. The null hypothesis indicating no technical inefficiency effects, $H_0 = \gamma = \mu = \eta = 0$, are all rejected at the 1% significance level.

Table A.4 presents technical efficiency (TE) and returns to scale (RTS) for the industry, VI and NVI structures from 2006 to 2020.

Table A.4 TE and RTS for IT Manufacturing Industry and VI and NVI Structures from 2006 to 2020

Year	TE			RTS		
	Industry	VI	NVI	Industry	VI	NVI
2006	0.354	0.400	0.322	0.980	0.981	0.965
2007	0.350	0.394	0.317	0.982	0.984	0.961
2008	0.356	0.387	0.332	0.985	0.988	0.958
2009	0.352	0.379	0.329	0.988	0.992	0.955
2010	0.354	0.389	0.344	0.991	0.996	0.952
2011	0.350	0.393	0.337	0.994	0.999	0.949
2012	0.343	0.378	0.333	0.997	1.003	0.946
2013	0.341	0.381	0.329	1.000	1.007	0.943
2014	0.332	0.370	0.317	1.002	1.011	0.940
2015	0.328	0.357	0.305	1.005	1.014	0.937
2016	0.318	0.352	0.318	1.008	1.018	0.934
2017	0.313	0.341	0.293	1.011	1.022	0.930
2018	0.308	0.335	0.286	1.014	1.025	0.927
2019	0.306	0.325	0.305	1.017	1.029	0.924
2020	0.296	0.327	0.300	1.020	1.033	0.921
Average	0.333 (-0.013)	0.367 (-0.014)	0.317 (-0.003)	0.999 (0.038)	1.006 (0.050)	0.942 (0.047)

Note: Average changing rate are in parentheses below TE and asymptotic standard errors are in parentheses below RTS.

TE concurrently deteriorated over the time periods, however TE of the VI structure dominated that of the entire industry, which fell a little faster than that of the NVI structure. The null hypothesis of constant returns to scale (CRS) technology against the alternative hypotheses of non-CRS technology, given C-D SFPF, was tested on the average estimates of RTS of the industry, VI and NVI structures by T-test at 1% significance level, and results identified CRS for the industry, VI and NVI structures.

Table A.5 Firms' Survival and Actual Patterns in Firms' Strategy in Korea's IT Manufacturing Industry from 2006 to 2020

	Number of firms	%	Number of observations	%
Stayed in business for 15 years	166	9.2	2,490	22.7
Did not stay in business for 15 years	1,644	90.8	8,492	77.3
VI firms throughout	288	15.9	1,225	11.2
NVI firms throughout	831	45.9	3,566	32.5
VI→NVI firms and remain as such	91	5.0	563	5.1
NVI→VI firms and remain as such	173	9.6	1,026	9.3
VI↔NVI firms alternating more than once	427	23.6	4,602	41.9
Total	1,810	100	10,982	100

Table A.5 shows firms' survival rate and actual patterns in firms' strategy in IT manufacturing industry from 2006 to 2020, where the total number of observations is the number of firms that took part at least once in manufacturing processes during 2006 to 2020, and the total number of firms is the number of unique firms from 2006 to 2020.

Out of the total number of firms, 1,810 (100%), 166 (9.2%) firms had survived, but 1,644 (90.8%) firms had not survived over the 15-year period. The small share of surviving firms in the IT manufacturing industry (9.2%) is due to an intrinsic characteristic of rapid technical change and short product cycles of the IT manufacturing.

In the IT manufacturing industry, the share of "VI firms throughout" (15.9%) is 30%, lower than that of "NVI firms throughout" (45.9%); that of "VI→NVI firms and remain as such" (5.0%) is only a half that of "NVI→VI firms and remain as such" (9.6%), and the share for "VI↔NVI firms alternating more than once" is the largest (23.6%).

Table A.6 Frequency of Firm Dynamics in IT Manufacturing Industry from 2006 to 2020

Year	Industry				VI structure				NVI structure			
	Entry		Exit		Entry		Exit		Entry		Exit	
	New VI	New NVI	Exiting VI	Exiting NVI	New VI	Shift NVI →VI	Exiting VI	Shift VI→ NVI	New NVI	Shift VI→ NVI	Exiting NVI	Shift NVI →VI
2006	n.a.	n.a.	20	62	n.a.	n.a.	20	8	n.a.	n.a.	62	26
2007	14	47	64	113	14	75	64	17	47	17	113	13
2008	87	166	24	46	87	33	24	8	166	20	46	16
2009	10	24	25	32	10	41	25	36	24	8	32	8
2010	16	23	49	82	16	27	49	14	23	75	82	29
2011	20	134	21	52	20	22	21	9	134	28	52	29
2012	11	70	14	55	11	31	14	12	70	22	55	20
2013	8	28	38	60	8	24	38	6	28	14	60	24
2014	18	38	12	33	18	30	12	33	38	13	33	33
2015	3	6	49	71	3	42	49	30	6	16	71	16
2016	18	75	11	31	18	13	11	8	75	23	31	95
2017	7	15	24	33	7	42	24	20	15	3	33	24
2018	6	29	39	46	6	23	39	31	29	5	46	6
2019	15	48	28	36	15	8	28	84	48	2	36	36
2020	12	35	n.a.	n.a.	12	17	n.a.	n.a.	35	17	n.a.	n.a.
Total	245	418	738	752	245	428	418	316	738	263	752	375

Table A.6 presents frequency of firm dynamics in IT manufacturing industry from 2006 to 2020. The frequency rose sharply in 2007-2008, and 2010-2011, which was triggered by the 2008 global financial crisis, the subsequent economic downturn, and the industrial restructuration, and market selection forces.

The frequency of entry, exit, and strategic shifts of NVI firms was higher than that of VI firms because of their insecure status in the supply chain, and thus, they tend to act on firm dynamics.

Table A.7 shows average impacts of firms' business duration of incumbents, entry, and exit on

TFP growth of Korea's IT manufacturing industry, and average impacts of firms' business duration of incumbents, entry, exit, and strategic shifts on TFP growth of VI and NVI structures from 2006 to 2020. There follows coefficients with t-values in their CD-SFPF.

Table A. 7 Coefficients with t-values in the SFPF of Korea's IT Manufacturing Industry and Its VI and NVI Structures and the Average Impact of Firm Dynamics on TFP Growth from 2006 to 2020

Industry	Incumbent	effect	Entry	impact	Pre-exit	impact
	Business duration of VI firms	Business duration of NVI firms	New VI entrants	New NVI entrants	Exit VI structure and industry	Exit NVI structure and industry
Coefficients (*t*-value)	$\widehat{\alpha_V}$	$\widehat{\alpha_N}$	$\widehat{\alpha_{VE}}$	$\widehat{\alpha_{NE}}$	$\widehat{\alpha_{VX}}$	$\widehat{\alpha_{NX}}$
	0.015 (−3.63)	−0.010 (−2.35)	0.123 (2.71)	0.025 (0.89)	-0.132 (-3.71)	-0.193 (-6.77)
Average impact	−0.7	−0.4	0.7	0.5	−0.4	−0.4
VI structure	Incumbent	effect	Entry	impact	Pre-exit	impact
	Business duration of VI firms		New VI entrants	Shift NVI→VI structure Entry impact on VI structure	Exit VI structure and industry	Shift VI→NVI structure Pre-exit impact on VI structure
Coefficients (*t*-value)	$\widehat{\beta_V}$		$\widehat{\beta_{VE}}$	$\widehat{\beta_{SE}}$	β_{VX}	$\widehat{\beta_{SX}}$
	0.011 (1.74)		0.110 (2.22)	0.034 (0.87)	-0.157 (-4.02)	-0.009 (-0.21)
Average impact	0.6		1.8	0.0	−1.1	−0.1
NVI structure	Incumbent	effect	Entry	impact	Pre-exit	impact
		Business duration of NVI firms	New NVI entrants	Shift VI→NVI structure Entry impact on NVI structure	Exit NVI structure and industry	Shift NVI→VI structure Pre-exit impact on NVI structure
Coefficients (*t*-value)		$\widehat{\omega_N}$	$\widehat{\omega_{NE}}$	$\widehat{\omega_{SE}}$	$\widehat{\omega_{NX}}$	$\widehat{\omega_{SX}}$
		−0.003 (−0.67)	0.049 (1.64)	0.160 (3.36)	−0.188 (−6.74)	0.053 (1.38)
Average impact		−0.1	1.3	1.6	−0.7	0.5