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How do Export Pioneers Emerge and How are They Related to Product Creators?

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In this paper, we empirically examine how export pioneers emerge and how they are related to product creators/innovators, utilizing a rich plant-product level dataset from the Korean manufacturing sector for the period of 1990-1998. Our analysis covers the process from the appearance of product creators as well as product imitators to the emergence of export pioneers. We find, first, that product imitators are larger, more productive and older than product creators. Second, most export pioneers are nevertheless found to be product creators. This result is largely due to the fact that almost all export pioneers export the products in the same year as product creation. Third, there are similarities as well as differences between product creators and export pioneers. Plants that are more productive or larger are more likely to become product creators as well as export pioneers. However, previous exporting experience positively affects the probability of export pioneering only, while plants' engagement in R&D positively affects the probability of product creation only. We discuss possible explanations for our main empirical results as well as their policy implications.

Key Word: Export Pioneer, Product Innovation, Imitation
JEL Code: F14, F63, O47

I. Introduction

Many developing countries try to develop new export industries as a key element of their development strategy. Korea is not an exception. During the past few decades since the growth take-off in the 1960s, Korea has experienced the continuous diversification of her export product portfolio and has witnessed the appearance of new export industries. In order for a new export industry to appear, there should be an export pioneer: the first firm which exports a product for the first time in a country. A small but growing number of studies are paying attention to the role played by these entities in the economic development of a country. Most of these

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studies examined whether export pioneers generate positive spillover upon the entry of export followers. One issue which is at least as important as the issue of export spillover to understand the process of new export industry development is, however, how export pioneers are born. This is the main question addressed in this paper. There are, however, surprisingly few existing studies that seek to answer this question.

If a product is to be exported for the first time in an economy, it should exist in the first place via product innovation/creation. That is, if an export pioneer is to emerge, there should be a product creator, the first firm that produces a product for the first time in a country. Thus, one natural starting point for examining the process of the emergence of export pioneers would be the product creation stage.

In this paper, we examine empirically the overall dynamic process, from the birth of product creators to the emergence of export pioneers, utilizing a plant-product level micro-dataset for Korean manufacturing. Specifically, we try to identify plant characteristics which affect firm behaviors along the various stages of this process. We are particularly interested in asking what type of plants are more likely to become product creators or export pioneers and in examining how these two types of plants are related to each other.

Do we have any reason to expect that export pioneers and product creators are more or less the same firms? Standard theories of heterogeneous firms in international economics, such as that by Melitz (2003) and its various extensions (e.g., Arkolakis, 2010; Eckel and Neary, 2010), would predict that firms with higher productivity and hence a larger size are likely to be those that produce and export a certain product for the first time in the economy. Having higher productivity rates, these firms will face larger expected profits from product creation/innovation and export pioneering and, hence, would be more willing to incur the sunk cost of product development as well as the sunk cost of exporting before other firms with lower expected profits. Viewed in light of these theories, export pioneers and product creators are expected to be the same entities.

There are also reasons, however, for expecting that the characteristics of export pioneers and product creators may be different. After a firm creates a product, imitators or followers may start to produce the same product. Again, standard theories of heterogeneous firms would predict that product creators are more productive and, hence, larger than product imitators. That is, creators created a product before others because they are more productive. However, Wagner and Zahler (2015) shows that this is not the case. Using Chilean data, they analyze export market entry by export pioneers and export followers and find that export pioneers are smaller than export followers. With regard to this result, they argue that export pioneers that are good at exploration may be worse than export followers at exploitation or scaling up — producing the export-pioneered product on a larger production scale. One theoretical explanation provided by Wagner and Zahler (2015) for why export followers are larger (and more productive) than the export pioneer is as follows. In the face of uncertainty in the export profitability of a product, export pioneers appear randomly out of a plant productivity distribution. Once the export profitability of the product is revealed to be high due to the trial of the export pioneer, the most productive firms then react by self-selecting and entering the market for this product.[1] In our view,

[1]For a more detailed explanation, see Wagner and Zahler (2015).

arguments similar to those of Wagner and Zahler (2015) can be made with regard to the case of product creators and product imitators; product imitators are more productive and larger than product creators. Indeed, this is what we find in this paper. It should be noted that export pioneers can emerge not only from product creators but also from product imitators, at least conceptually. In view of the empirical findings and arguments by Wagner and Zahler (2015), it is possible for product imitators, which are more productive and larger than comparable product creators, to become export pioneers. Under this scenario, export pioneers may differ from product creators.

In this paper, we empirically examine how export pioneers emerge and how they are related to product creators/innovators, utilizing a rich plant-product level dataset from the Korean manufacturing sector for the period of 1990-1998. Our analysis covers the process from the appearance of product creators as well as product imitators to the emergence of export pioneers. We find, first, that product imitators are larger, more productive and older than product creators. Second, most export pioneers are nevertheless found to be product creators. This result largely stems from the fact that almost all export pioneers export the product in the same year as product creation. Third, there are similarities as well as differences between product creators and export pioneers. Plants that are more productive or larger are more likely to become product creators as well as export pioneers. However, previous exporting experience positively affects the probability of export pioneering only, while plants' engagement in R&D positively affects the probability of product creation only. We discuss possible explanations for our main empirical results as well as their policy implications.

There are several interesting findings in this paper. First, we find that imitators of created products are larger and more productive than the product creators, consistent with the findings of Wagner and Zahler (2015) but somewhat at odds with standard theories of heterogeneous firms. Second, we find that almost all export pioneers come from product creators, in spite of the above finding of product imitators being larger and more productive than product creators. This seemingly paradoxical result is largely due to the fact that almost all export-pioneer-product-creators are those which exported the created product in the same year as product creation, leaving no time for more productive imitators to become export pioneers. We provide an explanation for this finding in section 5. Third, we find that plants that are more productive or larger are more likely to become product creators and export pioneers. There are, however, some interesting differences in the characteristics between export pioneers and product creators. Previous exporting experience positively affects the probability of export pioneering only, while plants' engagement in R&D positively affects the probability of product creation only. We discuss how these results shed light on policy again in section 5.

Our paper is related to the existing literature in several ways. First, the paper is closely related to a small but growing body of literature on export discovery/pioneering. Hausmann and Rodrik (2003) argue that self-discovery of what one is good at producing, which corresponds to product creation in our paper, is key to the economic growth of developing countries; they show theoretically that there is too little self-discovery and too much imitation, as self-discovery is easily imitated. They provide some empirical evidence using trade data consistent with their theory. Several subsequent papers have examined whether there is spillover, either technological or informational, from export pioneering. Iacovone and Javorcik (2010) present evidence from Mexico that export-pioneered products are quickly followed by other firms. Wagner and Zahler (2015) show, using detailed Chilean data, that the probability of export followers' entry into the export market increases if export pioneers survive more than one year of exporting. Other studies examine the issues of how export pioneers are born, as in our study. Freund and Pierola (2010) and Artopoulos, Friel, and Hallak (2013) document an important role of export pioneers in the emergence of a new export industry in Peru and Argentina, respectively. However, these studies rely on descriptive analysis or use case studies of ex-post successful export-pioneering episodes. In contrast, Hahn *et al*. (2018) examines empirically how export pioneers are born starting from the time of the first production of a product, utilizing a plant-product dataset for Indonesian manufacturing. Our paper utilizes a comprehensive dataset of manufacturing plants and products for Korean manufacturing, and provides systematic econometric evidence on the process from product creation to export pioneering as in Hahn *et al*. (2018). Our paper is most clearly differentiated from Hahn *et al*. (2018) in that our paper is focused on comparing the characteristics of product creators with those of export pioneers based on implications of existing theories. Second, our study is related to the earlier studies of firm-level exporting activity, such as those by Clerides, Lach, and Tybout (1998), Bernard and Jensen (2004), Eaton, Kortum, and Kramarz (2004; 2011), and Feenstra and Kee (2008), among others.[2] Again, our paper is differentiated from these studies in that it examines how a firm exports a product for the first time in the economy starting from the production of the product for the first time in the economy.

This paper is organized as follows. In the next section, we explain and describe our data. Section 3 provides our empirical evidence of the process from product creation to the appearance of product imitators. Section 4 discusses our empirical results on the emergence of export pioneers. Section 5 provides a further discussion of our main empirical results as well as their policy implications. The final section concludes the paper.

II. Data, Definition, and Some Basic Facts

A. *Data*

This study utilizes two datasets. The first dataset consists of plant-level census data from the *Mining and Manufacturing Census* published by Statistics Korea. During the sample period, the dataset covers all plants with five or more employees in the mining and manufacturing industries. We use data on the manufacturing industries. It is an unbalanced panel dataset with about 70,000 to 100,000 plants for each year from 1990 to 1998.[3] For each year, the value of production, shipments,

[2]Because there is a considerable body of literature on this topic, we will not provide a comprehensive survey of the literature here. For this literature, see Wagner (2007) and Bernard *et al*. (2011).

[3]It appears that the plant-product dataset used in this study exists for the 2000s and 2010s inside Statistics Korea. I have asked Statistics Korea many times to allow me to access the datasets for 2000s and 2010s. However, the replies from Statistics Korea have always been that due to changes in internal regulations which took place during the 2000s, they cannot release information on exports (and R&D) either at the plant level or at the product

and tangible fixed assets as well as the number of production and non-production workers are available. The second dataset is an unpublished plant-product dataset by Statistics Korea for the same period, which provides information on the value of total and export shipments for each plant-product observation. We can calculate the value of the domestic shipments of a plant-product by subtracting export shipments from total shipments. The two datasets can be merged using the plant identification number. The plant-product dataset covers approximately 70 to 80 percent of plants in the plant dataset depending on the year. The plant identification code and product code are consistent over time within the sample period.[4]

B. *Definitions*

The plant-product dataset has an eight-digit product code, which we use to identify a *product*. The total number of distinct products with a positive value of shipments increases from 2,531 in 1990 to 3,351 in 1997 and then decreases to 3,299 in 1998. A product can be produced by multiple plants. For example, a mid-sized passenger car can be produced by both Hyundai and Kia. Each plant-product is a *product variety* such that the Sonata is one product variety and the K7 is another product variety of the same product, i.e., a mid-sized passenger car. The total number of product variety instances in our dataset increases from 74,932 in 1990 to 100,812 in 1996, after which it decreases to 86,215 in 1998.

We define *product creation* or *creation* as the production of a certain product for the first time in the economy. The *product creator* or *creator* is the plant which creates a product. Given that a product can be created by more than one plant, there can be multiple product creators of one *created product*. To use these definitions in our analysis, we need to provide an operational definition of a created product. A created product is a product which did not exist in our dataset during the period of 1990-1991 and that began to be produced by some plant(s) during the period of 1992-1998. For example, if a product is produced in 1992 for the first time in an economy, it is considered to be a product created in 1992. After a product is created in a certain year, other plants may also begin to produce that product eventually, a situation defined with the terms *product imitation* or *imitation*. A *product imitator* or an *imitator* defines the plant which begins imitative production of the product after 1992. Accordingly, a product imitator may have produced the imitated product for the first time from the viewpoint of the plant but not from the viewpoint of the economy. *Export pioneering* is defined as the exporting of a certain product for the first time in an economy. The terms *export pioneer* and *export-pioneered product* can be defined analogously. Operationally, in this case an export-pioneered product is a product which did not exist in the export market in 1990-1991 and began to be exported by some plant(s) during the years 1992-1998. As with the created product,

level. Without this information, a study like this would not be feasible. In fact, I do have access to plant-product data up to 2002. However, I was not able to use the information for the period from 1999 to 2002 due to a major industrial classification change. Given that the first five digits of the eight-digit product code are industry classification code, the product classification scheme also changed with the change in the industrial classification scheme. This is why I confined my analysis to the period of 1990-1998, during which the product codes are consistent over time.

[4]For a more detailed description of the datasets, see Hahn (2012). The author obtained the datasets from Statistics Korea when the author was a researcher at the Korea Development Institute. I am grateful to Statistics Korea for allowing access to these datasets.

there can be multiple export pioneers of one export-pioneered product.

C. *Basic Facts*

Table 1 shows the number of created and export-pioneered products for each year from 1992 to 1998. The total number of created products during that period is 980. The number of created products per year varies considerably over the years, with a low of 44 in 1996 and a high of 225 in 1997. The total number of export-pioneered products during the same period is 1,283. The corresponding yearly figures show a low of 88 in 1996 and a high of 281 in 1992. The numbers of export-pioneered products tend to be higher than those of created products, as the export-pioneered products can arise from those products which are not created products, i.e., those products that already existed during the period 1990-1991, and also because the number of such non-created products tends to be large relative to the number of created products.

The industries for which the numbers of created or export-pioneered products are largest are the communication equipment, machinery and equipment, and chemical industries. However, the number of created or export-pioneered products may be large simply because the number of product categories in these industries would be large. Accordingly, in the second and fourth columns of Table 2, we also show the number of created or export-pioneered products as the share of the total number of product categories in the corresponding industry. Then, we find that office and computing machinery, communication equipment, and apparel are the industries for which the shares of created products are largest.[5] The industries for which the shares of export-pioneered products are the largest are office and computing machinery, communication equipment, and apparel. Thus, Table 2 is broadly consistent with the perception that the growth of the Korean manufacturing sector in the 1990s was driven by active product innovation and export pioneering in computing machinery and communication equipment.

TABLE 1—NUMBER OF CREATED AND EXPORT-PIONEERED PRODUCTS

Year	Number of products	
	Created	Export-pioneered
1992	178	281
1993	180	245
1994	76	125
1995	84	121
1996	44	88
1997	225	211
1998	193	212
Total	980	1,283

Source: Author's own calculation.

[5]Tobacco is the industry for which the shares of created or export-pioneered products are among the largest, but we do not want to emphasize this because there are only four product categories in this industry. A similar point can be made for the recycling industry.

TABLE 2—INDUSTRY DISTRIBUTION OF CREATED AND EXPORT-PIONEERED PRODUCTS

KSIC 2-digit code	Name	Created products		Export-pioneered products		Industry total products
		No. of products	Share of industry products	No. of products	Share of industry products	No.
		A	=(A/Y)*100	B	=(B/Y)*100	Y
15	Food and beverage	58	15.3	123	32.5	378
16	Tobacco	2	50.0	3	75.0	4
17	Textiles	45	16.7	60	22.3	269
18	Apparel	64	41.3	58	37.4	155
19	Leather and footwear	5	7.9	10	15.9	63
20	Wood and wood products	5	6.0	23	27.7	83
21	Pulp and paper	28	27.2	34	33.0	103
22	Publishing and printing	5	10.9	7	15.2	46
23	Petroleum	4	11.8	6	17.6	34
24	Chemical	93	20.6	127	28.2	451
25	Rubber and plastics	11	8.1	16	11.9	135
26	Non-metallic mineral	32	18.6	49	28.5	172
27	Basic metal	41	16.5	63	25.4	248
28	Fabricated metal	42	16.3	54	20.9	258
29	Machinery and equipment	135	19.4	220	31.7	695
30	Office and computing machinery	60	60.0	57	57.0	100
31	Electrical machinery	56	31.1	62	34.4	180
32	Communication equipment	178	54.9	160	49.4	324
33	Precision instruments	35	22.3	43	27.4	157
34	Automobile	22	30.6	23	31.9	72
35	Other transport equipment	25	27.5	32	35.2	91
36	Furniture	34	13.7	51	20.5	249
37	Recycling	0	0.0	2	66.7	3
Total	All manufacturing	980	23.0	1,283	30.0	4,270

Source: Author's own calculation.

As explained above, when a product is created, it can be created by multiple plants. Figure 1 show the distribution of 980 created products according to the number of product creators. The greatest number of products created by a single plant is 208, which accounts for nearly 21 percent of all created products in this case. The number of created products decreases as the number of simultaneous creators increases. For example, there are 117 products which were created by two

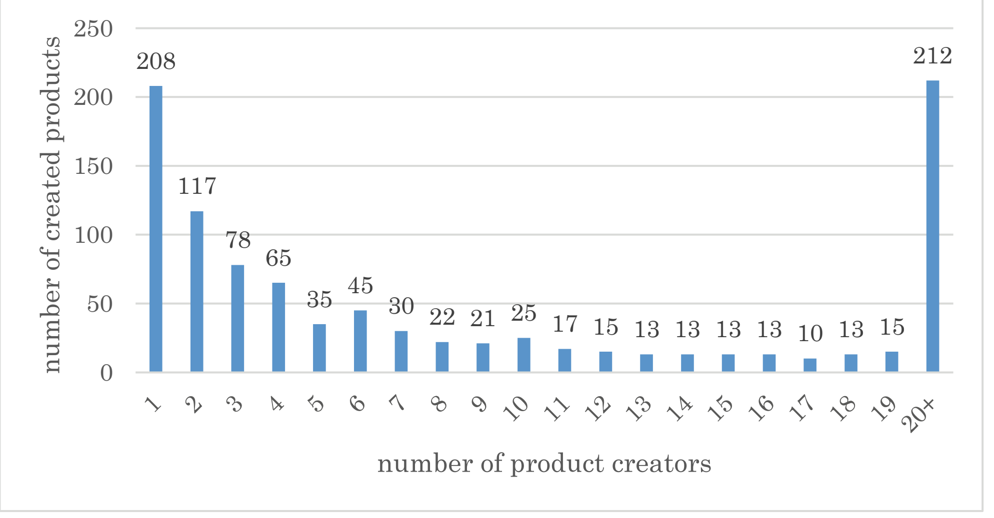


FIGURE 1. DISTRIBUTION OF CREATED PRODUCTS ACCORDING TO THE NUMBER OF PRODUCT CREATORS

plants in the same year. However, 212 created products have more than 20 creators.

When product creators produce created products, do they produce them for the domestic market only, for both the domestic and export markets, or for the export market only? In other words, what does the distribution of created products according to the initial shipment destination look like? We attempt to answer this question from the two standpoints of created "products" and created "product varieties." Table 3 shows that there are 19,690 created product varieties for 980 created products.[6] In terms of product varieties, most (about 84 percent) created product varieties are produced for the domestic market only in the year they were initially produced. Some of the plants which produce these created product varieties may become export pioneers in the future, but they are not export pioneers at least during the first year of production. What captures our attention in Table 3 is that the remaining 3,245 created product varieties (16 percent) are exported during the very first year of production. Among them, 2,512 created product varieties (about 13 percentage points) are produced for both the domestic and export market, while the remaining 733 created product varieties are exported, bypassing the domestic market, in the first year of production. Given our definition of export pioneers, these 3,245 plants are export pioneers. This implies that these plants became both a product creator and an export pioneer in the same year. In other words, for these created product varieties, the export pioneers are the product creators themselves. Moreover, these created product varieties did not require any time lag between product creation and export pioneering. In terms of products, approximately 65 percent of the created products are exported by some plants in the year the product was created.[7] This feature of the data has an import implication which we will discuss in section 5.

[6]As explained above, more than one plant can create the same product in the same year; therefore, the total number of created product varieties exceeds the total number of created products.

[7]The share of exported products in the first year of production is much larger than the share of exported product varieties because, due to plant heterogeneity, only a subset of plants will export the same created product.

TABLE 3—SHIPMENTS DESTINATION OF CREATED PRODUCT VARIETIES AND CREATED PRODUCTS

Destination	Created product varieties		Created products	
	Number	(share)	Number	(share)
Domestic only	16,445	(83.52)	341	(34.8)
Domestic and export	2,512	(12.76)	632	(64.49)
Export only	733	(3.72)	7	(0.71)
Total	19,690	(100.0)	980	(100.0)

Source: Author's own calculation.

III. From Product Creation to Imitation

After products or product varieties are created, they go through a selection process; some of them survive and others cease to be produced over time. For some created products, product imitators appear. Export pioneers will emerge from the pool of product creators and product imitators. In this section, we examine the dynamic process from the appearance of product creators to the appearance of product imitators. In the next section, we will examine how export pioneers emerge. In doing so, we are mainly interested in identifying plant-level determinants of plants' behaviors at various stages of this dynamic process, which helps us to understand how export pioneers are related to product creators.

A. *Who will become product creators?*

What types of plants are likely to become product creators? To answer this question, we estimate the following probit model.

$$\begin{aligned}&\Pr(Product\ Creator_{ijt} = 1 \mid X_{ijt-1})\\ &= \Psi(\beta_1 \ln TFP_{ijt-1} + \beta_2 \ln Worker_{ijt-1} + \beta_3 Exporter_{ijt-1} + \beta_4 Innovator_{ijt-1} +\\ &\quad \beta_5 \ln Age_{ijt-1} + \beta_6 Multi_{ijt-1} + \beta_7 \ln KI_{ijt-1} + \beta_8 \ln SI_{ijt-1} + \gamma_1 XRatio_{jt-1} +\\ &\quad \gamma_2 HHI_{jt-1} + \gamma_2 R\&DInt_{jt-1} + u_j + u_t)\end{aligned}$$

$Product\ Creator_{ijt}$ is an indicator variable which equals 1 if plant i in industry j creates a product variety in year t, equaling 0 otherwise. $\ln TFP$ is plant total factor productivity (log)[8], $\ln Worker$ is the number of workers (log), $Exporter$ is an dummy variable which equals one if a plant has a positive export shipments and zero otherwise, Innovator is a dummy variable which equals one if a plant has a positive R&D expenditure and zero otherwise, $\ln Age$ represents the age of the plant, $Multi$ is a dummy variable which equals one if a plant is a multiproduct plant and zero otherwise, $\ln KI$ is the capital intensity of the plant (=tangible fixed

[8]We estimated plant total factor productivity using the methodology of Levinsohn and Petrin (2003) according to the two-digit KSIC industry.

assets/workers, log), and $\ln SI$ is a proxy for skill intensity (=non-production workers/total workers, log). We additionally include time-varying industry characteristics as controls, in this case the industry exports-shipments ratio (*XRatio*), the Herfindahl-Hirschman index (*HHI*), and the industry R&D intensity (*R&DInt* = R&D/shipments). All independent variables are lagged by one year to address the endogeneity issue. We also introduce industry and year fixed effects. The sample includes all plant-year observations from 1992 to 1998 in five-digit industries for which there are product creators. However, we dropped observations of product creators after product creation so as to mitigate the problem of reverse causality.

Table 4 shows that plants that are productive, large, or engaged in R&D are more likely to become a product creator, which is not at all surprising. If product creation requires innovation activity and if there are financial market imperfections, large, productive, R&D-engaged plants are likely to be in a better position to introduce a product for the first time in the economy. There is no evidence, however, that previous

TABLE 4—WHO WILL BECOME PRODUCT CREATORS?

Explanatory variable	[1]	[2]
lpln*TFP*	0.0022***	0.0021***
	(0.0008)	(0.0008)
ln*Worker*	0.0029***	0.0033***
	(0.0004)	(0.0004)
Exporter	-0.0001	0.0003
	(0.0010)	(0.0010)
Innovator	0.0023**	0.0046***
	(0.0011)	(0.0012)
ln*Age*	-0.0003	-0.0006
	(0.0004)	(0.0005)
Multiprp	0.0143***	0.0119***
	(0.0008)	(0.0008)
ln*KI*	0.0001	-0.0014***
	(0.0004)	(0.0004)
ln*SI*	0.0018***	0.0001
	(0.0007)	(0.0007)
XRatio	-0.0039	-0.0044
	(0.0041)	(0.0030)
HHI	0.0271***	0.0713***
	(0.0056)	(0.0042)
R&D Intensity	0.0476**	0.2242***
	(0.0231)	(0.0209)
Industry Dummy	KSIC 5 dgt	KSIC 3dgt
Year Dummy	Yes	Yes
No. Obs.	226,796	235,558
Log likelihood	-26,359.75	-31,637.07
Pseudo R^2	0.2333	0.1283

Note: Estimated marginal effects. The numbers in parenthesis are robust standard errors. ***, **, and * indicates that the estimated coefficient is significant at the 1, 5, and 10 percent level, respectively.

Source: Author's own calculation.

exporting experience helps plants to create products, as suggested by the insignificant *Exporter* variable. With regard to the industry characteristics, *HHI* and *R&DInt* are estimated to be significantly positive, indicating that product creation is more likely in industries which are more concentrated or are technologically sophisticated.

Table 3 indicates that some product varieties are created and exported in the same year. This implies that the characteristics of *some* export pioneers are identical to those of the product creators, shown in Table 4. However, this does not warrant us to infer, based on Table 4, that export pioneers are also more likely to be large, productive plants engaged in R&D given that export pioneers can emerge not only from product creators but also from product imitators. We postpone examining what types of plants become export pioneers out of a pool of product creators and imitators until the next section.

B. *Survival of Created Product Varieties and Created Products*

After products or product varieties are created, they go through a selection process of survival. Figure 2 shows the production duration of 2,275 product varieties and 178 products created in 1992. What is most noteworthy in Figure 2 is that approximately half of the created product varieties are produced for only one year and then disappear. After three years, about 67 percent of the created product varieties stop being produced. Only about 20 percent of the created product varieties survive longer than five years. In terms of created products, the figure shows a pattern which is quite different, understandably, from the previous one. Although some created products completely disappear from the economy within the first several years, most (about 84 percent) of the created products survive for more than five years. The difference in survival patterns between created products and the created product varieties indicates that there is some selection among the plants which created the same product, which is most likely more important than selection

[2,275 product varieties created in 1992]

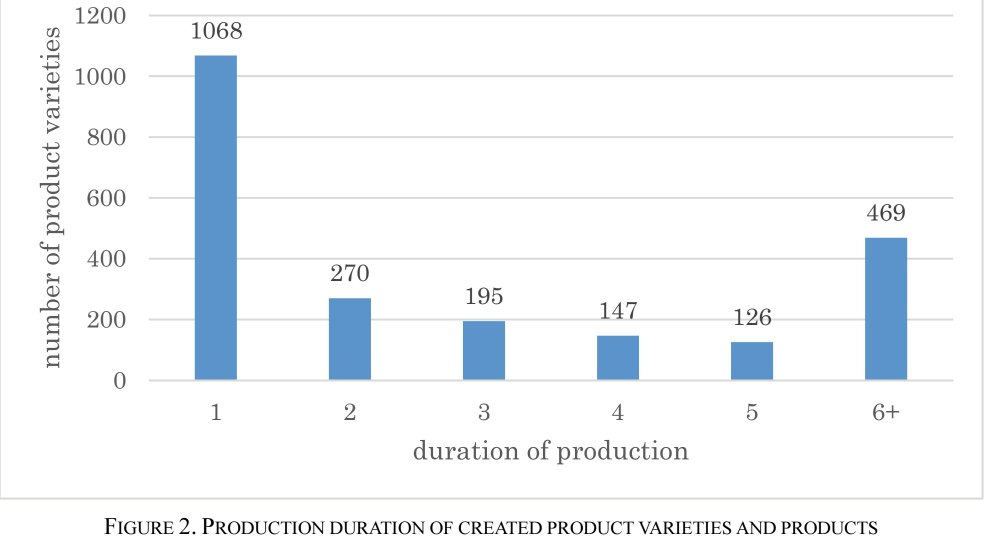


FIGURE 2. PRODUCTION DURATION OF CREATED PRODUCT VARIETIES AND PRODUCTS

[178 products created in 1992]

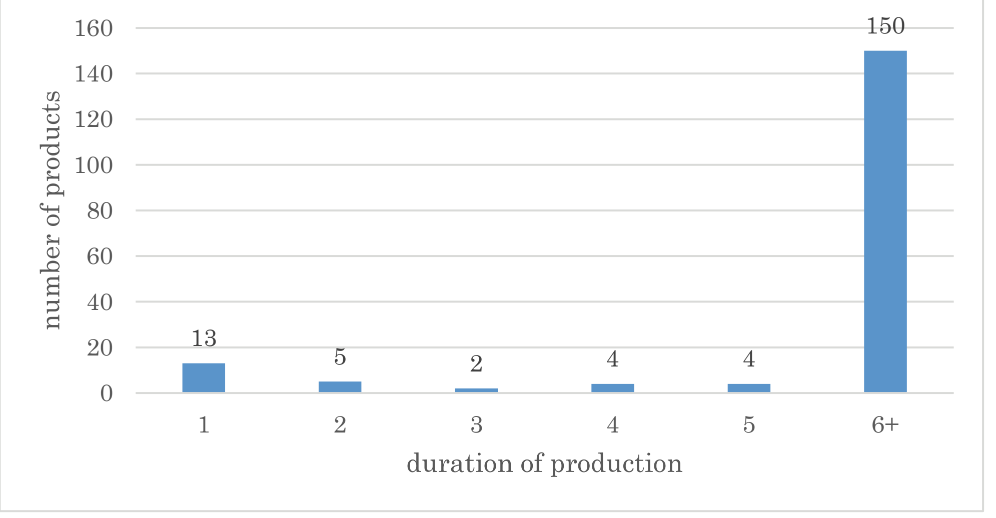


FIGURE 2. PRODUCTION DURATION OF CREATED PRODUCT VARIETIES AND PRODUCTS (CONT'D)

Source: Author's own calculation.

among products. For each product possibly created by multiple plants, a strong force of selection is working among plants, but most created products continue to be produced by a small number of survivors even after five years. Motivated by this observation, we further explored the plant-level characteristics determining the probability of survival for more than one year for the created product varieties by estimating a probit model with the same explanatory variables presented in Table 4 using the full sample of created product varieties, which we do not report here. We find that product varieties created by large, old, exporting plants are more likely to survive for more than one year.

C. *When does the first imitator appear and how many imitators are there?*

Export pioneers may emerge not only out of product variety creators but also out of product variety imitators. Thus, we examine here when the first imitator appears after the appearance of a product variety creator. Table 5 shows the distribution of 980 created products according to the creation year and the first imitation year. The first imitator appears very quickly. For nearly 75 percent of created products, the first imitator appears merely one year after product creation. In the case of cohorts of products created in 1992 and 1993, approximately 90 percent those products are imitated within five years. The fact that most created products are imitated within a short period of time suggests that export pioneers can emerge out of product imitators as well as product creators if the product creators do not export the created product varieties immediately. Specifically, plants which created the 16,455 product varieties produced for the domestic market only in the first year of production, as shown in Table 3, may lose their chance of becoming export pioneers due to the quick appearance of imitators.

TABLE 5—WHEN DOES THE FIRST IMITATOR APPEAR?

Created in	Imitated first in 1993	1994	1995	1996	1997	1998	Not followed	Total
1992	132	11	12	3	2	2	16	178
1993		136	17	6	0	6	15	180
1994			54	9	4	3	6	76
1995				59	8	3	14	84
1996					36	3	5	44
1997						171	54	225
1998							193	193
Total	132	147	83	77	50	188	303	980

Source: Author's own calculation.

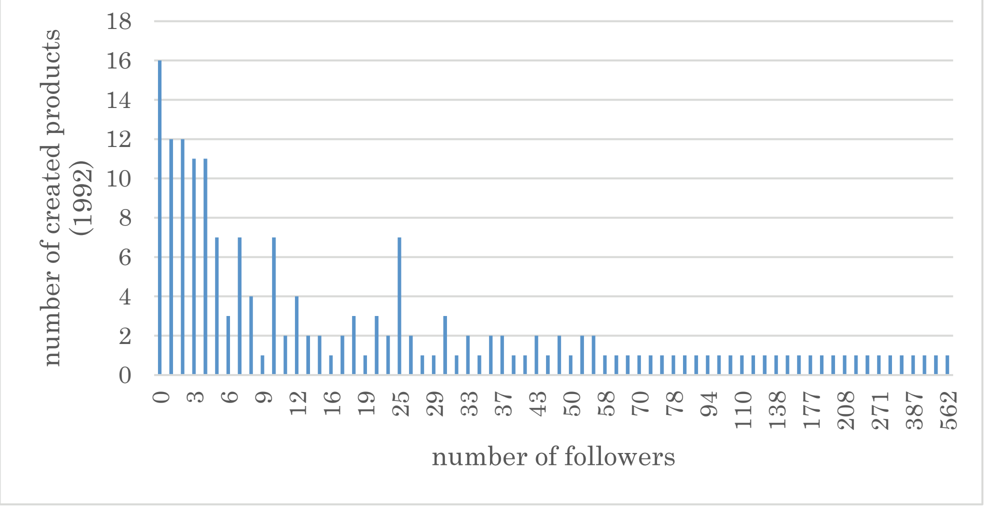


FIGURE 3. DISTRIBUTION OF 178 PRODUCTS CREATED IN 1992 ACCORDING TO THE NUMBER OF IMITATORS

Source: Author's own calculation.

After the creation of products, increasing numbers of imitators, if any, may appear over time and a new industry will be formed. One may wonder how many followers appear. Among the 178 products created in 1992, close to 30 percent of them have five or fewer imitators while about 42 percent have ten or fewer imitators. It is interesting, however, to note that there are more than one hundred imitators for a small subset of created products.

D. *Characteristics of imitators vis-à-vis creators*

How do the characteristics of imitators compare with those of product creators? Are imitators larger, more productive, older, and/or more capital- or skill-intensive, for example, than product creators? Answering these questions may help us to understand the emergence of export pioneers, as export pioneers can appear out of imitators as well as creators. First, we constructed a sample of product creators and product imitators for all created product. For each creator and imitator, we kept observations only for the year when product creators created products and product imitators imitated products. Using this sample, we ran the following simple regressions.

$$C_{ipt-1} = \gamma_0 + \gamma_1 Imitator_{ip} + u_p + u_t + \varepsilon_{ipt}$$

Imitator is a dummy variable which takes a value of one if plant i producing a created product p is a product imitator and zero if they are a product creator. The characteristics of plants are those for one year before the product creation or imitation. We included product and year fixed effects. Table 6 shows the estimated coefficients of the imitator dummy variable.

The table shows that there are some differences between creators and imitators in terms of plant characteristics one year before creation/imitation and that the characteristics of imitators relative to pioneers change as they start producing those products. For the year before creation/imitation, imitators are found to be significantly more productive and larger than creators, as shown in the first two rows of the table. These results may seem surprising and somewhat at odds with what would be predicted by standard theories of heterogeneous firms in international economics, as pioneered by Melitz (2003); firms that are more productive and hence larger are more likely to be the pioneers. However, this result parallels the findings of Wagner and Zahler (2015) with regard to export pioneers and export followers.

TABLE 6—CHARACTERISTICS OF IMITATORS IN COMPARISON WITH CREATORS

Dependent Variable	Plant characteristics at t-1	
	Coefficients	No. Obs.
lpln*TFP*	0.0693***	26,725
	(0.0159)	
ln*Worker*	0.0756***	26,797
	(0.03)	
Exporter	0.0132	26,797
	(0.0099)	
Innovator	0.0105	26,797
	(0.0087)	
ln*Age*	0.0423*	25,763
	(0.0222)	
Multiprp	-0.0196*	26,797
	(0.011)	
ln*KI*	0.1079***	26,785
	(0.0269)	
ln*SI*	0.0127	22,321
	(0.0143)	
Product fixed effect	Yes	
Year fixed effect	Yes	

Note: The numbers in parenthesis are robust standard errors. ***, **, and * indicates that the estimated coefficient is significant at the 1, 5, and 10 percent level, respectively.

Source: Author's own calculation.

They find using detailed Chilean Customs exports data that export pioneers export less than comparable followers for the same new export product for Chile. Their explanation for this finding is that firms that are good at exploration (creation) may have a comparative disadvantage at producing (scaling up) so that export followers that are good at scaling up export more than comparable pioneers. One theoretical explanation provided by Wagner and Zahler (2015) for why export followers are larger (and more productive) than export pioneer is as follows. In the face of uncertainty in the export profitability of a product, export pioneers appear randomly out of a plant productivity distribution. Once the export profitability of a product is revealed to be high due to the trial of the export pioneer, the most productive firms then react by self-selecting and entering the export market of this product.[9] Our results suggest that a mechanism similar to that provided for export market entry by Wagner and Zahler (2015) may also be working in product creation/imitation; plants that are good at exploring (creation) may be different from plant that are good at producing and scaling up (imitation).[10] Table 6 also shows that imitators tend to be older and have more capital-intensive production structures than creators. The former result suggests that plants that are good at exploration are likely to be younger plants. The latter result appears to be consistent with our explanation above that imitators are those that have a comparative advantage at scaling up.

IV. The Emergence of Export Pioneers

At this stage, we examine how export pioneers emerge. We start by documenting when export pioneers appear for created products.

A. *When do Export Pioneers Appear?*

We have shown in Table 1 that 980 products were created in various years during our sample period. Then, for each cohort of created products, when does the export pioneer appear? Table 7 shows the distribution of the created products according to the year of product creation and the year of export pioneering. First, most created products are exported for the first time in the economy, i.e., export-pioneered, during the sample period. Specifically, 792 created products (about 80 percent) were exported for the first time from the viewpoint of the economy during our seven-year sample period. Table 1 shows that there are 1,283 export-pioneered products which are either created or non-created products. Accordingly, we find that a majority (about 62 percent) of the export-pioneered products are those products which were created during our sample period. Second and more interestingly, one clear tendency is that when created products are first exported, they are exported during the same year they were created. For these products, there is no time lag between product creation and export pioneering. Specifically, 639 products (65 percent) out of 980

[9]For a more detailed explanation, see Wagner and Zahler (2015).

[10]Another reason for imitators being larger than creators may be that larger and older firms are more likely to perform process innovation rather than product innovation and that imitation requires the capability of process innovation. I am thankful to an anonymous referee for this interpretation.

TABLE 7—FOR CREATED PRODUCTS, WHEN DO EXPORT PIONEERS APPEAR?

Created in	First exported in								
	1992	1993	1994	1995	1996	1997	1998	Not exported	Total
1992	98	21	11	6	4	2	5	31	178
1993		111	16	6	6	8	3	30	180
1994			42	10	2	4	2	16	76
1995				52	11	4	2	15	84
1996					28	5	0	11	44
1997						158	25	42	225
1998							150	43	193
Total	98	132	69	74	51	181	187	188	980

Source: Author's own calculation.

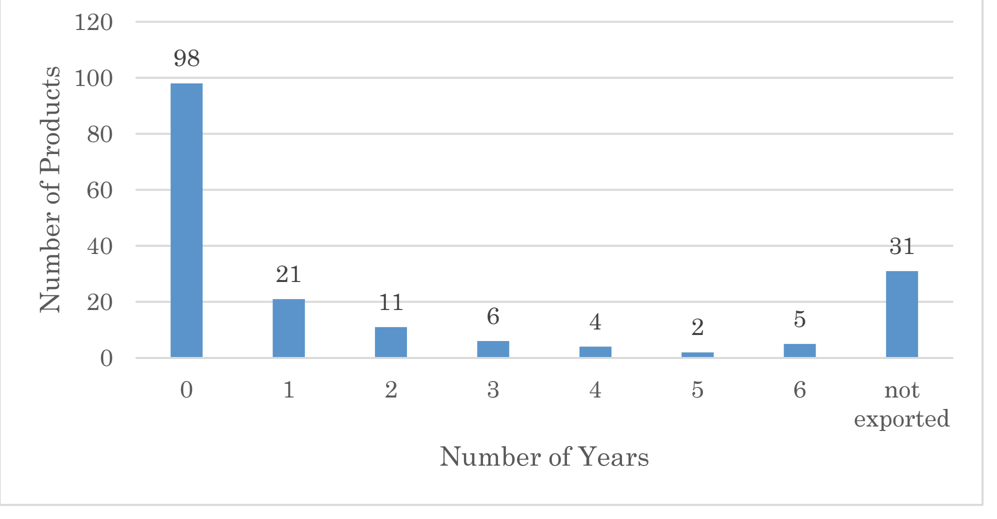


FIGURE 4. NUMBER OF YEARS FROM PRODUCT CREATION TO EXPORT PIONEERING FOR 178 PRODUCTS CREATED IN 1992

Source: Author's own calculation.

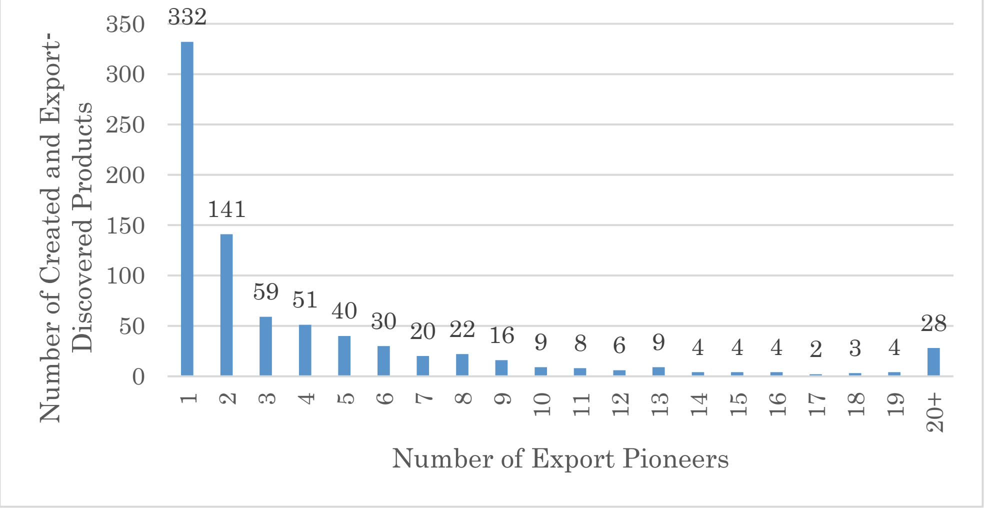
created products are exported the very year they were created.[11] There are some created products which are first exported with a time lag, but these are relatively few. Figure 3 shows the distribution of 178 products created in 1992 according to the number of years it takes from product creation to export pioneering. Here, 98 products are initially exported during the year of product creation. We see a clear tendency in that the number of emerging export pioneers decreases as the time lag between product creation and export pioneering increases. For those products for which product creation and export pioneering occurred during the same year, export pioneers are the same entity as the product creators. For those products for which export pioneering occurred with a time lag after product creation, we cannot tell whether product creators or product imitators became export pioneers.

[11]This result was discussed previously, as shown in Table 1.

B. *How many export pioneers are there?*

When a created product is first time exported, is this generally done by a single plant or by multiple plants? Figure 5 show the distribution of export-pioneered products according to the number of export pioneers. The upper figure shows the distribution for 792 "created and export-pioneered" products. However, according to our definition of an export-pioneered product, export-pioneered products can arise not only from created products but also from those products for which we do not

[792 Created and Export-Pioneered Products]



[1,283 Export-Pioneered Products]

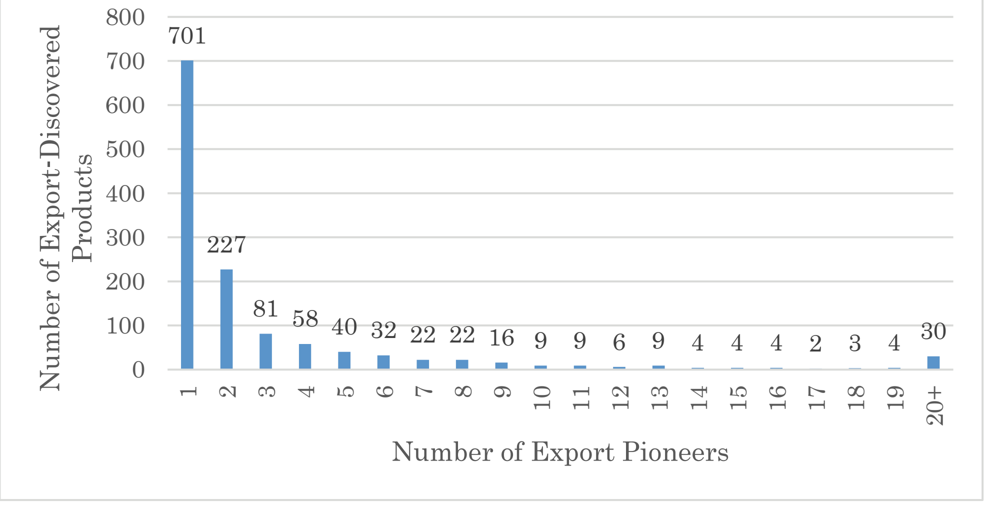


FIGURE 5. DISTRIBUTION OF EXPORT-PIONEERED PRODUCTS ACCORDING TO THE NUMBER OF EXPORT PIONEERS

Source: Author's own calculation.

have information about the creation year, i.e., non-created products. The number of export-pioneered products from among the non-created products is 491, meaning that the total number of export-pioneered products identified for our sample period is 1,283 (= 792+491). The lower figure shows the distribution for the 1,283 export-pioneered products according to the number of export pioneers (plants).

We find that roughly half of the export-pioneered products were pioneered by a single plant. The number of export-pioneered products tends to become small quickly as the number of export pioneers become larger. However, there are some products for which twenty or more plants simultaneously exported a product for the first time in the economy.

We have shown above that some created products are instantly exported while others are exported with some time lag. We have also shown that some created products are export-pioneered by a single plant while others are export-pioneered by multiple plants at the same time. One can therefore ask what factors determine how soon a created product is exported and what factors determine how many export pioneers simultaneously begin exporting a given created product. To address the former question first, we focus on several industry characteristics, specifically those factors presented in Table 4 of section 3. First, we constructed a sample of products created during the period of 1992-1995. Then, for each created product, we kept one observation for the year in which that product was exported for the first time in the economy. Using this sample, we estimated the probit model below.

$$\begin{aligned}&\Pr(Export\ Pioneered_p = 1 \mid X_{jt-1})\\&\quad = \Psi(\gamma_1 XRatio_{jt-1} + \gamma_2 HHI_{jt-1} + \gamma_2 R\&DInt_{jt-1} + u_t)\end{aligned}$$

Here, $Export\ Pioneered_p$ takes a value of one if product p was first exported within n years after its creation and zero if it was first exported after n years. We set n equal to 0 or 2, which makes two separate dummy variables. The independent variables are the same industry characteristics used in Table 4, i.e., $XRatio$, HHI, and $R\&DInt$, which are measured at the five-digit industry level to which the product belongs.[12] We take the values of these industry characteristics one year prior to the product being export-pioneered. Because the calendar year for export-pioneering differs across products, we include year fixed effects.

Table 8 shows the estimated marginal effects. We find that the industry export ratio as well as the industry concentration ratio matter with regard to how soon a created product is first exported. We also find that a created product is more likely to be exported for the first time within two years, specifically when the industry export ratio is higher. To the extent that the industry export ratio captures the strength of the comparative advantage of the industry, this result suggests that when plants create a product in industries for which a country has a stronger comparative advantage, they are likely to bring it to the export market sooner. We also find that when a product is created in a more concentrated industry, it is less likely to be exported for the first time soon. One interpretation of this result could be that the incentive to export a created product early is weak in concentrated industries because

[12]The first five digits of the eight-digit product code make up the industry code to which the product belongs.

TABLE 8—WHEN DO EXPORT PIONEERS APPEAR AND HOW MANY APPEAR?

	Dependent variable		
	Export-discovered after creation within		No. export pioneers
	0 year	2 years	(2 years)
	Probit		OLS
Explanatory variable	[1]	[2]	[4]
Export ratio	0.4011***	0.2425***	0.4998**
	(0.0986)	(0.0897)	(0.2170)
HHI	-0.4481***	-0.4112***	-1.3595***
	(0.1048)	(0.0814)	(0.2285)
R&D Intensity	2.1320**	1.2418	2.1203**
	(0.9952)	(0.8066)	(0.8566)
Year Dummy	Yes	Yes	Yes
No. Obs.	498	498	381
Log pseudolikelihood	-311.52	-252.85	
Pseudo R^2	0.0668	0.0687	
R^2			0.0735

Note: The numbers in the first two columns are the estimated marginal effects from the probit model. The numbers in the third column are the estimated coefficients. The numbers in parenthesis are robust standard errors. ***, **, and * indicates that the estimated coefficient is significant at the 1, 5, and 10 percent level, respectively.

Source: Author's own calculation.

the competition pressure is weak. The industry R&D intensity variable is estimated to be positive but either only marginally significant or insignificant.

C. *Where do export pioneers come from?*

Thus far, we have provided various types of evidence about the process from product creation to the emergence of export pioneers. Conceptually, although we have already shown in Table 3 that approximately 65 percent of created products are instantly exported the year that they are created by some plant(s), export-pioneering plants or export pioneers can emerge not only from product creators but also from product imitators, with or without a time delay after product creation/imitation. Export pioneers can also emerge for products for which we cannot identify when they were produced for the first time in the economy. Here, we attempt to summarize how many export pioneers there are in our sample and where they come from. To do this, we count the total number of export pioneer plants and examine the corresponding distribution according to the plant type. There are five types of export pioneers: export pioneers that exported a created product in the same year as product creation (creator-pioneer without a delay), export pioneers that exported a created product with some time lag after product creation (creator-pioneer with a delay), export pioneers that exported an imitated product in the same year as product imitation (imitator-pioneer without a delay), export pioneers that exported an imitated product with some time lag after product imitation (imitator-pioneer with a delay), and finally export pioneers that exported a non-created product for the first time in the economy (pioneer of non-created product). Figure 6 shows the distribution.

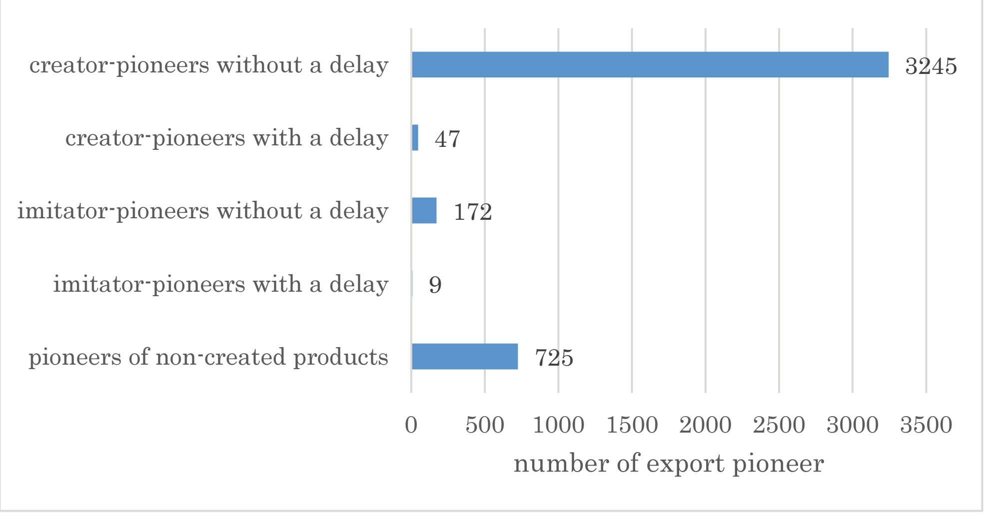


FIGURE 6. WHERE DO EXPORT PIONEERS COME FROM?

Source: Author's own calculation.

There are 4,198 export pioneer plants in total identified in our sample according to our definition. This number is greater than the total number of export-pioneered products, 1,283, in Table 1, as it is possible for multiple plants simultaneously to become export pioneers of the same product. What is most interesting and surprising in Figure 6 is that a predominant portion of export pioneers, approximately 77 percent of them (3,245 plants), are *creator-pioneers without a delay*.[13] There are only 47 plants that are creator-pioneers with a delay. Thus, there is a clear tendency for most product creators that become export pioneer ex post to have brought the created products to the export market instantly. Another interesting and surprising finding is that there are only a few export pioneers born from product imitators; there are only 172 imitator-pioneers without a delay and nine imitator-pioneers with a delay. In short, first, most export pioneers come from product creators, not from product imitators, and, second, most export pioneers created and exported the product in the same year. We consider this result as one of our main empirical findings. We postpone until the next section a discussion of our conjecture of the cause behind these findings, as well as their implications.

D. *Who will become export pioneers?*

As the final step in our empirical analyses, we examine the types of plants that are likely to become export pioneers. One of the key questions raised in this paper is how export pioneers are related to product creators. To address this question, we attempted to clarify the process from product creation to the emergence of export pioneers. To do so, we started by asking what types of plants are more likely to become product creators and found that plants that are productive, large, or engaged

[13]Hahn *et al*. (2018) finds a similar result for Indonesia.

in R&D are more likely to become a product creator. We also found from Figure 6 that a predominant portion of export pioneers come from product creators such that export pioneer plants are almost a subset of product creator plants. The question therefore arises as to what types of plants are likely to become export pioneers. To answer this question, we estimate the following probit model.

$$
\begin{aligned}
&\Pr(\mathit{Export\ Pioneer}_{ijt} = 1 \mid X_{ijt-1}) \\
&= \Psi(\beta_1 \ln TFP_{ijt-1} + \beta_2 \ln Worker_{ijt-1} + \beta_3 Exporter_{ijt-1} + \beta_4 Innovator_{ijt-1} + \\
&\quad \beta_5 \ln Age_{ijt-1} + \beta_6 Multi_{ijt-1} + \beta_7 \ln KI_{ijt-1} + \beta_8 \ln SI_{ijt-1} + \gamma_1 XRatio_{jt-1} + \\
&\quad \gamma_2 HHI_{jt-1} + \gamma_2 R\&DInt_{jt-1} + u_j + u_t)
\end{aligned}
$$

$\mathit{Export\ Pioneer}_{ijt}$ is an indicator variable which equals 1 if plant i in industry j export-pioneers a product variety in year t, equaling 0 otherwise. All independent variables are the same ones shown in Table 3 and are lagged by one year to address the endogeneity issue. We also introduce industry and year fixed effects. The estimated marginal effects are shown in Table 9.

We find that plants that are more productive or larger in size are more likely to become an export pioneer.[14] This result is consistent with what is implied by the results of Melitz (2003) and the various extensions of their findings. According to these theories, more productive and hence larger firms are likely to be the first to enter the export market. We also find that plants which have previous exporting experience are more likely to be export pioneers. If there exist plant-specific sunk costs of export market entry, as in Melitz (2003), such as setting up distribution channels or establishing buyer-supplier relationships, which plants with previous exporting experience have already paid and do not have to pay again, it is expected that existing exporters will realize higher ex-ante export profitability of a created product compared to those that do not have previous exporting experience.

Then, how do the plant-level determinants of becoming export pioneers compare with those of becoming product creators? There are some similarities as well as differences, which are likely to be important to understand the connection between export pioneers and product creators. Plant productivity and plant size positively affect both the probability of becoming an export pioneer and the probability of becoming a product creator. The fact that there are some similarities between the two sets of determinants would not be surprising given our finding from Figure 6 that most export pioneers are creator-pioneers without a delay.

More interesting are the differences in the plant-level determinants between Table 4 and Table 9. First, the *exporter* dummy variable, which was not significant in Table 4, is significantly positive in Table 9. The presence of plant fixed sunk costs of entry into the export market may explain this result because plants which have previous exporting experience and hence, have paid the sunk cost do not have to pay the cost again when they attempt to export a new created product. Second, the *innovator*

[14] Table 8 shows results with industry fixed effects at the five-digit or three-digit industry level in columns 1 and 2. The two results are somewhat different, but we assign more weight to the results with five-digit level industry fixed effects given that three-digit industries are considered to be overly broad for our purposes.

TABLE 9—WHO WILL BECOME EXPORT PIONEERS?

Explanatory variable	[1]	[2]
lpln*TFP*	0.0012***	0.0008
	(0.0005)	(0.0005)
ln*Worker*	0.0040***	0.0035***
	(0.0003)	(0.0002)
Exporter	0.0168***	0.0168***
	(0.0006)	(0.0006)
Innovator	0.0007	0.0016***
	(0.0006)	(0.0006)
ln*Age*	-0.0002	-0.0001
	(0.0003)	(0.0003)
Multiprp	0.0031***	0.0031***
	(0.0005)	(0.0005)
ln*KI*	0.0007***	0.0003
	(0.0002)	(0.0002)
ln*SI*	0.0014	0.0011***
	(0.0004)	(0.0004)
XRatio	0.0027	0.0015
	(0.0025)	(0.0018)
HHI	-0.0011	0.0143***
	(0.0033)	(0.0024)
R&D intensity	0.0123	0.0409***
	(0.0148)	(0.0121)
Industry Dummy	KSIC 5 dgt	KSIC 3dgt
Year Dummy	Yes	Yes
No. Obs.	201,546	215,718
Log pseudolikelihood	-9,860.23	-10,962.58
Pseudo R^2	0.2693	0.1980

Note: Estimated marginal effects. The numbers in parenthesis are robust standard errors. ***, **, and * indicates that the estimated coefficient is significant at the 1, 5, and 10 percent level, respectively.

Source: Author's own calculation.

dummy variable, which was significantly positive in determining the probability of becoming a product creator, is not significant, although it is positive, in determining the probability of becoming an export pioneer. We discuss the policy implications of these differences in the next section.

As the final analysis of this paper, we examined the determinants of the probability of a plant becoming a *creator-pioneer without a delay*. To do this, we constructed a sample of product creators and kept observations only for the year of product creation. Then, we used the same explanatory variables presented in Table 9 with values for one year before product creation and estimated the probability, $\Pr(\textit{Creator-pioneer without a delay}_i)$. $\textit{Creator-pioneer without a delay}_i$ takes a value of one if a plant becomes a creator-pioneer without a delay in the next year and zero if it becomes a product creator which does not export the created product in the year of product creation. The estimated marginal effects are shown in Table 10. The result in Table 10 is similar to the result in Table 9 in that plant productivity,

TABLE 10—WHO WILL BECOME CREATOR-PIONEERS WITHOUT A DELAY?

Explanatory variable	[1]	[2]
lpln*TFP*	0.0137**	0.0108*
	(0.0060)	(0.0056)
ln*Worker*	0.0313***	0.0275***
	(0.0034)	(0.0033)
Exporter	0.3026***	0.3094***
	(0.0061)	(0.0056)
Innovator	0.0122	0.0114
	(0.0095)	(0.0092)
ln*Age*	-0.0022	-0.0024
	(0.0043)	(0.0042)
Multiprp	-0.0436***	-0.0494***
	(0.0076)	(0.0073)
ln*KI*	0.0007	0.0024
	(0.0033)	(0.0031)
ln*SI*	0.0057	-0.0007
	(0.0056)	(0.0054)
XRatio	0.1330***	0.1839***
	(0.0346)	(0.0253)
HHI	-0.1409***	-0.0806**
	(0.0499)	(0.0346)
R&D intensity	-0.1558	-0.6886
	(0.2614)	(0.2225)
Industry Dummy	KSIC 5 dgt	KSIC 3dgt
Year Dummy	Yes	Yes
No. Obs.	10,181	10,706
Log pseudolikelihood	-3,648.59	-3,920.18
Pseudo R^2	0.3532	0.3274

Note: Estimated marginal effects. The numbers in parenthesis are robust standard errors. ***, **, and * indicates that the estimated coefficient is significant at the 1, 5, and 10 percent level, respectively.

Source: Author's own calculation.

plant size, and the exporter dummy are positively and significantly estimated. This is somewhat expected given that most export pioneers are creator-pioneers without a delay. Conditional on plants being would-be product creators, those which bring the created product to the export market instantly are likely to be experienced exporters.

V. Further Discussions and Implications for Policy

In this section, we discuss further some of our main empirical findings. Then, we discuss policy implications drawn out from our paper's results. In section 4, we showed by Figure 6 two results: first, most export pioneers come from product creators, not from product imitators, and, second, most export pioneers created and exported the product in the same year. These two results are closely related because if *all* export pioneers created and exported the product in the same year, there cannot be any imitators which become export pioneers because imitators of a created product, by our definition, can only appear at least one year after the product has already been exported. Accordingly, the result which needs an explanation the most is that finding that most export pioneers create and export the product in the same year. Although a formal theory would be needed to explain this result rigorously, we leave this task to future researchers. Instead, we give some conjectures, based on our intuition, for the causes of this result.

When a firm (or a plant) creates a product and if it intends to export the product, it has in principle the choice between exporting it immediately and exporting it sometime later. Suppose that there exists a fixed cost of export pioneering. Then, the decision to export this product will be determined by comparing the fixed cost with the expected future export profit from this product. Suppose also that there is learning associated with production experience of the created product in the domestic market such that the marginal cost of production decreases as the length of domestic production increases. If we rule out the possibility of imitation, the product creator will choose the optimal timing for exporting the product. Exporting the product earlier will give the firm an export profit stream from earlier on, but the amount of the expected profit will be smaller due to the unexploited learning potential. In contrast, if the firm decides to export the product sometime later, it can earn larger current flows of export profits but their present value may become smaller due to the discount. Now suppose that there is a positive probability of the entry of imitators. Imitators, if they succeed in product imitation, also have the choice of entering the export market as well either earlier or later. If the imitators decide to enter the export market as well sometime later, the expected export market profits of the product creator will be reduced. Thus, the possibility of the future entry of imitators not only into the domestic market but also into the export market will tilt the incentive of the product creator toward exporting the created product earlier so that it can enjoy first-mover advantage at least temporarily. As we have shown in Table 5, the first imitator appears very quickly; for about 75 percent of created products, the first imitator appears only one year after product creation. Moreover, this and other subsequent imitators may also decide to enter the export market as export followers. Then, if the creator is to enjoy the first-mover advantage in the export market, it must export the created product not long after product creation. This could be one possible explanation of the prevalence of creator-pioneers without a delay.

Another possible reason for the prevalence of creator-pioneers without a delay may be related to the "experimentation and learning" motive of new exporters, as in Albornoz *et al*. (2012). Motivated by the empirical findings by Eaton *et al*. (2008) and Besedes and Prusa (2006) that there is a prevalence of short-lived trade relationships in the trade data, Albornoz *et al*. (2012) builds a theoretical model of sequential exporting. In that model, when firms are uncertain about their export profitability and if the export profitability is correlated across time and destination markets, firms may use their initial export experience to draw out information about export profitability in other markets. This experimentation and learning motive of initial exports can explain why firms initiate initial exports in spite of the high probability of failure. If the initial exporting is driven by experimentation or testing motive, firms may decide to test earlier rather than later when they have a new product which can potentially be exported.

At this point, we discuss some policy implications from the empirical findings of our paper. We have shown that most export pioneers nearly form a subset of product creators. We have also shown that there are two differences between plant-level determinants of product creation (Table 4) and plant-level determinants of export pioneering (Table 9). That is, while previous exporting experience positively affects the probability of becoming an export pioneer, it does not have any significant effect on the probability of becoming a product creator. In contrast, while the innovator dummy variable does not have any significant effect on the probability of becoming an export pioneer, it affects positively the probability of becoming a product creator. We focus our discussion on possible policies to promote the emergence of export pioneers.[15]

To the extent that most export pioneers are product creators, promoting product creators would certainly help export pioneers to emerge. However, this is not likely to be enough. As we have shown, previous exporting experience also helps product creators to become export pioneers. In this regard, for an effective policy of promoting export pioneers, policies to support product creation/innovation need to be complemented by policies to increase the number of exporters by, for example, supporting would-be first-time exporters. In a similar vein, increasing the number of exporters is not likely to be very effective for inducing more export pioneers to emerge because, as we have shown, if a plant is to become an export pioneer, it has to be a product creator in the first place. Increasing the number of exporters may be desirable given the existence of the various plausible benefits from firms' exporting activities which free markets cannot be expected to deliver. In sum, the empirical evidence presented here suggests that a possible export-pioneer promotion program must include both the promotion of product creation/innovation and factors that increase the number of exporters that are linked together somehow.[16]

VI. Summary and Concluding Remarks

In this paper, we empirically examined how export pioneers emerge and how they are related to product creators/innovators, utilizing a rich plant-product level dataset from the Korean manufacturing sector for the period of 1990-1998. In so doing, we examined the process from the appearance of product creators to the emergence of export pioneers and attempted to identify plant-level determinants during the various decisions of plants during this process. The main empirical findings of our paper are as follows. First, most export pioneers are product creators which export the created

[15]Although a growing number of studies document positive externalities from export pioneers to followers, I am not aware of any countries, including Korea, with a separate policy package targeted the promotion of export pioneers. For example, existing export promotion programs in Korea, such as information provision, marketing assistance and access to finance at favorable terms, do not differentiate between export pioneers and export followers. Nevertheless, it may be worthwhile to discuss a conceptual policy framework for promoting export pioneers equipped with the evidence provided by our paper.

[16]Another way of promoting export pioneers may be to introduce a policy targeting directly would-be export pioneers, those which export a product for the first time in the economy. I do not devote much space to discussing this type of policy, not because such a policy lacks rationale but because I did not discuss in detail the rationale for such a policy in this paper. See Hahn (2019) and Wagner and Zahler (2015) for evidence of positive spillover generated by export pioneers for Korea and Chile, respectively.

product in the same year of product creation. Second, plants that are more productive or larger are more likely to become product creators and export pioneers. Previous exporting experience positively affects the probability of export pioneering only, while plants' engagement in R&D positively affects the probability of product creation only. We discussed possible explanations for our main empirical results as well as their policy implications.

There are several limitations of this paper. First, although we provided a couple of possible explanations for the prevalence of export pioneers which export the created product in the same year of creation, a formal theoretical explanation may be warranted, which we leave for a future study. Second, due to data availability issues, our analysis was confined only to Korea and our sample period was limited to 1990-1998. It may be interesting to examine whether similar results can be found for a more recent period for Korea or for a broader set of countries. Finally, it may be worthwhile to examine the dynamics of export pioneers themselves after they are born. We leave this also as a future study.

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Measuring the Impact of a Trade Dispute with a Supply-side Shock Using a Supply-driven Input-Output Analysis: Korea-Japan Dispute Case†

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The purpose of this paper is to measure the impact of the recent Korea-Japan trade dispute on the Korean economy using supply-driven input-output analysis. In July 2019, Japan announced the decision to tighten the export control of three materials which are indispensable in the manufacturing of semiconductors and electronic display panels. Japan's decision directly affects production in Korea's semiconductor and display sectors and is hence not a demand shock. For this reason, a standard demand-driven input-output analysis is not valid despite the fact that it can still be applied. The impact of Japan's decision on Korea's aggregate and individual sectors' gross output, GDP and employment were computed using both methods.

Key Word: Supply-driven Input-Output Analysis,
Demand-driven Input-Output Analysis,
Korea-Japan Trade Dispute
JEL Code: D57, F13, F14

I. Introduction

Countiries involved in trade disputes usually choose demand-side trade policy tools. Specifically, when there is a trade dispute or a trade 'war' between two countries, both countries choose trade policy tools that will exert negative demand shocks on the opposing country's exports. Typical examples are tariffs and import quotas, both of which aim to reduce imports of the opposing country's products.

Some trade disputes enter an entirely different phase. Occasionally, for example, exports of products which are indispensable intermediate inputs in the opposing country's key sectors are directly regulated or even embargoed. A striking instance

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took place in August of 2020, when the United States announced new sanctions which prohibit any foreign company from supplying semiconductors produced using US technology to the Chinese company Huawei. In fact, the trade dispute between China and United States is said to have begun in 2018 or even years earlier, witnessing the use of many traditional trade policy tools, but recent policy tools would be regarded as supply-side tools in the sense that they affect the supply side of the market.

Japan's decision strictly to control the export of three materials which are essential to the production of semiconductors and display panels in July of 2019 was another striking example of a supply-side trade policy. This policy, which was said to initiate the Korea-Japan trade dispute, triggered a fierce conflict between the two nations afterwards. Japan's decision remains in place as of December of 2020.

Supply-side trade policy tools can be regarded as 'strong' or 'extreme' tools compared to demand-side tools, and trade disputes during which supply-side tools are employed tend to involve a greater variety of, and fiercer, phases. Usually, supply-side trade policy tools are not regarded as 'traditional' trade policy tools. Moreover, these tools affect the supply side of the controlled products directly, meaning that their impacts on both parties differ from the effects of demand-side tools. Additionally, the target country of supply-side tools, even when unspecified, is usually more obvious.

The purpose of this paper is to measure the impact of the Korea-Japan trade dispute on the Korean economy by means of a supply-driven input-output (IO) analysis. It is possible to apply a traditional demand-driven IO analysis mechanically by 'pretending' that the change in production was caused by a final demand shock. However, a demand-driven IO analysis can be used only when the shock affects the final demand and thus cannot be applied to the current situation. Supply-driven IO analyses have been used in various situations but have not been applied to trade disputes with supply-side trade policy tools.

The paper is organized as follows. Section 2 explains the motivation of the paper in more detail and reviews the literature. Sections 3 and 4 explain the methodology and the data, respectively, and the results of the paper are given in Section 5. Section 6 concludes the paper.

II. Motivation and Literature

Most trade disputes have significant impacts on the countries involved. Also, it is likely for trade disputes to escalate due to the involved countries' efforts to have a greater impact on the opposing country so as to 'win' the dispute, causing the dispute to grow into a trade 'war.'

Trade disputes can have various phases depending on many factors, such as the trade pattern between the countries involved, diplomatic relationships, political situations, the history of the disputes, and emotional factors, among others. The involved countries choose tools which may allow them to apply the strongest pressure on the opposing country. For example, demand-side tools such as tariffs or import quotas can be highly effective when the country is the biggest importer of the product in question.

Some policy tools affect the supply side of the products in question, as witnessed in the US-China and Korea-Japan disputes. In fact, the most influential and well-known incident of the use of a supply-side trade policy tool took place during the 'first oil crisis' in 1973-1974, when the Organization of the Petroleum Exporting Countries (OPEC) reduced the production of crude oil radically and began controlling oil exports strictly, though this was not a trade 'dispute.' A similar process was repeated in the 'second oil crisis' of 1979-1980; the world economy experienced skyrocketing oil prices and significant damage in almost every sector during and after these two crises.

The impact of demand-side policy tools on the opposing country can be measured using a standard demand-driven IO analysis, i.e., using the well-known formula $(\mathbf{I}-\mathbf{A}^d)^{-1}\Delta\mathbf{y}$, where $\mathbf{I}$ is the identity matrix, $\mathbf{A}^d$ is the domestic input coefficient matrix and $\Delta\mathbf{y}$ denotes the change in the final demand vector. This method, however, cannot be used for supply-side trade policy tools. Suppose that country A is the monopolistic producer of material AA, that AA is an indispensable raw material used to produce BB, and that BB is an important product in country B. Suppose that country A suddenly decreases their exports of AA. Unless country B succeeds in securing a substitute input for AA, the only option is to reduce the production of BB. Interrelated sectors will also be affected severely.

This type of impact cannot be computed using the above formula because the shock occurs on the supply side and because the formula above can be applied only to demand shocks. In a demand-driven IO analysis, the amounts of gross output and intermediate inputs are key endogenous variables, and they are determined by the final demand for the products, the major exogenous variables.

We have two options in this situation. The first is to apply the standard demand-driven IO analysis. While we are not supposed to apply a demand-driven IO analysis, we can still use this method, just as we can apply, e.g., the ordinary least square method when its assumptions are violated. We compute or assume a change in production due to the dispute and then assume that it was caused by a demand shock.

The second option is to use a supply-driven IO analysis. This was initially suggested by Ghosh (1958) and has been used in situations with supply-side shocks. However, the standard supply-driven IO analysis can be used only when the shock affects the value-added components, for example, a change in labor supply which affects the compensation of employees.

It is necessary briefly to explain the mechanics of a demand-driven IO analysis at this point. Upon the realization of a demand shock, the response of the supply side is to change production by the same amount because in IO analysis, the supply side is assumed to be infinitely elastic. This requires additional domestic intermediate inputs, imported intermediate inputs and primary production factors, of which the first is met by increases in production in the corresponding sectors, the second by imports, and the third by households. This is the second round, and the subsequent rounds are repeated infinitely in the same manner. The total impact is the sum of the impacts in each round, and we can compute the changes in production, value-added, imports and employment in individual sectors and in the entire economy as the sums of infinite geometric series. Considering that the analysis is interested in the sectors in the upstream which provide raw materials to the affected sector, we can refer to the impact of the shock in a demand-driven analysis as the 'backward linkage effect.'

A supply-driven IO analysis is interested in the impact of the shock on the sectors downstream to which the affected sector supplies intermediate input. Suppose that the production of a sector is decreased as the result of a supply shock. The product of the affected sector is used as a raw material in other sectors, which implies that other sectors also experience a decreased supply of this raw material and will be forced to decrease their production. This chain reaction will proceed infinitely in the same manner. The total impact is the sum of the infinitely many impacts in each round, and we can compute the decreases in gross output, value-added, imports and employment in individual sectors and in the entire economy. Considering that the analysis is interested in the sectors downstream to which the affected sector supplies raw materials, we refer to this impact as the ‘forward linkage effect.’

In order to apply a supply-driven IO analysis, however, we need to modify the method slightly because the shock did not affect value-added but gross output. For this purpose, we ‘exogenize’ the ‘affected’ sector, the sector BB in the aforementioned example, that is, the sector in which the embargoed product is used as an essential input. If the supply of product AA, whether domestic or imported, is reduced and cannot be replaced, then the affected sector is forced to reduce its gross output. Therefore, the gross output of the affected sector can no longer be treated as an endogenous variable. The gross output of the exogenized sector is treated as an exogenous variable in the supply-driven IO analysis.

The first step in this method is to estimate the decrease in the production of the affected sector. It is important to note that at the outset of the dispute, the decrease in the production of the affected sector will depend on the decrease in the material in question but will be gradually relieved for several reasons, such as import substitution, diversification of suppliers, and/or an improvement of the dispute due to negotiations.

The analysis proceeds in two directions from this stage. The estimated decrease in the production of the affected sector is used to compute its backward linkage effect, i.e., its impact on other endogenous sectors and on the entire economy using an ordinary demand-driven IO analysis. In the opposite direction, its forward linkage effect is computed by means of a supply-driven IO analysis. The overall impact is the sum of the two effects.

The body of literature on the demand-driven IO analysis is enormous such that reviewing the literature is almost impossible. In fact, it can be said that the demand-driven analysis was the primary objective of Leontief’s invention of IO tables and his analyses. Reyes and Mendoza (2013) noted that out of two main identities inside the IO tables, “Leontief concentrated his attention on the first one (the one which leads to the demand-driven IO analysis, specifically the Leontief inverse matrix).”

The impact of most shocks which affect the final demand of an economy or can be converted into such shocks can be computed by means of a demand-driven analysis. Most government expenditures, changes in household consumption levels, firms’ new investment projects, and changes in exports are typical examples. In recent decades, many countries compute the economic impacts of public infrastructure projects using a demand-driven IO analysis to enhance the efficiency of public finance. Korea’s Prefeasibility Studies performed by the Ministry of Economy and Finance and the Korea Development Institute which began in 1999 represents a good example.

The demand-driven IO analysis has also been used to measure the impact of trade disputes. Tian and Yang (2014) conducted a demand-driven IO analysis to measure the impact of the EU-China trade dispute around photovoltaic products. They used China's IO tables and computed the impact of antidumping on China's export of photovoltaic products and on the GDP of China. An IO analysis was also applied to a political dispute. Wu *et al*. (2016) used a demand-driven IO analysis to measure indirect economic losses in China caused by the dispute over the Diaoyu Islands, or Senkaku Islands, in 2012, which affected China's international trade.

The recent US-China trade dispute which started in 2017 invited a large number of studies. Considering the positions of the two countries in the world economy, the potential impact of the dispute, when it develops into a full-scale trade war, can be disastrous to most of their trade partner countries, not to mention themselves. For this reason, the dispute worried not only governments but also researchers all around the world, and almost every possible methodology has been employed to forecast the impact of the dispute.

Tyers and Zhou (2019) used a multi-region general equilibrium model and considered various scenarios to forecast the impact of the US-China dispute. Song and Lee (2018) used a computable general equilibrium (CGE) model to predict the economic impact of the US-China trade dispute. They considered several scenarios and forecasted the impacts on various macroeconomic variables of Korea as well as other countries involved.

Gentile *et al*. (2020) also applied a CGE model and used the Asian Development Bank's Multiregional Input-Output Tables (ADB MRIOT) to measure the impact of the US-China trade dispute on the involved countries and on the world economy. Two scenarios were considered in their study: the current state as of May of 2019 (the first scenario) and a 'full-scale tariff war' (an additional 25% tariff on all imported products). They computed the impacts on various aggregate variables of the US, China and many trade partner countries, at the same time showing, however, that some countries would benefit from the dispute by absorbing some import demand from both countries.

Additionally, the demand-driven IO analysis was used in many studies to forecast the impact of the US-China trade dispute. We can think of two main reasons. First, the IO analysis is relatively easy to use, apply and adjust, and the computation is fast. It involves relatively simple matrix operations, which can be executed on most desktop computers. Second, more countries are producing IO tables in recent years, and in particular, the recent availability of multi-country IO tables such as the World Input-Output Database (WIOD) has made it easy to compute the impact of a demand shock on the countries included in the database.

Jung (2017) assumed that the trade dispute will reduce both countries' mutual trade by 10% and computed the impact on the GDPs of China, the US, and Korea using a demand-driven analysis with WIOD. He estimated that Korea's GDP will decrease by 0.35%, with the proviso that the estimate depends on numerous unexpected factors. Kim and Kim (2018) also used a demand-driven IO analysis and the WIOT to forecast the impact of the US-China trade dispute on the Korean economy. They estimated the impacts on various aggregate variables and provided policy recommendations for Korea.

Abiad *et al*. (2018) also utilized the ADB MRIOT to forecast the impact of the

US-China trade dispute. The ADB MRIOT consists of the IO tables of 62 countries and 35 sectors, and in their study it was used to measure the impact on the GDP, exports and employment of developing ADB member countries as well as the US and developed European countries. They considered three scenarios: the status quo, 'the worse' scenario and 'the worst' scenario, also conducting a demand-driven IO analysis.

Xia *et al*. (2019) applied a demand-driven IO analysis to the 2013 edition of WIOD and forecasted the impact of the 2017 US-China trade dispute. The primary field of interest in their study was the energy sector, and they computed the impacts of the dispute in various scenarios on the GDP and energy consumption of not only the countries involved but also many of their trade partner countries.

Finally, a demand-driven IO analysis was also applied to the Korea-Japan trade dispute. Jeong *et al*. (2019) used the ADB MRIOT and computed the economic impact of the dispute on Southeast Asian countries using an indirect approach. They computed the contribution of Korea's export of electronic components, including semiconductors, to the GDPs of these countries, from which they concluded that the decrease in Korea's production of semiconductors due to the dispute could be detrimental to the Southeast Asian countries.

Jung *et al*. (2019) conducted the empirical study most pertinent to the motivation of this paper. They provided (i) the details and the expected consequences of Japan's export control of the three materials in July of 2019, (ii) the history of Japan's export of the three materials since their strengthening of export control and (iii) a reckoning of the aftermath of the dispute to Korea and Japan. For quantitative forecasts, they made two separate assumptions: (1) Korea's production of semiconductors will decrease by 10%; and (2) Japan's exports of chemical products, electronic equipment and machinery will decrease by 5%. Then they used a CGE model to predict the impacts on the Korean economy. They estimated that when Korea's semiconductor production decreases by 10%, Korea's GDP and total exports will decrease by 0.320~0.384% and 0.347~0.579%, respectively, depending on the monopolistic power of Korea's semiconductor supply. They also predicted that Korea's GDP and exports will decrease by 0.06% and 0.089%, respectively, as the result of the second assumption.

The supply-driven input-output analysis was devised by Ghosh (1958). He considered an economy in which firms' behaviors differ from those in Leontief's system. Clearly, both Leontief and Ghosh used the same input-output system, but Leontief assumed that the final demand is exogenous, the supply side is infinitely elastic, and the input coefficients are fixed or highly stable, whereas Ghosh assumed that value-added is exogenous and the distribution structure of the final products in terms of the composition of customers is fixed or highly stable. Two sets of assumptions, even with same tables, lead to two entirely different ways of analyzing the impacts of 'shocks' on endogenous variables, correspondingly referred to here as demand-driven and supply-driven IO analyses. Reyes and Mendoza (2013) compared the two types of analysis and provided a compact theoretical explanation of the difference and the relationship between them.

As described earlier, a supply-driven IO analysis can be applied when the production of a certain sector is affected due to an exogenous reason, in other words, when the gross output of a sector 'must' be reduced due to a reason unrelated to the final demand. While there can be a wide variety of causes, they can be sorted into three categories: (i) an exogenous shortage of labor such as a labor shortage due to a labor market mismatch and or a strike; (ii) an exogenous shortage of capital, that is, damage to the production capacity due to a natural disaster such as an earthquake or a flood, or non-natural causes such as accidents or a failed loan extension; and (iii) an exogenous shortage of intermediate inputs, especially when they cannot be easily replaced, caused by a natural disaster, e.g., a supply shortage of electricity due to an earthquake, or a non-natural accident, such as a reduction or stoppage of the supply of key materials, parts or components essential in a certain sector. Obviously, Japan's decision strictly to control the exports of the three materials essential for producing electronic displays and semiconductors is one of the most pertinent examples of the third category.

Davis and Salkin (1984) measured the impact of an exogenous decrease in the supply of water to the agricultural sector of the Kern County, California, US, on the value-added of various sectors and the aggregate economy of the county using both ordinary demand- and supply-driven IO analyses. The impact on the county's aggregate value-added computed from the supply-driven analysis was approximately 71% of that computed from the demand-driven analysis, and they concluded that the forward-linkage effect of the agricultural sector is weaker than the backward-linkage effect.

Chen and Rose (1986) studied the 'joint stability' of input and output coefficients theoretically and provided a short empirical work. As explained earlier, the demand-driven and the supply-driven IO analyses assume that input and output coefficients are fixed or highly stable, respectively. After the work of Ghosh (1958), many researchers studied if both sets of coefficients can be stable at the same time, in particular when the disturbance is not small. They showed that joint stability is theoretically possible, and provided an empirical example. They assumed that the supply of aluminum into Taiwan decreases by 50%, a major disturbance, assumed that output coefficients are fixed, and showed that the resulting changes in input coefficients are small at less than 1% in most sectors.

Groenewold *et al*. (1987) applied a supply-driven IO analysis to answer frequently asked questions in industrial and regional economics related to the 'contribution of a certain industry to the total employment in a region.' They addressed this issue by treating the industry in question as exogenous and applying a supply-driven IO analysis.

Roberts (1994) measured the economic impact of the quota on milk production on the UK economy using a modified IO analysis. She suggested that both backward and forward linkage effects be considered and showed that in the milk industry, the former type is more significant than the latter. Leung and Pooley (2002) estimated the economic impact of a 100% reduction in longline fishing on Hawaii's economy. They claimed that a demand-driven approach is not appropriate because the shock was not initiated by the demand side, and they applied a supply-driven IO analysis to estimate the impact. Fernández-Macho *et al*. (2008) used a supply-driven IO analysis to estimate the impact of the reduction in the total allowable catch of cod and hake on the economy of Galicia, Spain. Seung and Waters (2009) also used a supply-driven approach to estimate the backward and forward linkage effects of the fishery sector in Alaska. They classified the fishery sector into multiple subsectors and measured their backward and forward effects separately. They also conducted numerous policy simulations and estimated various economic impacts.

Kim (2015) applied a supply-driven IO analysis to the case of the 2010-2011 outbreak of foot-and-mouth (FAM) disease in Korea, one of the most serious incidents of FAM in the world. He computed the backward and forward linkage effects of the outbreak on individual sectors and on the national economy, and identified the sectors with the strongest backward and forward effects. He also showed that the estimated impact by a supply-driven analysis is greater than that by a demand-driven analysis.

Studies in this field agree that a supply-driven IO analysis is desired when the exogenous shock affects production, not the final demand, because the standard demand-driven IO analysis does not capture all economic impacts. Obviously, Japan's decision strictly to control the exports of three materials would directly affect production in the semiconductor and display sectors in Korea and not the final demands, which justifies the use of a supply-driven IO analysis. While the event fits the framework and satisfies the assumptions of the supply-driven IO type of analysis, empirical applications to the Korea-Japan trade dispute could not be found, and it is the goal of this paper to estimate the economic impacts in this manner. This paper follows the methodology adopted by Leung and Pooley (2002), Fernández-Macho *et al*. (2008), Seung and Waters (2009) and Kim (2015), all of which are based on Ghosh (1958).

III. Methodology

Let $\mathbf{A}^d$ be the $n \times n$ domestic input coefficient matrix of an economy, where n is the number of products/sectors. Also, let $\mathbf{x}$ and $\mathbf{y}^d$ be the $n \times 1$ vectors of the gross output and domestic final demand, respectively. The market clearing conditions for domestic products can be expressed as $\mathbf{x} = \mathbf{A}^d\mathbf{x} + \mathbf{y}^d$, where the terms on the right-hand side represent the intermediate and final demand for domestic products, respectively. The solution to the market clearing condition is $\mathbf{x} = (\mathbf{I} - \mathbf{A}^d)^{-1}\mathbf{y}^d$, or, equivalently,

$$(1) \qquad \Delta\mathbf{x} = (\mathbf{I} - \mathbf{A}^d)^{-1}\Delta\mathbf{y}^d .$$

The $n \times n$ matrix $(\mathbf{I} - \mathbf{A}^d)^{-1}$ is called the Leontief inverse matrix, and it measures the backward linkage effects. The (i, j) th element of $(\mathbf{I} - \mathbf{A}^d)^{-1}$ measures the change in the gross output of the i th sector when the domestic final demand for the j th product changes by one unit. Thus, the j th column of $(\mathbf{I} - \mathbf{A}^d)^{-1}$ gives the impacts of the domestic final demand for the j th product on the gross output of individual sectors.

Suppose an exogenous shock affects the gross outputs of particular sectors, and let n_1 be the number of affected sectors. Assume, without a loss of generality, that the affected sectors are the first n_1 sectors. As mentioned in the previous section, we can mechanically apply a demand-driven IO analysis, that is, we can apply (1). This implies we assume, incorrectly, that the exogenous shock affected the final demands of the n_1 sectors and that the magnitude of the shock is identical to the reductions in the gross outputs. In this case, the impacts of the shock on individual industries are represented by the first n_1 columns of $(\mathbf{I}-\mathbf{A}^d)^{-1}$, that is an $n \times n_1$ matrix.

We now move to the supply-driven IO analysis, and we will derive the procedure for the backward linkage effect first. Let n_2 be the number of unaffected sectors; i.e., $n_2 = n - n_1$. The market clearing condition for domestic products, $\mathbf{x} = \mathbf{A}^d\mathbf{x} + \mathbf{y}^d$, can be partitioned into the affected and the unaffected sectors, as follows:

(2) $$\begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{11}^d & \mathbf{A}_{12}^d \\ \mathbf{A}_{21}^d & \mathbf{A}_{22}^d \end{bmatrix} \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{bmatrix} + \begin{bmatrix} \mathbf{y}_1^d \\ \mathbf{y}_2^d \end{bmatrix}.$$

Because the shock affects the first n_1 sectors, their gross outputs are not determined by their final demands. Accordingly, they are no longer endogenous. Hence, the first equation in (2) does not hold, and we only consider the second; i.e., $\mathbf{x}_2 = \mathbf{A}_{21}^d\mathbf{x}_1 + \mathbf{A}_{22}^d\mathbf{x}_2 + \mathbf{y}_2^d$. This is the market clearing condition for the n_2 unaffected sectors in which the $\mathbf{x}_2$ variables are endogenous variables which depend on the exogenous variables $\mathbf{x}_1$ and $\mathbf{y}_2^d$. We solve the equation for $\mathbf{x}_2$, and we get $\mathbf{x}_2 = (\mathbf{I}-\mathbf{A}_{22}^d)^{-1}(\mathbf{A}_{21}^d\mathbf{x}_1 + \mathbf{y}_2^d)$, or, equivalently,

(3) $$\Delta\mathbf{x}_2 = (\mathbf{I}-\mathbf{A}_{22}^d)^{-1}\mathbf{A}_{21}^d\Delta\mathbf{x}_1$$

assuming that $\Delta\mathbf{y}_2^d = \mathbf{0}$. The $n_2 \times n_1$ matrix $(\mathbf{I}-\mathbf{A}_{22}^d)^{-1}\mathbf{A}_{21}^d$ measures the backward linkage effects of $\Delta\mathbf{x}_1$ on $\mathbf{x}_2$.

Let $\mathbf{B}^d$ be the domestic output coefficient matrix; that is, $\mathbf{B}^d = [b_{ij}^d] = [x_{ij}^d / x_i]$. Here, $b_{ij}^d = x_{ij}^d / x_i$ is the share of the i th product out of the total gross output, which is used as the intermediate input in the j th sector. It can be interpreted as the direct forward linkage effect of the i th product on the j th sector, and is referred to as the 'output coefficient,' compared to the 'input coefficient' $a_{ij}^d = x_{ij}^d / x_j$. Output coefficients are also called 'allocation,' 'supply' or 'sales' coefficients.

The decomposition of the total cost can be expressed as $\mathbf{x}' = \mathbf{w}^d + \mathbf{w}^m + \mathbf{v}$, where the left-hand side refers to total cost or total input while the terms on the right-hand side refer to the domestic intermediate input, the imported intermediate input and the value-added. We can show that $\mathbf{w}^d = \mathbf{x}'\mathbf{B}^d$, and the above equation becomes

(4) $$\mathbf{x}' = \mathbf{x}'\mathbf{B}^d + \mathbf{w}^m + \mathbf{v}.$$

Upon solving (4) for $\mathbf{x}$, we get $\mathbf{x}' = (\mathbf{w}^m + \mathbf{v})(\mathbf{I}-\mathbf{B}^d)^{-1}$, or equivalently,

(5) $$\Delta\mathbf{x}' = \Delta\mathbf{v}(\mathbf{I}-\mathbf{B}^d)^{-1}$$

assuming that $\Delta\mathbf{w}^m = \mathbf{0}$. This result can be found in Ghosh (1958, p.61), Miller and Blair (2009, p.547), and in the Bank of Korea (2014, p.138). This formula gives the increases in the gross outputs of individual sectors when the value-added vector changes by $\Delta\mathbf{v}$. The matrix $(\mathbf{I}-\mathbf{B}^d)^{-1}$ is called the 'output inverse matrix' or the 'Ghosh inverse matrix,' and it plays a role similar to that played by $(\mathbf{I}-\mathbf{A}^d)^{-1}$ in the demand-driven IO analysis.

Equation (4) can be partitioned for the affected and unaffected sectors, as follows:

$$(6) \qquad \begin{bmatrix}\mathbf{x}_1' & \mathbf{x}_2'\end{bmatrix} = \begin{bmatrix}\mathbf{x}_1' & \mathbf{x}_2'\end{bmatrix}\begin{bmatrix}\mathbf{B}_{11}^d & \mathbf{B}_{12}^d \\ \mathbf{B}_{21}^d & \mathbf{B}_{22}^d\end{bmatrix} + \begin{bmatrix}\mathbf{w}_1^{m}{}' & \mathbf{w}_2^{m}{}'\end{bmatrix} + \begin{bmatrix}\mathbf{v}_1' & \mathbf{v}_2'\end{bmatrix}.$$

Because the shock affects the first n_1 sectors, the first equation in (6) does not hold, and we only consider the second, $\mathbf{x}_2' = \mathbf{x}_1'\mathbf{B}_{12}^d + \mathbf{x}_2'\mathbf{B}_{22}^d + \mathbf{w}_2^{m}{}' + \mathbf{v}_2'$. In this equation, the $\mathbf{x}_2$ variables are endogenous variables which depend on the exogenous variables $\mathbf{x}_1$ and $\mathbf{v}_2$. We solve the equation for $\mathbf{x}_2$, and we get $\mathbf{x}_2' = (\mathbf{x}_1'\mathbf{B}_{12}^d + \mathbf{w}_2^{m}{}' + \mathbf{v}_2')(\mathbf{I}-\mathbf{B}_{22}^d)^{-1}$, or equivalently,

$$(7) \qquad \Delta\mathbf{x}_2 = [\mathbf{B}_{12}^d(\mathbf{I}-\mathbf{B}_{22}^d)^{-1}]'\Delta\mathbf{x}_1$$

assuming that $\Delta\mathbf{w}_2^m = \Delta\mathbf{v}_2 = \mathbf{0}$. The $n_2 \times n_1$ matrix $[\mathbf{B}_{12}^d(\mathbf{I}-\mathbf{B}_{22}^d)^{-1}]'$ measures the forward linkage effects of $\Delta\mathbf{x}_1$ on $\mathbf{x}_2$.

We have one more effect of the exogenous shock, which is the direct impact of the shock on $\mathbf{x}_1$, i.e., $\Delta\mathbf{x}_1$. It is the initial component of the shock from which backward and forward linkage effects proceed in the opposite directions, but it needs to be counted only once. In this paper, we will simply regard it as a component of the backward linkage effect. For this reason, we will stack an identity matrix of size $n_1 \times n_1$ on top of $(\mathbf{I}-\mathbf{A}_{22}^d)^{-1}\mathbf{A}_{21}^d$ and a zero matrix of size $n_1 \times n_1$ on top of $[\mathbf{B}_{12}^d(\mathbf{I}-\mathbf{B}_{22}^d)^{-1}]'$ for the sake of notational and computational convenience.

In sum, we have three $n \times n_1$ matrices of multipliers which measure the impacts of $\Delta\mathbf{x}_1$ on $\mathbf{x}_2$; (i) impacts computed using a standard demand-driven IO analysis given by the first n_1 columns of $(\mathbf{I}-\mathbf{A}^d)^{-1}$, (ii) direct and backward linkage effects from a supply-driven IO analysis computed by $(\mathbf{I}-\mathbf{A}_{22}^d)^{-1}\mathbf{A}_{21}^d$, and (iii) forward linkage effects computed by $[\mathbf{B}_{12}^d(\mathbf{I}-\mathbf{B}_{22}^d)^{-1}]'$. After these effects on gross outputs are computed, the impacts on value-added and employment can be computed by multiplying the value-added and employment coefficients.

IV. Data

As mentioned in section 1, we will apply the above method to the Korea-Japan trade dispute to measure its impact on the Korean economy. For this purpose, we used the IO tables of Korea in 2018, the most recent IO tables of Korea. Korea's 2018 IO tables are available at four levels of sector classification, with 33, 83, 165 and 381 sectors, of which the tables with 83 sectors were used in this paper because

TABLE 1—24-SECTOR CLASSIFICATION

No.	Sector	83-Sector number	Remark
1	Semiconductor and related devices	31	Exogenous sectors
2	Electronic signal equipment	32	
3	Agricultural, forest, and fishery goods	1~5	
4	Mined and quarried goods	6~7	
5	Food, beverages and tobacco	8~10	
6	Textile and leather products	11~12	
7	Wood and paper products	13~15	
8	Petroleum and coal products	16	
9	Chemical products	17~24	
10	Non-metallic mineral products	25~26	
11	Basic metal products	27~29	
12	Fabricated metal products	30	
13	Electric and Electronic products	33~37	Excluding semiconductor and display
14	Machinery and equipment	38~39	
15	Transport equipment	40~42	
16	Other manufactured products	43~44	
17	Utility	45~49	Electricity, gas, steam, hot water, water, sewage, waste treatment, etc.
18	Construction	50~51	
19	Wholesale and retail	52	
20	Transportation, storage and postal	53~57	
21	Food service and accommodation	58	
22	Business Service	59~74	Communication, broadcasting, IT, publishing, financial, real estate, R&D, professional service, etc.
23	Public administration and defense	75	
24	Social and personal services	76~83	Education, medical, social care, cultural, tour-related, sports, repair and other personal services

they are the tables with the smallest number of sectors in which the semiconductor and electronic display sectors are separately represented.

In this paper, the 83-sector classification was rearranged into a 24-sector classification, in which the semiconductor and electronic display sectors were located in the beginning of the classification, as shown in Table 1.[1] Gross output, value-added, exports and employment of these 24 sectors in 2018 are given in Table 2. Note that in 2018, the affected sectors, 1 and 2, account for approximately 5% of the total gross output and value-added in Korea, whereas they account for more than 20% of total exports.

[1]That is, $n_1 = 2$, $n_2 = 22$ and $n = 24$.

TABLE 2—GROSS OUTPUT, VALUE-ADDED, EXPORTS AND EMPLOYMENT OF 24 SECTORS IN 2018

(Unit: trillion won, thousand persons)

No.	Sector	Gross output	Value-added	Export	Employment
1	Semiconductor and related devices	134.4	78.0	122.8	88
2	Electronic signal equipment	64.3	23.8	40.6	57
3	Agricultural, forest, and fishery goods	62.8	33.2	0.8	1,222
4	Mined and quarried goods	4.5	2.2	0.1	18
5	Food, beverages and tobacco	132.8	33.7	8.2	337
6	Textile and leather products	72.6	14.6	26.2	269
7	Wood and paper products	47.0	15.2	4.2	173
8	Petroleum and coal products	144.5	36.4	55.8	11
9	Chemical products	286.3	76.8	103.1	450
10	Non-metallic mineral products	44.0	13.4	4.6	111
11	Basic metal products	145.6	27.6	45.0	131
12	Fabricated metal products	100.5	35.9	13.0	347
13	Electric and Electronic products	235.8	68.5	88.7	498
14	Machinery and equipment	146.2	43.3	57.8	414
15	Transport equipment	225.7	47.8	96.8	456
16	Other manufactured products	87.6	37.3	4.8	608
17	Utility	122.7	38.4	0.5	205
18	Construction	271.8	118.8	0.2	1,804
19	Wholesale and retail	280.0	150.6	31.5	3,428
20	Transportation, storage and postal	149.7	53.4	33.2	1,398
21	Food service and accommodation	164.0	55.5	9.9	1,945
22	Business Service	874.8	532.2	42.0	4,529
23	Public administration and defense	151.4	114.9	0.0	1,203
24	Social and personal services	387.3	221.8	2.1	4,795
	Total	4,336.6	1,873.4	792.1	24,495

Source: Bank of Korea.

V. Results

In July of 2019, Japan announced the decision to tighten the export control of three materials: fluorinated polyimide, photoresist and hydrogen fluoride. Fluorinated polyimide is an essential material in the manufacturing of LCD and OLED display panels, which, in turn, are essential parts in the manufacturing of smartphones and televisions, which account for a major portion of the Korean economy. Photoresist and hydrogen fluoride are essential materials in the manufacturing of memory semiconductors, which not only constitute a substantial portion of the Korean economy but also are essential parts in the manufacturing of various ICT products and electronic equipment.

Table 3 confirms that Japan's shares are substantial in Korea's import of these three materials as well as in the world markets, while Korea's shares in Japan's exports are much smaller. Furthermore, the affected sectors represent a major portion of the Korean economy, and three additional sectors, in this case other electronic

TABLE 3—MARKET SITUATIONS OF THE THREE MATERIALS

Product	Japan's share in the world market	Japan's share in Korea's import	Korea's share in Japan's export
Fluorinated polyimide	Around 90%	93.7%	22.5%
Photoresist	Around 90%	91.9%	11.7%
Hydrogen fluoride	Around 70%	43.9%	85.9%

Source: KITA, July 1, 3 and 10, 2019.

TABLE 4—AFFECTED SECTORS IN THE KOREAN ECONOMY IN 2018

(Unit: trillion won, thousand persons)

83-sector number	Sector	Gross Output	Value-added	Export	Employment
31	Semiconductor and related devices	134.4	78.0	122.8	87.8
32	Electronic signal equipment	64.3	23.8	40.6	57.1
33	Other electronic components	23.1	7.2	9.0	66.2
34	Computer and peripheral equipment	13.5	4.9	9.7	11.4
35	Telecomm., video, and audio equip.	56.6	14.1	27.0	59.3
	Total	291.8	128.0	209.1	281.9
	(Shares in all sectors)	(6.7%)	(6.8%)	(26.4%)	(1.2%)
	All sectors	4,336.6	1,873.4	792.1	24,495.4

Source: Bank of Korea.

components; computer and peripheral equipment; and telecommunication, video, and audio equipment, would be severely affected because semiconductors and display panels are indispensable in these sectors. These five sectors accounted for 26.4% of Korea's total exports, 6.7~6.8% of the total gross output and GDP, and 1.2% of total employment in 2018. See Table 4.

In order to apply the supply-driven IO analysis, we need to estimate, or at least make a rigorous assumption of, the magnitude of the direct impact of the shock on the gross output of the affected sectors, i.e., $\Delta\mathbf{x}_1$ in equations (3) and (7). In other words, we need to estimate the changes in the production levels of the affected sectors.

This estimation is straightforward in some situations. In the work by Kim (2015), for example, the official numbers of culled animals infected by foot-and-mouth disease were published, from which the production decreases in the corresponding sectors could be estimated almost exactly. There are other situations in which a precise estimation of the change in production in the affected sector is straightforward. Production quotas are a typical example.

Unfortunately, however, this is complicated in some situations, specifically when the relationship between the shock and the direct impact is uncertain, as in the case of Japan's export control. If the three materials are perfectly irreplaceable and if Japan enforces the embargo strictly, the production levels of Korea's semiconductor and display sectors will then decrease by 91.9% and 93.7%, representing Japan's shares in Korea's imports of fluorinated polyimide and photoresist, respectively (Table 3).

However, these figures highly overestimate the actual impact even if the above assumptions are true because it is possible for the firms in these sectors to have accumulated sufficient inventories of the materials and prepare alternative materials while the stockpiles last. In this sense, the above figures could be regarded as the maximum level of the direct impact.

Hong (2020) computed the actual imports of the three materials before and after the shock using trade statistics, which are given in Table 5. That study found that (i) the import of fluorinated polyimide from Japan rather increased and that Japan's share did not change much after the control, suggesting that Japan did not enforce the decision strictly. In addition, a Korean company succeeded in localizing the material. It was also found that (ii) the import of photoresist from Japan dropped significantly directly after Japan's decision, but it recovered quickly to the level before the shock. Japan's share decreased by 6.1%p from 92.8% to 86.7%, but was replaced by a detour import through Belgium. This was possible because Japan did not restrict the export of the material to Korea through a third country. In other words, the import of photoresist from Japan did not change much. Finally, it was found that (iii) the import of hydrogen fluoride from Japan dropped severely after Japan's decision. A major portion of the import of this product was replaced by supplies from domestic firms and from Chinese and Taiwanese firms.

It can be concluded from Table 5 that the impact of Japan's export control on production in the semiconductor and display sectors was insignificant. In fact, Hong (2020) concluded that the impact was limited. This conclusion, however, underestimates the impact on production in the affected sectors for many reasons. First, the data in Table 5 consider only the short-term impact and may underestimate the impact if the production levels of the affected sectors were increasing. Second, the data in Table 5 do not take the inventory of the materials into consideration and may underestimate the impact if the inventory levels of the materials were exhausted. Third, Japan's decision has not changed since the outset of the export control, and it is possible that Japan will enforce the decision more strictly.

TABLE 5—IMPORTS OF THE THREE MATERIALS SINCE JAPAN'S EXPORT CONTROL

(Unit: million US dollar)

		Before control 2018 12 months	After control July 2019~May 2020 11 months
Fluorinated polyimide	Total	24	32
	From Japan	22	30
	(share)	(92.7%)	(92.9%)
Photoresist	Total	286	317
	From Japan	265	275
	(share)	(92.8%)	(86.7%)
Hydrogen fluoride	Total	147	70
	From Japan	63	7
	(share)	(42.4%)	(9.5%)

Note: Japan's shares in this table are slightly different from those in Table 3.

Source: Hong (2020).

In order to estimate the direct impact more rigorously, the actual production and the exports of the affected sectors were also studied. First, the manufacturing production index of the semiconductor sector since 2017 is presented in Figure 1.[2] Note that the production levels of semiconductors since July of 2019 were all larger than those in July of 2019. This can be regarded as an evidence that Japan's decision did not have an impact on semiconductor production in Korea. However, the fluctuation in early 2020 may have stemmed from the unstable supply of the raw material, and the growth trend since early 2020 could be seen as slightly lower compared to the trend in 2019.

Exports of semiconductors and displays and their year-on-year growth rates are given in Figures 2 and 3, respectively. As shown in Figure 2, exports of semiconductors and displays in 2019 were lower than those in 2018, resulting in negative growth rates in 2019, as can be observed in Figure 3. As shown in Figure 3, however, the growth rates of the exports of the two products (thick solid and broken curves) were lower than that of total exports (thin solid curve), even after the base effect was exhausted. Moreover, the gap is roughly 10%. If we interpret the total exports as an indicator of the global economic trend, the gap can then be regarded as an impact that cannot be explained by economic trends worldwide. It is possible that Japan's decision was one of the causes despite the fact that it is not easy to determine the source of the gap quantitatively due to the insufficient number of observations.

Considering the above information, we assume that the direct impact of Japan's export control on the affected sectors is a 10% decrease in production; that is, the gross outputs of the semiconductor and display sectors decrease by 10% each as a result of Japan's export control. Subsequently, we compute its impact on other sectors and on the national economy using standard demand-driven and supply-driven IO analyses. Thus far, Jung *et al*. (2019) present the only quantitative study of this issue, also assuming that Korea's semiconductor production will decrease by 10%.

It should be noted that an IO analysis is linear and additive and that the results can therefore be used for various scenarios. When the production of the affected

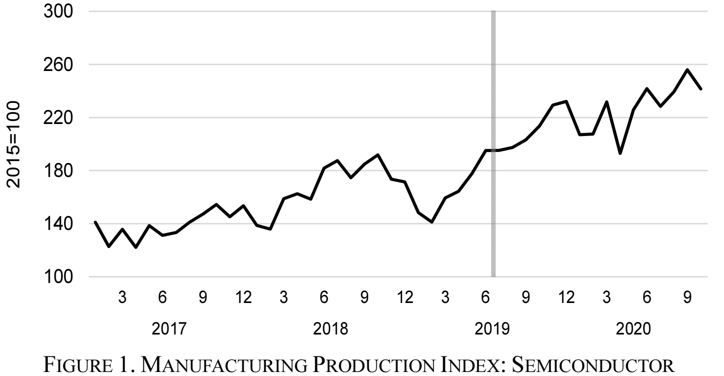

FIGURE 1. MANUFACTURING PRODUCTION INDEX: SEMICONDUCTOR

Source: Statistics Korea.

[2]The manufacturing production index of the display sector is not published.

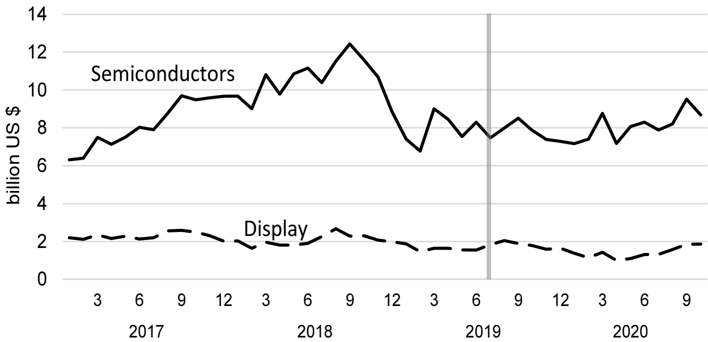

FIGURE 2. MONTHLY EXPORTS OF SEMICONDUCTORS AND DISPLAYS (AMOUNTS)

Source: Korea International Trade Association.

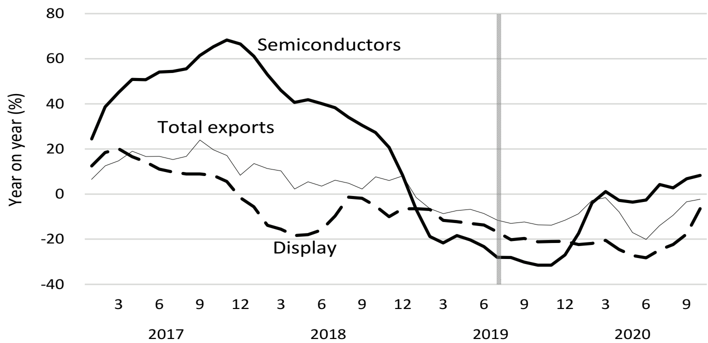

FIGURE 3. MONTHLY EXPORTS OF SEMICONDUCTORS AND DISPLAYS (GROWTH RATES)

Source: Korea International Trade Association.

sectors decreases by 15%, for example, the impact on other sectors and on the national economy can easily be obtained simply by multiplying the results obtained later in this paper by 1.5.

Backward and forward linkage coefficients are given in Table 6. As mentioned earlier, the direct impacts of the shock, a 2×2 identity matrix, are included in the backward linkage effect coefficient vectors. According to Table 6, the overall backward linkage coefficients for semiconductors and displays were 1.2426 and 1.4505, respectively. This implies that the corresponding backward impacts of one-unit exogenous shocks in these two sectors on the upstream sectors which provide raw materials to these sectors are 0.2426 and 0.4505 units.

Table 6 shows that the business service sector is most severely affected by the shocks in both the semiconductor and display sectors, signifying that both sectors heavily depend on high-tech professional services. Chemical products, other electric and electronic products, and the utility, wholesale and trade and transportation sectors also receive significant backward linkage impacts from the shocks in the semiconductor and display sectors.

The overall forward linkage coefficients were estimated at 0.0551 and 0.3420, respectively, implying that the forward impacts of one-unit exogenous shocks in these two sectors on the downstream sectors which use semiconductors and displays

TABLE 6—BACKWARD AND FORWARD LINKAGE COEFFICIENTS ON GROSS OUTPUT ACCORDING TO THE SUPPLY-DRIVEN IO ANALYSIS

No.	Sector	Backward linkage		Forward linkage	
		Semi-conductor	Display	Semi-conductor	Display
1	Semiconductor and related devices	1.0000	0.0000	0.0000	0.0000
2	Electronic signal equipment	0.0000	1.0000	0.0000	0.0000
3	Agricultural, forest, and fishery goods	0.0012	0.0019	0.0002	0.0007
4	Mined and quarried goods	0.0003	0.0040	0.0000	0.0001
5	Food, beverages and tobacco	0.0025	0.0040	0.0004	0.0020
6	Textile and leather products	0.0018	0.0031	0.0003	0.0015
7	Wood and paper products	0.0026	0.0049	0.0002	0.0009
8	Petroleum and coal products	0.0060	0.0143	0.0002	0.0011
9	Chemical products	0.0283	0.0624	0.0010	0.0043
10	Non-metallic mineral products	0.0013	0.0531	0.0002	0.0010
11	Basic metal products	0.0226	0.0177	0.0005	0.0024
12	Fabricated metal products	0.0051	0.0085	0.0007	0.0035
13	Electric and Electronic products	0.0303	0.0408	0.0212	0.1905
14	Machinery and equipment	0.0098	0.0052	0.0045	0.0267
15	Transport equipment	0.0015	0.0034	0.0031	0.0261
16	Other manufactured products	0.0209	0.0225	0.0019	0.0099
17	Utility	0.0183	0.0457	0.0006	0.0033
18	Construction	0.0012	0.0017	0.0021	0.0141
19	Wholesale and retail	0.0208	0.0314	0.0013	0.0048
20	Transportation, storage and postal	0.0133	0.0345	0.0007	0.0042
21	Food service and accommodation	0.0059	0.0094	0.0007	0.0032
22	Business Service	0.0454	0.0763	0.0117	0.0260
23	Public administration and defense	0.0000	0.0000	0.0004	0.0016
24	Social and personal services	0.0035	0.0055	0.0034	0.0138
	Total	1.2426	1.4505	0.0551	0.3420

Source: Author's computations.

as raw materials are 0.0551 and 0.3420 units, respectively. Small forward linkage coefficients of semiconductors are rooted in the peculiar output structure in this case. Out of a total production amount of about 134 trillion won, only 7.4%, or close to 10 trillion won, is used as raw materials in the country, while most of the production, 123 trillion won, is exported. The share of intermediate demand as a percent of gross output is 36.5% for displays, and this share is greater for other manufactured products. Kim (2015) reports that the overall forward linkage coefficients for dairy cattle, beef cattle and swine are 1.318, 1.554 and 1.787, respectively, which are much greater than those for semiconductor and display panels.

The sector of other electric and electronic products is most severely affected by the shocks in both sectors, which is intuitive given that semiconductors and display panels are essential components in those sectors. The results of this paper also imply that machinery, transport equipment and construction are other important downstream

TABLE 7—COEFFICIENTS OF GROSS OUTPUT FROM SUPPLY-DRIVEN AND DEMAND-DRIVEN ANALYSES

No.	Sector	Supply-driven		Demand-driven	
		Semi-conductor	Display	Semi-conductor	Display
1	Semiconductor and related devices	1.0000	0.0000	1.0421	0.0069
2	Electronic signal equipment	0.0000	1.0000	0.0019	1.2002
3	Agricultural, forest, and fishery goods	0.0013	0.0026	00012	0.0023
4	Mined and quarried goods	0.0004	0.0042	0.0004	0.0049
5	Food, beverages and tobacco	0.0029	0.0060	0.0026	0.0048
6	Textile and leather products	0.0022	0.0046	0.0019	0.0038
7	Wood and paper products	0.0028	0.0058	0.0027	0.0059
8	Petroleum and coal products	0.0062	0.0154	0.0062	0.0172
9	Chemical products	0.0293	0.0667	0.0296	0.0751
10	Non-metallic mineral products	0.0015	0.0541	0.0014	0.0638
11	Basic metal products	0.0231	0.0201	0.0236	0.0214
12	Fabricated metal products	0.0058	0.0120	0.0053	0.0103
13	Electric and Electronic products	0.0514	0.2313	0.0316	0.0491
14	Machinery and equipment	0.0143	0.0319	0.0102	0.0063
15	Transport equipment	0.0047	0.0295	0.0016	0.0041
16	Other manufactured products	0.0228	0.0325	0.0219	0.0272
17	Utility	0.0189	0.0490	0.0192	0.0550
18	Construction	0.0033	0.0158	0.0012	0.0020
19	Wholesale and retail	0.0220	0.0362	0.0217	0.0379
20	Transportation, storage and postal	0.0139	0.0387	0.0139	0.0415
21	Food service and accommodation	0.0066	0.0126	0.0062	0.0113
22	Business Service	0.0570	0.1023	0.0474	0.0919
23	Public administration and defense	0.0004	0.0017	0.0000	0.0001
24	Social and personal services	0.0069	0.0194	0.0037	0.0067
	Total	1.2977	1.7925	1.2977	1.7495

Source: Author's computations.

sectors.

The first two columns of Table 7 are the sum of the backward and forward linkage coefficients, that is, the total coefficients from the supply-driven IO analysis, including direct impacts. The total supply-driven coefficients are 1.2977 and 1.7925. Table 7 also gives the demand-driven coefficients. This result shows that both sets of coefficients are very similar to each other. However, this result is not general, instead being a coincidence. In the work of Kim (2015), the supply-driven coefficients of the above-mentioned products (3.247, 3.724 and 4.110) were significantly higher than the demand-driven coefficients (1.942, 2.174 and 2.319).

The impacts of Japan's export control scheme as represented by the reduction in gross output are computed in Table 8. This is obtained by multiplying the direct impacts, 13.4 and 6.4 trillion won, by the coefficients in Table 7. The total impact is estimated to be 29.0 trillion won, of which the contributions of the shocks in semiconductor and display sectors are 17.4 (60.2%) and 11.5 (39.8%) trillion won,

TABLE 8—IMPACTS OF THE TRADE DISPUTE ON GROSS OUTPUT ACCORDING TO THE SUPPLY-DRIVEN INPUT-OUTPUT ANALYSIS

(Unit: billion Korean won)

No.	Sector	Semiconductor		Display		Total
		Backward	Forward	Backward	Forward	
1	Semiconductor and related devices	13,442.4	0.0	0.0	0.0	13,442.4
2	Electronic signal equipment	0.0	0.0	6,433.9	0.0	6,433.9
	Total direct impact	13,442.4	0.0	6,433.9	0.0	19,876.3
	(share)	(80.5%)	(0.0%)	(68.9%)	(0.0%)	(68.6%)
3	Agricultural, forest, and fishery goods	16.0	2.1	12.2	4.8	35.1
4	Mined and quarried goods	4.4	0.3	26.0	0.7	31.6
5	Food, beverages and tobacco	33.4	5.9	25.6	12.8	77.7
6	Textile and leather products	24.8	4.2	20.1	9.6	58.7
7	Wood and paper products	34.8	2.4	31.3	6.1	74.6
8	Petroleum and coal products	80.1	2.8	92.1	7.1	182.1
9	Chemical products	380.8	12.8	401.6	27.8	823.0
10	Non-metallic mineral products	17.3	2.6	341.7	6.3	367.9
11	Basic metal products	303.7	6.8	113.8	15.4	439.7
12	Fabricated metal products	68.8	9.4	54.9	22.6	155.6
13	Electric and Electronic products	406.8	284.6	262.4	1,225.9	2,179.6
14	Machinery and equipment	131.8	60.3	33.5	171.9	397.4
15	Transport equipment	20.8	42.2	21.9	168.0	253.0
16	Other manufactured products	281.4	25.4	145.0	63.9	515.7
17	Utility	246.2	8.2	294.3	21.0	569.8
18	Construction	15.7	28.7	10.8	91.0	146.3
19	Wholesale and retail	279.3	16.9	202.3	30.8	529.3
20	Transportation	178.2	9.3	221.7	27.2	436.4
21	Food service and accommodation	79.6	9.3	60.6	20.5	170.0
22	FIRES	609.8	156.8	490.9	167.0	1,424.4
23	Public administration and defense	0.4	4.8	0.3	10.5	16.0
24	Social and personal services	47.2	45.5	35.6	89.1	217.4
	Total indirect impact	3,261.3	741.1	2,898.6	2,200.2	9,101.2
	(share)	(19.5%)	(100.0%)	(31.1%)	(100.0%)	(31.4%)
	Total	16,703.7	741.1	9,332.5	2,200.2	28,977.5
		17,444.8 (60.2%)		11,532.6 (39.8%)		

Source: Author's computations.

respectively. The total impact consists of the direct impact (19.9 trillion won, 68.6%), the backward linkage effect (6.2 trillion won, 21.2%) and the forward linkage effect (2.9 trillion won, 10.2%). Electric and electronic products and the business services sectors are the sectors most severely damaged by the dispute.

The impacts of Japan's export control on Korea's GDP are given in Table 9. The total impact is estimated to be 13.6 trillion won. This consists of the contributions of the shock to the semiconductor sector (9.3 trillion won, 68.9%) and to the display sector (4.2 trillion won, 31.1%). The total impact consists of the direct impact (10.2 trillion won, 75.1%), the backward linkage effect (2.3 trillion won, 17.3%) and the

TABLE 9—IMPACTS OF THE TRADE DISPUTE ON VALUE-ADDED ACCORDING TO A SUPPLY-DRIVEN INPUT-OUTPUT ANALYSIS

(Unit: billion Korean won)

No.	Sector	Semiconductor		Display		Total
		Backward	Forward	Backward	Forward	
1	Semiconductor and related devices	7,800.8	0.0	0.0	0.0	7,800.8
2	Electronic signal equipment	0.0	0.0	2,377.8	0.0	2,377.8
	Total direct impact	7,800.8	0.0	2,377.8	0.0	10,178.6
	(share)	86.2%	0.0%	68.5%	0.0%	75.1%
3	Agricultural, forest, and fishery goods	8.5	1.1	6.4	2.5	18.5
4	Mined and quarried goods	2.1	0.2	12.4	0.4	15.1
5	Food, beverages and tobacco	8.5	1.5	6.5	3.3	19.7
6	Textile and leather products	5.0	0.8	4.0	1.9	11.8
7	Wood and paper products	11.3	0.8	10.1	2.0	24.2
8	Petroleum and coal products	20.2	0.7	23.2	1.8	45.9
9	Chemical products	102.2	3.4	107.8	7.5	220.9
10	Non-metallic mineral products	5.3	0.8	104.0	1.9	111.9
11	Basic metal products	57.6	1.3	21.6	2.9	83.4
12	Fabricated metal products	24.6	3.3	19.6	8.1	55.6
13	Electric and Electronic products	118.1	82.6	76.2	356.0	632.9
14	Machinery and equipment	39.0	17.9	9.9	50.9	117.7
15	Transport equipment	4.4	8.9	4.6	35.6	53.6
16	Other manufactured products	119.9	10.8	61.8	27.2	219.7
17	Utility	77.1	2.6	92.2	6.6	178.4
18	Construction	6.9	12.6	4.7	39.8	63.9
19	Wholesale and retail	150.2	9.1	108.8	16.5	284.7
20	Transportation	63.6	3.3	79.1	9.7	155.8
21	Food service and accommodation	26.9	3.2	20.5	6.9	57.5
22	FIRES	371.0	95.4	298.6	101.6	866.6
23	Public administration and defense	0.3	3.7	0.2	8.0	12.1
24	Social and personal services	27.0	26.0	20.4	51.0	124.5
	Total indirect impact	1,249.7	289.9	1,092.8	742.1	3,374.5
	(share)	13.8%	100.0%	31.5%	100.0%	24.9%
	Total	9,050.5	289.9	3,470.6	742.1	13,553.1
		9,340.4 (68.9%)		4,212.7 (31.1%)		

Source: Author's computations.

forward linkage effect (1.0 trillion won, 7.6%). Electric and electronic products and business services sectors are the sectors most severely damaged by the dispute, also in terms of GDP.

Employment effects were also computed. The total reduction in employment was estimated to be 53,659 persons, with the contributions of the shocks on the semiconductor and display sectors being 27,290 (50.9%) and 26,369 (49.1%) persons, respectively. The total impact consists of the direct impact (14, 494 persons, 27.0%), the backward linkage effect (28,202 persons, 52.6%) and the forward linkage effect (10,964 persons, 20.4%). The patterns of the impacts on employment differ considerably from those on the gross output and value-added due to the difference in the average labor productivity levels among the sectors.

We can compare our results with those of Jung *et al*. (2019). We observed that the impacts of the Korea-Japan trade dispute as computed by demand-driven and supply-driven IO analyses are nearly identical and that when the gross output of the semiconductor sector decreases by 10%, Korea's GDP is expected to decrease by 9.3~9.4 trillion won, which is 0.5% of the aggregate GDP. This is 30~67% higher than the estimate by Jung *et al*. (0.320~0.384%).

Not only it is difficult to trace the cause of the difference rigorously, but we cannot directly compare the accuracy or forecasting power of these results. There are two conceivable causes of the difference, however. First, an IO analysis, unlike other methodologies, takes the inter-relationships among sectors into account explicitly. Hence, an underestimation of the impacts is likely if inter-industry relationships are not considered. Second, on the other hand, the results of an IO analysis can be interpreted as 'instantaneous' magnitudes of the sectors' responses to shocks. Accordingly, this method tends to overestimate the impact. This is similar to the slope of the tangent line of a concave increasing function, as an IO analysis assumes a Leontief production function, i.e., fixed proportions among production factors, but in reality, adjustments in firms' behaviors take place such that the effects of shocks are mitigated over time.

VI. Conclusion

In this paper, we estimated the impact of the Korea-Japan trade dispute using a supply-driven input-output analysis. The Korea-Japan trade dispute, unlike typical trade conflicts which proceed into intensifying trade policy tools to affect the opposing country's exports, began with Japan's export control of three materials which are indispensable for the production of semiconductors and display panels, two key products in the Korean economy recently. Japan's action, when effective, would inevitably result in a large-scale cutback in production in Korea and thus in severe damage to Korea's GDP. Unlike typical trade conflicts, again, the shock is the supply-side version because the decrease in production was caused by a decrease in the supply of an intermediate input, which, in turn, was caused by an exogenous non-economic factor.

This makes the standard demand-driven IO analysis invalid, and a supply-driven IO analysis was adopted in this paper in order to estimate the impact of the Korea-Japan trade dispute. The supply-driven IO analysis was initially devised by Ghosh (1958) and later modified to incorporate supply-side shocks on gross output.

The results of this paper show that when the gross outputs of the semiconductor and display panel sectors decrease by 10% each, Korea's aggregate gross output will decrease by 0.67% (29.0 trillion won), the aggregate GDP will decrease by 0.72% (13.6 trillion won) and employment will decrease by 0.22% (53,659 persons). When the gross output of only the semiconductor sector decreases by 10%, the decrease in the aggregate GDP was estimated to be 0.50% (9.3~9.4 trillion won). This is 30~67% higher than the estimate by Jung *et al*. (0.320~0.384%).

The results of this paper can be utilized in several ways. The method used in this paper is easy to apply and does not require complicated modelling compared to macro-econometric models or computable general equilibrium models. In addition, the results are linear and additive and can therefore be used in various scenarios.

The methods used in this paper can be extended to a multi-country setting. For example, we can measure the impacts of a supply-side shock caused by the Korea-Japan trade dispute not only on Korea but also on Korea's major trade partners. The World Input-Output Database or the OECD's Inter-Country Input-Output tables can be used for this purpose.

The result of this paper has many limitations. First, the direct impact of an exogenous shock, the crucial component of a supply-driven IO analysis, could not be estimated rigorously. We 'assumed' that the gross outputs of the semiconductor and display sectors would decrease by 10% each as a result of Japan's export control based on statistics pertaining to imports of controlled materials and the production and export levels of semiconductors and display panels. Hence, a more rigorous estimation is desired.

Second, the timeliness of the paper is seriously limited because one and a half years have already passed since the outset of the dispute. In this sense, the results of the paper cannot be used to 'predict' the impact of the shock.

Third, supply-driven IO analysis assumes that allocation coefficients are fixed; that is, the distribution structure in terms of the demand composition is fixed. This assumption implies that customers are not identical to producers, which is regarded as implausible by some researchers.

Lastly, the lenience of using the result based on the method's linearity is simply the other side of the method's critical drawback. The results of this paper are interpreted as the 'instantaneous strength' or the 'direction' of the economy's response, tending to ignore the adjustment processes of the agents involved and to overestimate the impact. For example, firms in the semiconductor and electronic display sectors began making efforts, immediately after or even before Japan's export control, to produce the materials in question themselves or to search for alternative suppliers. Many of those efforts were successful, which implies that the damage to the Korean economy was reduced; that is, the initial forecast overestimated the impact.

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Trade Liberalization and Manufacturing Productivity Changes in Korea during the Past Three Decades†

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The main objective of this study is to determine whether there have been TFP increases in the Korean manufacturing sector due to trade liberalization since the 1990s. Based on the methodology proposed by Pavcnik (2002), which focuses on the channel through which trade liberalization measures enhance overall industrial productivity by triggering the exit of low-productivity firms, this study tests the following two hypotheses: first, the TFP increase in the Korean tradable industry is not higher than that in the non-tradable industry, and second, plants with lower TFP levels did not exit from the tradable industry. Through the rejection of these two hypotheses, it is possible to infer indirectly the effect of trade liberalization on firm productivity rates in Korea since the 1990s. First, this analysis reveals that since the 1990s, the TFP of the tradable sector compared to the non-tradable sector presented a statistically meaningful increase only in the 2000s, when China joined the WTO and trade increased sharply between Korea and China. Secondly, TFP growth in the tradable sector was positively affected by exits, as it was plants with lower TFP levels that ceased to exist.

Key Word: Trade Liberalization, Productivity, Exit
JEL Code: F13, F14, O3

I. Introduction

Policies related to the growth of the manufacturing industry are diverse, including industrial support policies such as R&D policies, fair competition policies, and financial support policies. Considering the role that exports have played in the development of the Korean manufacturing industry, among the various policies that affect the growth of the manufacturing industry, the importance of the foreign

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economic policy that determines the degree of trade liberalization with other countries cannot be overlooked in the growth of the manufacturing industry.

Import barriers such as tariffs, which are the main tools in foreign economic policies, have a great influence on the domestic market competition environment in terms of both the 'economy of scale' and 'strengthening market competition'. As Melitz (2003) pointed out, the expansion of export opportunities due to trade liberalization creates a favorable environment for export companies with high productivity, whereas the expansion of imports due to the opening of the domestic market creates a more unfavorable condition for domestic marginalized companies, leading to corporate restructuring and the exit of low-productivity companies.

The entry and exit of firms is the process of creative destruction, which Schumpeter noted and which is the driving force of innovation. The exit of low-productivity firms is the key to restructuring, and this restructuring has the effect of increasing the overall productivity of the industry; if the exit is not smooth, the entry of new firms may not be smooth. Han (2003) empirically analyzed the relationship between the creative destruction process of entry and exit and the increase in the total factor productivity (TFP) of industries using data for each business entity in Korea from 1990 to 1998. He found that Korea's entry and exit of businesses is more active than in other countries and that the factors of entry and exit account for approximately 45-65% of the increase in the TFP from 1990 to 1998 in Korea's manufacturing industry. In other words, his research shows that the process of entry and exit played a major role in improving the efficiency of the Korean manufacturing industry in the past.

This study will analyze the relationship between Korea's trade liberalization policy and productivity in the Korean manufacturing industry. Since the 1980s, Korea has implemented foreign economic policies for trade liberalization several times. As the WTO Uruguay Round in the 1980s and 1990s progressed, tariffs in Korea fell sharply through the first (1984-88) and second (1989-94) Advance Notice System for tariff rate reduction. In addition, diplomatic relations between Korea and China in 1992 functioned as an important foreign economic policy that greatly influenced trade liberalization between the two countries. Since the 2000s, Korea's tariff cuts have been the result of FTAs.[1] In the 2010s, with the Korea-EU FTA in 2011, the Korea-US FTA in 2012, and the Korea-China FTA in 2015, Korea signed FTAs with a number of major trading partners, excluding Japan. An empirical analysis of how Korea's trade liberalization policy since the 1990s has affected productivity in the Korean manufacturing industry can have meaningful policy implications for future foreign economic policies.

Extensive empirical studies exist on the impact of trade liberalization on productivity.[2] From the standpoint of domestic companies, trade liberalization can be divided into four categories in terms of final goods and intermediate goods, and exports and imports. The first is the expansion of export opportunities in the final

[1]The Korea-Chile FTA took effect in 2004, and the Korea-Singapore FTA and the Korea-EFTA FTA came into effect in 2006. In 2007, the Korea-ASEAN FTA in goods went into effect, and in 2010, the Korea-India FTA went into effect.

[2]See, for example, Tybout *et al.* (1991) and Pavcnik (2002) for Chile; Iscan (1998) and Tybout and Westbrook (1995) for Mexico; Muendler (2002) and Hay (2001) for Brazil; Krishna and Mitra (1998) and Topalova and Khandelwal (2011) for India; Harrison (1994; 1996) for the Ivory Coast.

goods market, the second is the expansion of import competition in the final goods market, the third is the improvement of access to imported intermediate goods, and the fourth is competition with the imported intermediate goods. Shu and Steinwender (2018) reviewed empirical studies on the impact of trade liberalization on corporate innovation through the lens of these four categories. They found, first of all, that there were various heterogeneities in the impact of trade liberalization on productivity and innovation. With regard to expanding export opportunities and improving access to intermediate goods for import, the majority of empirical results showed that this improves the productivity and innovation of enterprises. However, there were many differences in the effects of import competition. Most existing studies that have empirically analyzed the effects of tariff reductions in developing countries have found a positive effect on domestic productivity. Meanwhile, both positive and negative effects of reduced tariffs were found to coexist in the case of developed countries, and there have been few empirical studies of the competition for import intermediate goods.[3]

In the Korean case, empirical studies that analyzed the effect of mitigating the import barrier include those by Choi and Tcha (2005), Han (2007), and Lee (2007). Choi and Tcha (2005) empirically investigated the negative impact of Chinese imports, that is, the increase in the exit of existing SMEs and the impediment of entry of new SMEs in industries with a high Chinese import penetration rate. They also pointed out that the capital intensity of surviving SMEs did not increase, meaning that the increase in imports from China hindered capital accumulation by SMEs. Han (2007) also concluded that imports from China, in particular, were related to the decline in the share of employment in the domestic manufacturing industry and that they negatively affected the value-added and the share of employment in labor-intensive industries. Lee (2007) analyzed how changes in import tariffs measured by the effective tariff rate had an effect on the total factor productivity of individual manufacturing businesses. Through a regression analysis of the entire manufacturing industry, however, he empirically showed that the lower the import tariff barrier is, the higher the total factor productivity of individual businesses becomes.

This study shows differences in the methodology and analytical period from previous studies that empirically analyzed the effects of import liberalization in Korea. It is well known that it is difficult to measure the direct causal relationship between trade liberalization and manufacturing productivity.[4] In an influential study of the effects of trade policy on productivity, Pavcnik (2002) proposed a difference-in-differences methodology to measure the relationship between trade liberalization and manufacturing industry productivity in order to overcome this direct measurement problem. Unlike previous studies of the effects of import liberalization in Korea, the present study adopts the difference-in-differences methodology proposed by Pavcnik (2002) and divides the entire Korean manufacturing industry into the tradable sector, including export-led, import-competing and intra-trade

[3]Kee (2015) seems to be the only study that is relevant to the impact of foreign input competition in that his study showed that domestic firms in the Bangladeshi garment sector enjoy positive spillovers from sharing the same local suppliers with foreign-owned firms.

[4]There have been several discussions of the limitations of the methodologies of existing empirical studies on the effects of import liberalization. For discussions on this, see Rodrik (1992), Rodríguez and Rodrik (2000), Goldberg and Pavcnik (2016), and Irwin (2019).

industries, and the non-tradable sector based on the share of imports and exports. Based on this, in order to examine the relationship between trade liberalization and changes in the productivity of manufacturing sectors in Korea, the changes in TFP in each tradable sector compared to those of the non-tradable sector are estimated through a regression analysis. This study also analyzes three periods since the 1990s, excluding the period of the Korean financial crisis in the 1990s and the global financial crisis in 2007. These are 1991-97, 2002-07, and 2012-17.

This study focuses on how trade liberalization, especially the easing of import barriers, improves productivity across industries through the exit of low-productivity firms. In order to examine the effects of the exits of low-productivity firms on productivity, the first step is to estimate the production function to estimate productivity for each manufacturing plant. After deriving the TFP for each plant based on the estimated production function, the TFP of each tradable and non-tradable industry is obtained by a weighted average based on the added value of each plant. In addition, with the methodology suggested by Melitz and Polanec (2015), the growth factors of the TFP of each tradable and non-tradable sector are decomposed into entry, survival, and exit to examine the effect of the exits on the TFP of the manufacturing sector. In the second step, a regression analysis is conducted to estimate the changes in the TFP of existing firms in the tradable sector compared to those in the non-tradable sector and to compare the TFPs of exiting and existing firms classified by trade type.

The main results of this study are as follows. First, it was found that plants with low TFP levels exited in tradable and non-tradable industries, indicating that exits had a positive effect on improving productivity in the manufacturing industry. This is similar to the findings of Han (2003), showing that exits contributed to the increase in productivity in the Korean manufacturing industry. Second, the increase in the TFP in the tradable industry compared to the non-tradable industry after the 1990s was statistically significant only in the second period of the 2000s. These findings are robust to several econometric specifications.

The second result may be surprising because it was the first period of the 1990s when tariff cuts were considerable. However, the overall increase in exports and imports in the 2000s was nearly twice that of the 1990s. If tariff cuts do not lead to increased trade volumes, the impact on firm productivity would be limited, as the influence of trade liberalization on the productivity rates of firms differs depending on how a company responds to the business environmental changes that trade liberalization brings. For example, if the expansion of export opportunities due to trade liberalization only results in the expansion of production by low-productivity companies without efforts to improve TFP, the productivity of the related export industry may decrease. The second result of this study indicates that firms in tradable industries made greater efforts to improve their productivity rates in response to the business environmental changes that trade liberalization brought in the 2000s than in the 1990s and 2010s.

The remainder of this paper is organized as follows. In Section 2, both of the estimation methods for the productivity and regression modeling strategies are presented. Section 3 provides an overview of the data used in this study. This section also provides decomposition results of the growth factors of TFP and regression results of productivity changes according to each trade type. Through this, we see how exit, entry, and survival factors influence the productivity change of each trade type. In addition, through a regression analysis, the impacts of firm exits on productivity rates are estimated and the effects of Korea's trade liberalization on productivity since the 1990s are inferred indirectly. Finally, in Section 4, the results of this study are summarized and the limitations of this study are addressed. In addition, future research topics are presented and policy suggestions are made.

II. The Econometric Model

A. *Productivity Estimation*

TFP refers to the part of production that is not explained by the input of all measurable factors of production, unlike single-factor productivity aspects such as labor productivity and capital productivity. In general, TFP is interpreted as a technological change in economics. A widely used method to measure TFP is to use the Cobb-Douglas production function, where Y represents production, L is labor input, K is capital input, and A is defined as TFP, which is the part of production not explained as labor and capital input.

(1) $$Y = AL^{\alpha}K^{\beta}$$

TFP estimation methods include a growth accounting method and a production function estimation approach. The growth accounting method is based on Solow (1956; 1957). In this approach, TFP is assumed to be the remaining part of production that is not explained by changes in L and K in equation (1). However, in order to estimate TFP in this way, limited assumptions such as a constant return to scale, perfect competition in the input market, and neutral technological changes are required.

The production function estimation method was proposed in order to solve the endogenous problem due to the possibility of the existence of a correlation between the production factor and the error term. Typical methods that use this approach include those by Olley and Pakes (1996) and Levinsohn and Petrin (2003). They attempted to control the endogenous problem using what was termed a control function approach. Olley and Pakes (1996) sought to solve the endogenous problem caused by the correlation between the unobservable TFP and production factors by means of investment. In other words, looking at TFP as a function of investment, it is possible to redefine the production function as a function of production factors such as labor, capital and investment. We can also redefine the production function as a function of observable variables. Olley and Pakes (1996) proposed to estimate the defined function first and then estimate TFP through it. However, this method can result in a left censoring problem, as there may be years in which investments are not made in the data. Levinsohn and Petrin (2003) tried to complement the method by Olley and Pakes (1996) using intermediate goods instead of investment. In other words, they sought to control the endogenous problem by defining TFP as a function of intermediate goods and capital and redefining the production function as a function of labor, capital, and intermediate goods.

In the 'Mining and Manufacturing Survey' of the National Statistical Office in Korea, data related to the cost of production paid by companies, such as their electricity costs, are compiled. Therefore, it is easy to estimate the production function proposed by Levinsohn and Petrin (2003) using the electricity cost as a proxy variable for intermediate goods. In the present study, based on the method of Levinsohn and Petrin (2003), we estimate the TFP of manufacturing plants in Korea from 1991 to 2017 from the 'Mining and Manufacturing Survey', also using the value-added method proposed by Petrin *et al.* (2004).

As formulated by Petrin *et al.* (2004), the logarithmic expression of the Cobb-Douglas production function assumed in this study is expressed as follows:

$$(2) \qquad y_t = \beta_0 + \beta_l l_t + \beta_k k_t + w_t + \eta_t = \beta_l l_t + \Phi_t(k_t, m_t) + n_t$$

where $\Phi_t(k_t, m_t) = \beta_0 + \beta_k k_t + w_t(k_t, m_t)$.

Here, y_t, l_t, k_t, and m_t are the logarithm of the value-added, labor input, capital input, and intermediate goods respectively. w_t is the amount of change in TFP that the firm can observe, while η_t is the amount of change in TFP that the firm cannot observe.

We estimate the labor and capital coefficients for each KSIC (Korea Standard Industry Code) two-digit unit based on equation (2), after which we estimate the TFP for each plant using equation (3) below, where i, j, and t represent the individual plant, industry, and corresponding period, respectively. β_{li} and β_{ki} are the labor and capital coefficients for each industry, respectively, as estimated through equation (2).

$$(3) \qquad \ln TFP_{ijt} = y_{ijt} - \overline{\beta_{lj}} \ln L_{ijt} - \overline{\beta_{kj}} \ln K_{ijt}$$

B. *Productivity change by trade type*

This study focuses on the relationship between trade liberalization and productivity in Korea since the 1990s. Most existing studies on the relationship between trade liberalization and firm productivity analyzed the effect of trade liberalization on productivity through the change in productivity of firms. However, issues can arise when using this approach, as it is highly likely that productivity changes caused by changes other than trade liberalization also appear as trade liberalization effects. To overcome this problem, Pavcnik (2002) indirectly examined the impact of Chile's import liberalization on TFP in industry in Chile through a comparison of the TFP change of the traded industry sector versus the non-traded industry sector under the assumption that trade liberalization does not affect the productivity of non-traded industries.

This study examines the relationship between trade liberalization and productivity changes in Korea since the 1990s according to the methodology proposed by Pavcnik (2002) in order to test the following hypothesis. First, the TFP increase of the Korean tradable industry is not higher than that of the non-tradable industry. Second, plants with lower TFP levels did not exit from the tradable industry. Through the rejection of these two hypotheses, the effects of trade liberalization on firm productivity rates in Korea since the 1990s can be inferred indirectly.

Considering earlier work by Pavcnik (2002), the present study estimates the following equations for each period:

$$(4)\quad \ln TFP_{it} = \alpha_0 + \alpha_1(Trade) + \alpha_2(exit * Trade) + \alpha_3(Trade * Time)_{it} + \alpha_4 Z_{it} + v_{it}$$

TFP_{it} represents the TFP of each sector in each period, and $Time$ is a year dummy vector used to measure the effect of missing macroeconomic variables. $Trade$ is the vector of the dummy variables for the export-led, import-competing, and intra-trade sectors, $exit$ is the exit dummy, and Z_{it} is the industry dummy vector.

α_3 in equation (4) represents a coefficient indicating how much the TFP of each tradable sector has changed compared to the non-tradable sector in each year. Through these values, it is possible to determine the average TFP change rate of each tradable sector compared to the non-tradable sector for each year. These are coefficients that represent 'TFP changes within plants' for each tradable sector. Their values would be positive if trade liberalization has a positive effect on the productivity of the tradable sector compared to that of the non-tradable sector. In addition, if firms with low TFPs exit, the coefficient of the corresponding exit dummy vector would be negative.

The effect of trade liberalization on firms' productivity rates is theoretically not clear both in terms of exports and imports. With regard to imports, the expansion of imports due to trade liberalization causes the prices of domestic imported goods to fall. During this process, due to trade liberalization, exits by low-productivity firms can increase, and in such a case, the exit dummy coefficient is negative. In this environment, firms belonging to import-competing industries can maintain their survival through efforts to improve productivity, and in this case, the coefficient representing the change in TFP within plants by each tradable sector compared to the non-tradable sector appears as a positive number. On the other hand, firms belonging to an import-competing sector may not make efforts to increase productivity if they perceive as negative the business outlook of this industry. In this case, the change in productivity of the import-competing industry may appear negative as compared to that of the non-tradable industry.

With regard to exports, α_3 could be both positive and negative depending on the firm's response to expanded export opportunities. In order to expand profits in the expanded export market due to trade liberalization, export companies can make efforts to increase productivity by expanding their R&D investments and introducing advanced technologies. For a firm that did so successfully, the firm's productivity would increase and the coefficient representing the change in TFP within plants by each tradable sector compared to the non-tradable sector would become positive. On the other hand, if export market expansion does not results in efforts by high-productivity export firms to improve their productivity more and instead results in an increase in the proportion of production due to export expansion by low-productivity companies, the overall productivity of the export-led sector may decrease. If this is the case, the coefficient representing the change in TFP within plants according to each tradable sector compared to the non-tradable sector then becomes negative.

III. Empirical Results

A. *Data*

The data analyzed here consist of statistics for each plant in the National Statistical Office's 'Mining and Manufacturing Survey' from 1991 to 2017. This is a complete survey of mining and manufacturing businesses that employ ten or more employees. The target manufacturing industries in this study are those designated by the eighth standard manufacturing industry classification codes of the Korea Standard of Industry Classification (KSIC), excluding food and beverage manufacturing industries (15) and tobacco manufacturing industries (16) among the two-unit classification codes 15~37. Accordingly, this study analyzes the manufacturing industries included in KSIC 17~37.

In this study, based on the classification scheme devised of Pavcnik (2002), the import/export industry is defined as an industry with an import/export ratio of 15% or more. Therefore, an export-led industry is defined as an industry with an export ratio of 15% or more, and an import-competing industry is defined as an industry with an import ratio of 15% or more. In addition, an intra-trade industry is defined as an industry with export and import ratios of 15% or more, and the remaining industries are considered to be in the non-tradable sector, which overall has a share of exports or imports of less than 15%. In order to classify these defined industries according to the KSIC classification methodology, the 'Mining and Manufacturing Survey' is linked to the UN Comtrade export and import statistics as well as the Korea Customs Service's export and import trade statistics (2003-17). For this work, the KSIC data, International Standard Industrial Classification (ISIC), and Harmonized Commodity Description and Coding System (HS) Code linkage table were used.

This study analyses the period from 1991 to 2017 but excludes the period of the Asian financial crisis in the 1990s (1998-2001) and the period of the global financial crisis in 2007 (2008-11), when GDP rates declined significantly. Moreover, the growth rates of imports and exports were negative in 2001 and 2009. The Korean financial crisis and the global financial crisis were caused by financial factors rather than the actual sector. During these crises, it was thought that the exit and productivity changes of Korean firms would have been more influenced by macroeconomic factors other than those of trade liberalization. Accordingly, this study excludes those periods and classifies the overall period into three periods, the first being 1991-97, the second 2002-07, and the third 2012-17.

This study applies equation (2) to estimate the TFP for each plant. As the dependent variable, the value-added amount provided by the 'Mining and Manufacturing Survey' is used. Regarding the capital variable, the balance at the beginning of the year of the assets shown in the 'Mining and Manufacturing Survey' is used, with assets defined as the sum of the valuations of buildings, machinery and transportation equipment. For the labor variable, the total number of workers in this survey is used, and the power cost is used as the input of intermediate goods.

For the TFP estimation, it is necessary to make the nominal figures in the 'Mining and Manufacturing Survey' actual figures in order to use them as panel data. To this end, inflation was adjusted by a price index, which was selected as it is considered to be the most closely related to the variable in question. For labor costs, the consumer price index announced by the National Statistical Office was applied, and in the case of capital, the deflator for construction investment and facility investment was calculated using the "total capital formation by capital goods type" provided by the Bank of Korea. Electricity and water costs were adjusted using the electricity, gas and water price indices among producer price indices provided by the Bank of Korea. The producer price index provided by the Bank of Korea was used to change the nominal value added into the representational value.

B. *Decomposition of growth factors of TFP by trade type*

The annual rate of change in the TFP of an industry can be divided into the factors of surviving firms, entrant firms, and exiting firms. In addition, the factors of surviving firms can be distinguished as factors that increase the productivity of the firm itself and factors that result from the expansion of the firm's market share. In order to analyze the effects of productivity changes due to exits, this study decomposes the annual rate of change in TFP using the method proposed by Melitz and Polanec (2015), which is based on the results of Olley and Pakes (1996). According to Olley and Pakes (1996), the indicator of industrial productivity growth defined as the weighted average can be decomposed into two parts, as follows.

$$(5) \qquad \Phi_t = \sum_i s_{it}\phi_{it} = \overline{\phi_t} + \sum_i (s_{it} - \overline{s_t})(\phi_{it} - \overline{\phi_t}) = \overline{\phi_t} + \mathrm{cov}(s_{it}, \phi_{it})$$

Here, s_{it} and ϕ_{it} correspondingly represent the market share ($\sum_i s_{it} = 1$) and TFP of plant i, while $\overline{s_t}$ and $\overline{\phi_t}$ likewise represent the simple averages of the market share and TFP of firms in the relevant industry in year t, i.e.,

$$\overline{s_t} = \frac{1}{n_t} \; and \; \overline{\phi_t} = \left(\frac{1}{n_t}\right)\sum_{i=1}\phi_{it}$$

According to Equation (5), the annual TFP change index Φ_t of the industry can be decomposed into the covariance of the market share s_{it} and TFP ϕ_{it} and the simple average of the TFP $\overline{\phi_t}$ of the industry during the year Here, the covariance part indicates the extent to which the changes in the market share and resource reallocation of firms with different productivity levels contributed to the increase in industrial productivity. In other words, when the covariance is positive, it means that production by more efficient firms has increased.

Melitz and Polanec (2015) developed the Olley and Pakes (1996) method to decompose the difference in the TFP between t and $t+1$ into the factors of surviving firms, entrant firms, and exiting firms. By applying this method, we define s as the surviving group, x as the exiting group, and e as the entrant group, and define s_{Gt} as the G group's market share. At this point, the TFP of the G group between t and $t+k$ can be rewritten as follows:

$$\begin{aligned} \Phi_t &= \sum_i s_{it}\phi_{it} = s_{st}\Phi_{st} + s_{xt}\Phi_{xt} = \Phi_{st} + s_{xt}(\Phi_{xt} - \Phi_{st}), \\ \Phi_{t+k} &= \sum_i s_{i(t+k)}\phi_{i(t+k)} = s_{s(t+k)}\Phi_{s(t+k)} + s_{e(t+k)}\Phi_{e(t+k)} \\ &= \Phi_{s(t+k)} + s_{e(t+k)}(\Phi_{e(t+k)} - \Phi_{s(t+k)}) \end{aligned} \tag{6}$$

Let $\Delta_k\Phi = \Phi_{t+k} - \Phi_t$; then, we have the following using equation (6):

$$\begin{aligned} \Delta_k\Phi &= (\Phi_{s(t+k)} - \Phi_{st}) + s_{e(t+k)}(\Phi_{e(t+k)} - \Phi_{s(t+k)}) + s_{xt}(\Phi_{st} - \Phi_{xt}) \\ &= \Delta_k\overline{\phi_s} + \Delta_k \operatorname{cov}_s + s_{e(t+k)}(\Phi_{e(t+k)} - \Phi_{s(t+k)}) + s_{xt}(\Phi_{st} - \Phi_{xt}) \end{aligned} \tag{7}$$

The first line in Equation (7) decomposes the TFP change into the factors of surviving firms, entrant firms, and exiting firms. The second line is the decomposition of the survival firm factor into a simple average part and a covariance part according to Olley and Pakes (1996). The results of decomposing the annual rate of change in the TFP for each trade type according to Equation (7) are shown in Tables 1~3.

Looking at the characteristics of the first period through Table 1, the trend of the TFP increase was clear in the manufacturing industry as a whole, and TFP increased in all industries by trade type. In particular, the increases in TFP in export-led industries and import-competing industries were large. In the intra-trade industry, the increase in TFP was the smallest. When the factors of the productivity increase

TABLE 1— DECOMPOSITION OF TFP CHANGES BY TRADE TYPE (FIRST PERIOD)

	Year	Survival	Entry	Exit	All
All manufacturing	1991	0.000	0.000	0.000	0.000
	1992	0.116	-0.025	0.042	0.132
	1993	0.155	-0.067	0.076	0.164
	1994	0.287	-0.103	0.102	0.286
	1995	0.396	-0.131	0.133	0.398
	1996	0.336	-0.123	0.160	0.373
	1997	0.498	-0.114	0.183	0.566
Export-led	1991	0.000	0.000	0.000	0.000
	1992	0.145	-0.027	0.044	0.162
	1993	0.198	-0.028	0.072	0.242
	1994	0.235	-0.037	0.079	0.277
	1995	0.312	-0.004	0.105	0.413
	1996	0.399	-0.030	0.122	0.491
	1997	0.560	-0.014	0.123	0.669

TABLE 1— DECOMPOSITION OF TFP CHANGES BY TRADE TYPE (FIRST PERIOD) (CONT'D)

	Year	Survival	Entry	Exit	All
Import-competing	1991	0.000	0.000	0.000	0.000
	1992	0.178	-0.025	0.062	0.215
	1993	0.226	-0.061	0.079	0.244
	1994	0.306	-0.082	0.102	0.326
	1995	0.299	-0.097	0.138	0.340
	1996	0.466	-0.104	0.134	0.496
	1997	0.556	-0.115	0.149	0.590
Intra-trade	1991	0.000	0.000	0.000	0.000
	1992	0.118	-0.081	0.072	0.109
	1993	0.117	-0.143	0.126	0.100
	1994	0.276	-0.184	0.160	0.253
	1995	0.398	-0.217	0.191	0.372
	1996	0.233	-0.209	0.226	0.250
	1997	0.436	-0.195	0.251	0.492
Non-tradable	1991	0.000	0.000	0.000	0.000
	1992	0.033	0.051	-0.005	0.079
	1993	0.221	-0.028	0.010	0.203
	1994	0.383	-0.087	0.016	0.312
	1995	0.393	-0.107	0.035	0.322
	1996	0.614	-0.134	0.043	0.523
	1997	0.623	-0.108	0.053	0.568

were decomposed, the survival factor had the greatest positive effect on the TFP increase of the entire manufacturing industry and all types of trade. The exit factor also had a positive effect on the increase in TFP in all industries by trade type except for non-tradable industries in 1992. The positive effect of exits was strong in the intra-trade industries and smallest in the non-tradable industries, which may be interpreted as an effect of trade liberalization. The productivity of new entrants had a negative impact on the TFP of all trade types. However, considering that the increase in TFP of surviving companies is large, this indicates that the initial TFPs of newly entering businesses are low compared to those of incumbent firms, but their TFPs increase as business activities are carried out, and businesses that do not increase their TFP are expelled.

Table 2 shows the characteristics of the second period. As in the first period, the overall manufacturing industry and all industries by trade type showed an increase in TFP, but the increase decreased significantly compared to that in the first period. In particular, during the second period, the TFP increase in export-led industries was approximately 25%, and the TFPs in import-competing industries, intra-trade industries, and non-tradable industries were close to 13%. Examining the factors that increase productivity, as in the first period, survival factors have the greatest positive effect on the TFP increase in all industries by trade type. The exit factor also had a positive effect on the TFP increase in all types of trade. The positive effect of exits was particularly strong in the import-competing industries and intra-trade

TABLE 2— DECOMPOSITION OF TFP CHANGES BY TRADE TYPE (SECOND PERIOD)

	Year	Survival	Entry	Exit	All
All manufacturing	2002	0.000	0.000	0.000	0.000
	2003	-0.011	-0.029	0.036	-0.003
	2004	0.100	-0.055	0.061	0.160
	2005	0.132	-0.083	0.084	0.133
	2006	0.150	-0.122	0.105	0.133
	2007	0.185	-0.153	0.131	0.162
Export-led	2002	0.000	0.000	0.000	0.000
	2003	0.026	-0.054	0.049	0.021
	2004	0.082	-0.085	0.072	0.068
	2005	0.040	-0.067	0.098	0.071
	2006	0.081	-0.105	0.115	0.091
	2007	0.222	-0.111	0.135	0.245
Import-competing	2002	0.000	0.000	0.000	0.000
	2003	-0.015	-0.051	0.040	-0.025
	2004	-0.038	-0.074	0.077	-0.035
	2005	0.120	-0.125	0.092	0.086
	2006	0.150	-0.146	0.090	0.095
	2007	0.211	-0.194	0.110	0.128
Intra-trade	2002	0.000	0.000	0.000	0.000
	2003	-0.021	-0.047	0.051	-0.017
	2004	0.121	-0.079	0.087	0.129
	2005	0.169	-0.117	0.120	0.173
	2006	0.178	-0.170	0.149	0.157
	2007	0.145	-0.206	0.189	0.129
Non-tradable	2002	0.000	0.000	0.000	0.000
	2003	-0.029	0.003	0.040	0.014
	2004	0.073	-0.031	0.048	0.090
	2005	0.074	-0.060	0.073	0.086
	2006	0.124	-0.069	0.092	0.146
	2007	0.155	-0.078	0.052	0.129

industries, which were heavily influenced by imports, and was smallest in non-tradable industries. This can be interpreted as an effect of trade liberalization, similar to that in the first period. Like the first period, the productivity of newly entering companies negatively affected the TFP of all types of trade. In the second period, as in the first period, the initial TFP of newly entered firms was low, but TFP increased as business activities were carried out.

Unlike the previous period, the trend of increasing and decreasing TFPs in industries by trade type is mixed in the third period, as indicated in Table 3. TFP increased in export-import and non-tradable industries but decreased in export-led industries and import-competing industries. In particular, in export-led industries, the TFP decline was close to 50%. Looking at the factors that increase productivity,

TABLE 3— DECOMPOSITION OF TFP CHANGES BY TRADE TYPE (THIRD PERIOD)

	Year	Survival	Entry	Exit	All
All manufacturing	2012	0.000	0.000	0.000	0.000
	2013	0.046	-0.050	0.032	0.027
	2014	0.029	-0.134	0.051	-0.054
	2016	0.038	-0.127	0.088	-0.002
	2017	0.126	-0.206	0.105	0.025
Export-led	2012	0.000	0.000	0.000	0.000
	2013	0.042	-0.075	0.075	0.042
	2014	-0.049	-0.202	0.109	-0.142
	2016	-0.339	-0.208	0.156	-0.391
	2017	-0.468	-0.216	0.186	-0.498
Import-competing	2012	0.000	0.000	0.000	0.000
	2013	-0.067	-0.033	0.056	-0.045
	2014	-0.154	-0.137	0.075	-0.216
	2016	-0.120	-0.090	0.146	-0.065
	2017	-0.146	-0.134	0.153	-0.127
Intra-trade	2012	0.000	0.000	0.000	0.000
	2013	0.062	-0.051	0.011	0.021
	2014	0.112	-0.121	0.025	0.017
	2016	0.292	-0.147	0.070	0.215
	2017	0.375	-0.165	0.084	0.294
Non-tradable	2012	0.000	0.000	0.000	0.000
	2013	0.108	-0.006	0.013	0.115
	2014	0.114	-0.102	0.025	0.036
	2016	0.231	-0.054	0.067	0.244
	2017	0.180	-0.065	0.077	0.192

unlike in the previous period, the survival factors in export-led industries and import-competing industries negatively affected the increase in TFP. However, the exit factor had a positive effect on the increase in TFP in all trade types. The positive impact of exits was greater in export-led industries and import-competing industries, at 15-19%, than in import-export and non-tradable industries. During the third period, Korea signed FTAs with major trading partners such as the United States, the EU, and China, but the growth rates of exports and imports were sluggish.[5] During this period, exits still contributed to the productivity of all types of trade. However, it was found specifically that the number of surviving companies in the export-led and import-competing industries continued to decline. This may mean that only in the intra-trade industry did the innovation ecosystem of the survival of companies work smoothly and that the expansion of imports through trade liberalization helped to increase the TFP.

[5]In the third period, the annual average growth rates of exports and imports were 0.9% and -1.6%, respectively. See Table 5.

C. *Estimation results of TFP changes by trade type*

The TFP growth factor analysis mentioned above revealed that the productivity of all trade types increased during all periods subject to the analysis in this study, except for export-led industries and import-competing industries in the third period. Another finding was that exits had a positive effect on firm productivity rates. With this observation, we now estimate the following equations for each period to test the two hypotheses in this study, which are firstly that the TFP increase of the Korean tradable industry is not higher than that of the non-tradable industry, and secondly that plants with lower TFP levels did not exit from the tradable industry.

$$\begin{aligned} \ln TFP_{it} &= \alpha_0 + \alpha_{11}(ex)_{it} + \alpha_{12}(im)_{it} + \alpha_{13}(bi)_{it} + \alpha_{20}(exit)_{it} + \alpha_{21}(exit \times ex)_{it} \\ &+ \alpha_{22}(exit \times im)_{it} + \alpha_{23}(exit \times bi)_{it} + \alpha_{30}(T)_{it} + (\alpha_{31})_t(ex \times T)_{it} \\ &+ (\alpha_{32})_t(im \times T)_{it} + (\alpha_{33})_t(bi \times T)_{it} + \alpha_4 Z_{it} + v_{it} \end{aligned} \tag{8}$$

Equation (8) is a more elaborate form of equation (4). TFP_{it} represents the TFP of each sector in each period and $(T)_{it}$ is the year dummy vector used to measure the effects of the missing macroeconomic variables. ex, im, and bi are dummy variables for the export-led, import-competing, and intra-trade sectors, respectively. $(\alpha_{31})_t$, $(\alpha_{32})_t$, and $(\alpha_{33})_t$ in equation (8) are coefficients indicating how much the TFP of each tradable sector has changed compared to the non-tradable sector in each year. As noted earlier, these are coefficients that represent 'TFP changes within plants' for each tradable sector. If these values are positive, we reject the first hypothesis of this paper and conclude that trade liberalization has a positive effect on the productivity of the tradable sector compared to that of the non-tradable sector. Also, α_{20} in equation (8) is a coefficient indicating the extent to which the TFPs of exiting firms were lower than those of existing firms; if α_{20} is negative, we reject the second hypothesis of this paper and conclude that firms with low TFPs exited. The regression analysis results are summarized in the tables in the Appendix of this paper. In this section, the two main results of this paper are described.

The first main result of this study is that the increase in TFP in the tradable industry compared to that in the non-tradable industry after the 1990s was statistically significant only in the second period of the 2000s. This finding is robust to several econometric specifications, as indicated in the Appendix of this paper. Table 4 summarizes this finding.

At this point, we can assume that trade liberalization affects the tradable industry but does not affect the non-tradable industry, as in Pavcnik (2002). Hence, if the increase in TFP in the tradable industry directly affected by Korean trade liberalization is higher than that in the non-tradable industry, this can be interpreted as a positive effect of trade liberalization, as in Pavcnik (2002). In the second period, which marks the period of recovery from the shock of the Asian financial crisis of 1997, the reduction in tariffs through the FTAs was not significant. However, in the second period, economic growth was recorded at an annual average of 4.5%, and the growth rates of exports and imports exceeded the annual average of 18% due to the influence of China. During this period, with the explosive increases in exports

TABLE 4— CHANGES IN THE TFP OF EXISTING TRADABLE FIRMS COMPARED TO NON-TRADABLE FIRMS IN MODEL 2

(Unit: Natural log)

	Year	Export-driven (α_{31})	Import-competing (α_{32})	Intra-trade (α_{33})
1st period	1992	0.022* (0.013)	-0.036** (0.016)	-0.005 (0.012)
	1993	0.027** (0.013)	-0.092*** (0.016)	0.002 (0.012)
	1994	-0.023* (0.013)	-0.088*** (0.016)	0.002 (0.012)
	1995	-0.064*** (0.013)	-0.039** (0.016)	0.042*** (0.012)
	1996	-0.051*** (0.013)	-0.004 (0.016)	0.062*** (0.012)
	1997	-0.115*** (0.013)	-0.028* (0.016)	0.038*** (0.012)
2nd period	2003	0.015 (0.013)	0.012 (0.019)	0.027*** (0.010)
	2004	0.014 (0.013)	0.059*** (0.019)	0.056*** (0.010)
	2005	0.030** (0.012)	0.078*** (0.019)	0.079*** (0.009)
	2006	0.027** (0.012)	0.044** (0.019)	0.051*** (0.009)
	2007	0.055*** (0.012)	0.070*** (0.019)	0.057*** (0.009)
3rd period	2013	-0.025* (0.013)	-0.014 (0.017)	-0.027** (0.012)
	2014	-0.003 (0.013)	-0.000 (0.017)	-0.011 (0.012)
	2016	0.017 (0.013)	0.017 (0.018)	-0.002 (0.012)
	2017	0.052*** (0.013)	-0.002 (0.018)	0.045*** (0.013)

Note: 1) Figures in the parentheses denote the standard deviation, 2) Statistical significance levels: *** p<0.01, ** p<0.05 and * p<0.1, 3) The numbers of observations for the first, second, and third phases are correspondingly 331,750, 317,936, and 294,997. The respective R-squared values are 0.382, 0.215, and 0.230, 4) The Mining and Manufacturing Survey for 2015 is not included, as it was separated in 2015 with the start of the integrated economic statistics survey.

Source: By the author using Table 2-14~16 from Song (2019).

and imports, the growth of export-led industries, the decline in import-competing industries, and the outward growth stagnation of the import and export industries coexisted.

The analysis results of this study summarized in Table 4 show that in the second period, productivity was increasing in all tradable industries.[6] This result suggests that active efforts were made to increase the productivity of firms in all tradable industries in response to changes in the trade environment, such as the expansions of exports and imports. In particular, despite the fact that the share of the import-

[6]In models 3 and 4, applying a 10% cut off point, the export-led industry TFPs in 2005 and 2006 were found to be negative. However, those values were found to be positive in all other models. See Tables A1-2 and A2-2.

TABLE 5— MAJOR MACROECONOMIC CONDITIONS IN KOREA SINCE THE 1990S

(Unit: %)

	Year	GDP growth	Export growth	Import growth	Average tariff rate
1st period	1991	10.4	10.5	16.7	12.7
	1992	6.2	6.6	0.3	10.8
	1993	6.8	7.3	2.5	9.0
	1994	9.2	16.8	22.1	7.8
	1995	9.6	30.3	32.0	7.7
	1996	7.6	3.7	11.3	7.6
	1997	5.9	5.0	-3.8	7.7
	Annual average growth	7.5	11.2	10.0	-8.1
2nd period	2002	7.4	8.0	7.8	7.1
	2003	2.9	19.3	17.6	6.8
	2004	4.9	31.0	25.5	6.4
	2005	3.9	12.0	16.4	6.3
	2006	5.2	14.4	18.4	6.3
	2007	5.5	14.1	15.3	6.3
	Annual average growth	4.5	18.0	18.6	-2.3
3rd period	2012	2.3	-1.3	-0.9	6.1
	2013	2.9	2.1	-0.8	6.0
	2014	3.3	2.3	1.9	6.0
	2015	2.8	-8.0	-16.9	6.0
	2016	2.9	-5.9	-6.9	6.0
	2017	3.1	15.8	17.8	N/A
	Annual average growth	3.0	0.9	-1.6	-0.3

competing industry showed a downward trend,[7] the productivity increase in the industry was higher than that in the non-tradable industry. This can be interpreted as a result of promoting market competition due to the increase in imports. In other words, firms attempted to increase their own productivity for their own survival.

In the first period, the tariff rate cut was large, but after 1995, except for intra-trade industries, no increase in TFP in the trading industry could be confirmed. Most export-led industries and import-competing industries are light industries, and major heavy and chemical industries such as petrochemicals and semiconductors are classified as intra-trade industries in this period. The 1990s was a time when Korea's industrial structure was transforming from light industry to heavy and chemical industry due to the rise of China. Therefore, it can be interpreted that export-led and import-competing industries, mainly composed of light industrial firms, viewed their future business prospects negatively due to the expansion of Chinese exports to Korea and the world and did not take strong measures to improve their productivity. On the other hand, in the intra-trade industry, mainly heavy and chemical industrial firms, TFP increased after 1995. It can also be interpreted that the positive business

[7]See Table 2-5 in Song (2019), p.35.

outlook in this industry brought about productivity improvement efforts due to the rise of China.

In the third period, TFP increase in the tradable industry was not confirmed in most periods. During this period, although FTAs with major trading partners such as the EU, the United States, and China took effect, the average effective tariff rate was not significantly reduced. This occurred because, due to the nature of the FTA negotiations, the decline in tariff rates for sensitive items that have a large impact on the domestic industry will be implemented in the longer term.[8] As a result, it may be reasonable to interpret that the full effect of signing an FTA with major countries in the third period has not yet been felt. Nevertheless, it raises concern that the effect of increasing TFP in the tradable industry could not be confirmed in the third period. Increasing TFP in the tradable industry is possible when there are active efforts to increase productivity by firms in this industry. In this regard, it is a very worrisome result that we cannot find evidence that firms in tradable industries made active efforts to increase their productivity rates in given situation in which the trade environment was expected to change due to the conclusion of FTAs with major countries.

The second main result of this study is that plants with low TFP exited from the tradable and non-tradable industries and these exits had a positive effect on the productivity improvement in the manufacturing industry. This finding is also robust to several econometric specifications, as indicated in the Appendix of this paper. Table 6 summarizes this finding in this paper.

If trade liberalization intensifies market competition in the domestic market and therefore accelerates the exit of firms with low productivity in import-related industries, this can be interpreted as a positive impact of import liberalization in terms of overall productivity. In general, trade liberalization can lead to an increase in exits by import-competing industries due to increased imports and a decrease in exits by export-led industries due to export expansion. This study did not analyze

TABLE 6— EFFECTS OF AN INCREASE IN TFP DUE TO FIRM EXITS IN MODEL 2

(Unit: Natural log)

	1st period (1991-1997)	2nd period (2002-2007)	3rd period (2012-2017)
Exit (α_{20})	-0.183*** (0.007)	-0.207*** (0.006)	-0.253*** (0.012)
Export-driven industry (α_{21})	0.063*** (0.008)	-0.015 (0.010)	0.039*** (0.013)
Import-competing industry (α_{22})	-0.005 (0.011)	-0.097** (0.015)	0.017 (0.017)
Intra-trade industry (α_{23})	0.045*** (0.008)	0.006 (0.008)	0.032*** (0.013)
Number of observations	331,750	317,936	294,997
R-squared	0.382	0.215	0.230

[8]For industrial products in the Korea-China FTA, tariffs on 59% of items were eliminated immediately after the FTA came into force in December of 2015, and tariffs on 90% of items are phased out within ten years after the FTA came into force. Excluding concessions from industrial products accounted for 2.4% of items. Moreover, 96.1% of tariffs on Korean industrial products, excluding agricultural products and textiles, were phased out within five years in the Korea-US FTA. See explanatory notes on both FTAs by the Korean government (available at https://fta.go.kr/cn/doc/2/ and https://fta.go.kr/webmodule/_PSD_FTA/us/data/13/k_us_12.pdf).

the effect of trade liberalization on exits. However, it was found that firms with low total factor productivity exited from the tradable industry as a whole, with this result showing that these exits had a positive effect on the TFP of the tradable industry. Since the 1990s, the TFPs of firms that exited were 15 to 25% lower than those of surviving firms. In the import-competing industry, the TFPs of firms that exited in the second period were approximately 30% lower than those of the surviving firms. In most models applied in this paper, this effect was slightly lower in export-led industries and intra-trade industries in the first and third periods.

D. *Sensitivity Analysis*

This sector explores the robustness of the findings in this paper. Various specification results of this regression are reported in the Appendix. Table A1 summarizes the regression results with different import/export ratios, while Table A2 summarizes those with different estimation methods. Like Pavcnik (2002), models 1 and 2 applied cut-off points of 15%; for example, firms belong to an industry whose ratio of imports to total domestic output exceeds 15% are characterized as import-competing firms. I also experimented with different cut-off points. The results are robust to definitions based on cut-off points of 10 (models 3 and 4) and 25% (models 5 and 6). The results of the regression analysis after recalculating the capital amount of the firms using the Perpetual Inventory Method and removing outliers with a TFP of 0 or less are presented in Table A2 (models 7 and 8). In addition, the results of a regression analysis of a fixed effects model including the plant fixed effect are also presented in Table A2 (models 9 and 10).

The regression analysis above did not take into account the exchange rate. In general, the movement of the exchange rate affects the profitability of companies in the tradable sector. Therefore, the exchange rate can also affect productivity of the tradable industry. The results of a simple regression analysis of the effect of exchange rates on productivity are shown in Table 7. What can be seen here is that the exchange rate may have some influence on the productivity of non-tradable and intra-trade industries, but it is insignificant such that it has little effect. This means that the exclusion of the exchange rate from my initial analysis is unlikely to affect the robustness of the results of the previous regression analysis.

TABLE 7— RELATIONSHIP BETWEEN PRODUCTIVITY AND EXCHANGE RATES

	Year 1991~97	Year 2002~07	Year 2012~17
Exchange rate	-0.0001*** (0.000)	0.0001*** (0.000)	0.0053*** (0.0010)
Exchange rate *export-led	-0.0002*** (0.000)	-0.0001*** (0.000)	-0.0001*** (0.000)
Exchange rate *import-competing	-0.0002*** (0.000)	-0.0002*** (0.000)	-0.0002*** (0.000)
Exchange rate *intra-trade	-0.0001*** (0.000)	-0.0001*** (0.000)	-0.0001*** (0.000)

Note: 1) Figures in the parentheses denote the standard deviation, 2) Statistical significance levels: *** p<0.01, ** p<0.05 and * p<0.1, 3) Exchange rate data is the yearly average of the KRW/USD exchange rate provided by the Bank of Korea and the economic statistics system (https://ecos.bok.or.kr/, access date: December 18, 2019).

Source: By the author using Table 2-17 from Song (2019).

IV. Conclusion

Since the 1980s, there have been many changes in Korea's trade environment. Diplomatic relations between Korea and China were established in 1992, the WTO Uruguay Round negotiations were concluded in the 1990s, several FTAs were signed in the 2000s and the 2010s, and exports and imports of Korea and other countries around the world increased significantly until the 2010s. The questions here focus on the effect of Korea's trade liberalization policy on firm productivity rates since the 1990s, especially whether it has improved productivity in all industries by enhancing the productivity of existing firms and/or through the exits of low-productivity firms. In order to answer these questions, this study examines how the dynamic process of firm exits affected the productivity of the Korean manufacturing industry and analyzes the changes in productivity rates in the tradable sector compared to those in the non-tradable sector.

There are relatively few studies on Korea's import liberalization policy, despite the fact that the policy overall likely strengthened market competition and, therefore, innovations. In general, because trade liberalization has a variety of effects on the productivity of firms and industries, factors such as the macroeconomic environment - other than trade liberalization – may have also affected the productivity of firms and industries, measuring the effect of trade liberalization on the productivity of Korean manufacturing is not an easy task. Considering this difficulty, this study analyzed the relationship between trade liberalization and manufacturing productivity in Korea using a methodology proposed by Pavcnik (2002).

The main results of this study are as follows. First, it was found that exits had a positive effect by increasing TFP, as plants with low TFP levels exited across industries. This effect was typically significant in the import-competing industry. Second, since the 1990s, the increase in TFP in the tradable industry compared to that in the non-tradable industry was statistically significant only in the second period. The tariff rate cut was largest in the first period, but since 1995, except for the intra-trade industries, no increase in the TFP in the tradable sector compared to the non-tradable sector could be confirmed. This appears to be related to the fact that export-led industries and import-competing industries mainly consist of light industrial firms. Another factor is the rise of China. In other words, because businesses in the export-led industrial and import-competing industrial categories may view their future business prospects negatively due to the rise of China, they did not make much of an effort to improve their productivity rates. It can be said that a positive business outlook brings about productivity improvement efforts.

In the third period, a TFP increase in the tradable sector was not confirmed in most periods. This raises concerns because the third period is when the FTAs with major trading countries such as the EU, the US and China came into effect. This is a very worrisome result of the analysis because it suggests that Korean manufacturing firms in tradable industries did not make active efforts to increase their productivity rates in a situation where changes in the trade environment could be expected due to the conclusion of the FTAs with major countries. However, given that Korea's exports and imports declined across the board in the third period, except for 2017, due to global economic environment at that time, it is too early to conclude that the FTAs with major countries did not benefit the Korean economy in terms of productivity based on this analysis only.

This study has several limitations. First, this study did not test for a direct causal relationship between trade liberalization and TFP. In addition, any direct link between trade liberalization and firm exits was also excluded from the analysis. The study did not analyze factors that increase TFP in the tradable industry through the introduction of advanced foreign technology and improved access to intermediate goods. Future research on these subjects will be needed.

Although innovative growth is being emphasized to increase the potential growth rate of the Korean economy, there has not been much discussion of the relationship between innovative growth and foreign economic policies. Trade liberalization, the main means of foreign economic policy, creates an environment in which competitive companies can expand through ‘economy of scale’ effects, but ‘strengthening market competition’ effects due to the expansion of imports strengthen competition in the market of import-competing industries, leading to the exit of marginal companies. Consequently, it is a double-edged sword. The exit of marginalized companies may cause social problems such as unemployment, but it has positive aspects, such as improving the overall productivity of the industry in the country.

Korea’s foreign economic policies, especially import regulation policies such as tariffs, with the main purpose of ‘promoting exports and protecting domestic industries’, have tended to protect domestic industries. Therefore, it is necessary to review the achievements of Korea’s import liberalization policy on domestic industries thoroughly and to consider transforming Korea’s foreign economic policy into a competitive foreign economic policy that drives the innovative growth of the Korean economy. The increase in exports pursued by Korea’s foreign economic policy thus far has contributed greatly to the growth and expansion of Korean companies due to the ‘economy of scale’ effect, but it is also true that the benefits have been largely concentrated on some of the largest export companies, which has led to the excessive market influence by these large companies. In addition, the side effects of foreign economic policies that prioritize the protection of domestic industries may be related to the decrease in exits and the decrease in the productivity increase in the overall manufacturing industry in the 2010s.

For active innovation in the Korean manufacturing industry, future foreign economic policies should accept the beneficial effects of exits as well, and change the direction toward minimizing the adverse effects of exits through welfare policies instead of the protection of domestic firms through import barriers. That is, foreign economic policies should be divided into industrial policies aimed at improving productivity and welfare policies aimed at improving the social safety net to mitigate the negative effects of firm exits. In terms of industrial policy, the reduction of import barriers should be designed so that the beneficial effects of firm exits are not impaired by the occurrence of economic rent and moral hazard. At the same time, the welfare policy aspects of foreign economic policies should be supplemented to minimize the adverse effects of exits.

APPENDIX

TABLE A1— REGRESSION RESULTS WITH DIFFERENT IMPORT/EXPORT RATIOS

[1. FIRST PERIOD]

		15%		10%		20%	
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
1st period	ex	-0.111*** (0.011)	-0.122*** (0.011)	0.056*** (0.012)	0.044*** (0.012)	-0.085*** (0.009)	-0.096*** (0.009)
	im	-0.141*** (0.012)	-0.140*** (0.012)	-0.166*** (0.013)	-0.165*** (0.014)	-0.053*** (0.011)	-0.059*** (0.011)
	bi	-0.097*** (0.009)	-0.104*** (0.009)	-0.022** (0.010)	-0.029*** (0.010)	-0.037*** (0.009)	-0.041*** (0.009)
	exit	-0.146*** (0.003)	-0.183*** (0.007)	-0.145*** (0.003)	-0.188*** (0.008)	-0.146*** (0.003)	-0.180*** (0.005)
	exit_ex		0.063*** (0.008)		0.076*** (0.010)		0.065*** (0.007)
	exit_im		-0.005 (0.011)		-0.006 (0.012)		0.045*** (0.010)
	exit_bi		0.045*** (0.008)		0.047*** (0.009)		0.024*** (0.008)
	ex*92	0.022 (0.013)	0.022* (0.013)	-0.003 (0.015)	-0.002 (0.015)	-0.027** (0.011)	-0.027** (0.011)
	ex*93	0.027** (0.013)	0.027** (0.013)	-0.018 (0.015)	-0.019 (0.015)	-0.042*** (0.011)	-0.043*** (0.011)
	ex*94	-0.019 (0.013)	-0.023* (0.013)	-0.056*** (0.015)	-0.061*** (0.015)	-0.052*** (0.011)	-0.056*** (0.011)
	ex*95	-0.062*** (0.013)	-0.064*** (0.013)	-0.036** (0.015)	-0.037** (0.015)	-0.019* (0.011)	-0.021* (0.011)
	ex*96	-0.048*** (0.013)	-0.051*** (0.013)	-0.018 (0.015)	-0.022 (0.015)	-0.032*** (0.011)	-0.035*** (0.011)
	ex*97	-0.112*** (0.013)	-0.115*** (0.013)	-0.110*** (0.015)	-0.114*** (0.015)	-0.085*** (0.011)	-0.089*** (0.011)
	im*92	-0.036** (0.016)	-0.036** (0.016)	-0.029* (0.018)	-0.029 (0.018)	-0.079*** (0.014)	-0.079*** (0.014)
	im*93	-0.092*** (0.016)	-0.092*** (0.016)	-0.068*** (0.017)	-0.068*** (0.017)	-0.147*** (0.014)	-0.148*** (0.014)
	im*94	-0.087*** (0.016)	-0.088*** (0.016)	-0.075*** (0.017)	-0.076*** (0.017)	-0.120*** (0.014)	-0.122*** (0.014)
	im*95	-0.039** (0.016)	-0.039** (0.016)	-0.011 (0.017)	-0.012 (0.017)	-0.035** (0.014)	-0.036*** (0.014)
	im*96	-0.004 (0.016)	-0.004 (0.016)	0.041** (0.017)	0.041** (0.017)	-0.055*** (0.014)	-0.057*** (0.014)
	im*97	-0.029* (0.016)	-0.028* (0.016)	0.006 (0.018)	0.007 (0.018)	-0.097*** (0.014)	-0.100*** (0.014)
	bi*92	-0.005 (0.012)	-0.005 (0.012)	0.013 (0.013)	0.014 (0.013)	-0.019 (0.011)	-0.019 (0.011)
	bi*93	0.002 (0.012)	0.002 (0.012)	0.028** (0.013)	0.027** (0.013)	-0.031*** (0.011)	-0.032*** (0.011)
	bi*94	0.005 (0.012)	0.002 (0.012)	0.017 (0.013)	0.013 (0.013)	-0.028** (0.011)	-0.029*** (0.011)
	bi*95	0.043*** (0.012)	0.042*** (0.012)	0.048*** (0.013)	0.047*** (0.013)	0.031*** (0.011)	0.030*** (0.011)
	bi*96	0.065*** (0.012)	0.062*** (0.012)	0.091*** (0.013)	0.089*** (0.013)	0.030*** (0.011)	0.029*** (0.011)
	bi*97	0.041*** (0.012)	0.038*** (0.012)	0.056*** (0.013)	0.054*** (0.013)	0.016 (0.011)	0.015 (0.011)
	Industry	YES	YES	YES	YES	YES	YES
	Year	YES	YES	YES	YES	YES	YES
	R	0.382	0.382	0.378	0.378	0.378	0.379
	N	331,750	331,750	331,750	331,750	331,750	331,750

TABLE A1— REGRESSION RESULTS WITH DIFFERENT IMPORT/EXPORT RATIOS (CONT'D)

[2. SECOND PERIOD]

		15%		10%		20%	
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
2nd period	ex	-0.109*** (0.009)	-0.107*** (0.010)	0.057*** (0.012)	0.059*** (0.012)	-0.152*** (0.008)	-0.154*** (0.009)
	im	-0.216*** (0.014)	-0.200*** (0.015)	-0.039*** (0.015)	-0.037** (0.015)	-0.132*** (0.011)	-0.120*** (0.011)
	bi	-0.085*** (0.008)	-0.086*** (0.008)	-0.046*** (0.009)	-0.048*** (0.010)	-0.156*** (0.008)	-0.160*** (0.008)
	exit	-0.212*** (0.003)	-0.207*** (0.006)	-0.215*** (0.014)	-0.220*** (0.009)	-0.213*** (0.003)	-0.214*** (0.006)
	exit_ex		-0.015 (0.010)		-0.011 (0.012)		0.014 (0.008)
	exit_im		-0.097*** (0.015)		-0.011 (0.016)		-0.089*** (0.011)
	exit_bi		0.006 (0.008)		0.013 (0.010)		0.026*** (0.008)
	ex*03	0.015 (0.013)	0.015 (0.013)	0.015 (0.014)	0.015 (0.014)	0.010 (0.011)	0.010 (0.011)
	ex*04	0.014 (0.013)	0.014 (0.013)	-0.017 (0.014)	-0.017 (0.014)	0.019* (0.011)	0.019* (0.011)
	ex*05	0.030** (0.012)	0.030** (0.012)	-0.014 (0.014)	-0.013 (0.014)	0.048*** (0.011)	0.048*** (0.011)
	ex*06	0.027** (0.012)	0.027** (0.012)	-0.031** (0.014)	-0.031** (0.014)	0.052*** (0.011)	0.053*** (0.011)
	ex*07	0.056*** (0.012)	0.055*** (0.012)	-0.025* (0.014)	-0.025* (0.021)	0.081*** (0.011)	0.082*** (0.011)
	im*03	0.010 (0.019)	0.012 (0.019)	0.004 (0.021)	0.004 (0.021)	0.017 (0.014)	0.018 (0.014)
	im*04	0.061*** (0.019)	0.059*** (0.019)	0.030 (0.021)	0.029 (0.021)	0.034** (0.014)	0.034** (0.014)
	im*05	0.078*** (0.019)	0.078*** (0.019)	0.047** (0.020)	0.047** (0.021)	0.055*** (0.014)	0.056*** (0.014)
	im*06	0.047*** (0.019)	0.044** (0.019)	0.099*** (0.022)	0.103*** (0.022)	0.012 (0.013)	0.010 (0.013)
	im*07	0.074*** (0.019)	0.070*** (0.019	0.015 (0.000)	0.014 (0.000)	0.037*** (0.013)	0.035*** (0.013)
	bi*03	0.027*** (0.010)	0.027*** (0.010)	0.024* (0.012)	0.000 (0.012)	0.036*** (0.010)	0.036*** (0.010)
	bi*04	0.056*** (0.010)	0.056*** (0.010)	0.022* (0.013)	0.024* (0.013)	0.098*** (0.010)	0.098*** (0.010)
	bi*05	0.079*** (0.009)	0.079*** (0.009)	0.037*** (0.012)	0.022* (0.012)	0.129*** (0.010)	0.129*** (0.010)
	bi*06	0.050*** (0.009)	0.051*** (0.009)	0.006 (0.012)	0.037*** (0.012)	0.130*** (0.010)	0.131*** (0.010)
	bi*07	0.057*** (0.009)	0.057*** (0.009)	-0.002 (0.012)	0.007 (0.012)	0.154*** (0.010)	0.155*** (0.010)
	Industry	YES	YES	YES	YES	YES	YES
	Year	YES	YES	YES	YES	YES	YES
	R	0.215	0.215	0.214	0.214	0.216	0.216
	N	317,936	317,936	317,936	317,936	317,936	317,936

TABLE A1— REGRESSION RESULTS WITH DIFFERENT IMPORT/EXPORT RATIOS (CONT'D)

[3. THIRD PERIOD]

		15%		10%		20%	
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
3rd period	ex	-0.057***	-0.063***	-0.004	-0.006	0.064***	0.070***
		(0.012)	(0.012)	(0.013)	(0.013)	(0.008)	(0.008)
	im	-0.189***	-0.191***	-0.059***	-0.065***	-0.114***	-0.112***
		(0.014)	(0.015)	(0.016)	(0.016)	(0.013)	(0.013)
	bi	-0.009	-0.015	-0.068***	-0.075***	0.046***	0.047***
		(0.010)	(0.010)	(0.011)	(0.011)	(0.008)	(0.008)
	exit	-0.223***	-0.253***	-0.224***	-0.261***	-0.224***	-0.213***
		(0.004)	(0.012)	(0.004)	(0.014)	(0.004)	(0.007)
	exit_ex		0.039***		0.019		-0.033
			(0.013)		(0.017)		(0.007)
	exit_im		0.017		0.046**		-0.017
			(0.017)		(0.018)		(0.011)
	exit_bi		0.032**		0.046***		-0.006
			(0.013)		(0.015)		(0.014)
	ex*13	-0.026**	-0.025*	-0.064***	-0.063***	-0.034***	-0.035***
		(0.013)	(0.013)	(0.016)	(0.016)	(0.011)	(0.011)
	ex*14	-0.006	-0.003	-0.035**	-0.033**	-0.019*	-0.021*
		(0.013)	(0.013)	(0.016)	(0.016)	(0.011)	(0.011)
	ex*16	0.016	0.017	-0.073***	-0.072***	-0.085***	-0.086***
		(0.013)	(0.013)	(0.016)	(0.016)	(0.011)	(0.011)
	ex*17	0.045***	0.052***	-0.026	-0.023	-0.080***	-0.086***
		(0.013)	(0.013)	(0.016)	(0.016)	(0.011)	(0.011)
	im*13	-0.015	-0.014	-0.052***	-0.050***	-0.011	-0.011
		(0.017)	(0.017)	(0.018)	(0.018)	(0.015)	(0.015)
	im*14	-0.001	-0.000	-0.025	-0.021	-0.009	-0.011
		(0.018)	(0.017)	(0.018)	(0.018)	(0.015)	(0.015)
	im*16	0.016	0.017	-0.032*	-0.030	-0.042***	-0.043***
		(0.018)	(0.018)	(0.019)	(0.019)	(0.015)	(0.015)
	im*17	-0.004	-0.002	-0.018	-0.010	-0.081***	-0.084***
		(0.012)	(0.018)	(0.019)	(0.019)	(0.015)	(0.015)
	bi*13	-0.028**	-0.027**	-0.035***	-0.033***	-0.027***	-0.027***
		(0.012)	(0.012)	(0.013)	(0.013)	(0.009)	(0.009)
	bi*14	-0.014	-0.011	-0.011	-0.008	-0.028***	-0.028***
		(0.012)	(0.012)	(0.013)	(0.013)	(0.009)	(0.009)
	bi*16	-0.003	-0.002	0.028**	0.029**	-0.070***	-0.070***
		(0.012)	(0.012)	(0.013)	(0.014)	(0.009)	(0.009)
	bi*17	0.040***	0.045***	0.076***	0.083***	-0.034***	-0.035***
		(0.012)	(0.013)	(0.013)	(0.013)	(0.009)	(0.009)
	Industry	YES	YES	YES	YES	YES	YES
	Year	YES	YES	YES	YES	YES	YES
	R	0.23	0.23	0.229	0.229	0.230	0.230
	N	294,997	294,997	294,997	294,997	294,997	294,997

Note: 1) Figures in the parentheses denote the standard deviation, 2) Statistical significance levels: *** p<0.01, ** p<0.05 and * p<0.1.

TABLE A2— REGRESSION RESULTS WITH DIFFERENT METHODS

[1. FIRST PERIOD]

		Perpetual Inventory Method		Fixed effect Model	
		Model 7	Model 8	Model 9	Model 10
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
1st period	ex	-0.117*** (0.010)	-0.127*** (0.010)	0.004 (0.013)	0.006 (0.013)
	im	-0.141*** (0.012)	-0.138*** (0.012)	0.023 (0.015)	0.022 (0.015)
	bi	-0.111** (0.009)	-0.117*** (0.009)	-0.041*** (0.010)	-0.040*** (0.010)
	exit	-0.154*** (0.003)	-0.186*** (0.006)	0.009*** (0.003)	-0.001 (0.007)
	exit_ex		0.063*** (0.008)		0.015* (0.009)
	exit_im		-0.020* (0.010)		-0.005 (0.012)
	exit_bi		0.037*** (0.007)		0.013 (0.008)
	ex*92	0.022* (0.013)	0.022* (0.013)	0.035*** (0.010)	0.033*** (0.010)
	ex*93	0.041*** (0.012)	0.040*** (0.012)	0.047*** (0.010)	0.045*** (0.010)
	ex*94	-0.010 (0.012)	-0.014 (0.012)	0.014 (0.010)	0.010 (0.011)
	ex*95	-0.059*** (0.012)	-0.060*** (0.012)	-0.016 (0.011)	-0.020* (0.011)
	ex*96	-0.052*** (0.012)	-0.055*** (0.013)	0.003 (0.011)	-0.020* (0.011)
	ex*97	-0.114*** (0.013)	-0.118*** (0.015)	-0.063*** (0.011)	-0.069*** (0.012)
	im*92	-0.028* (0.015)	-0.028* (0.015)	-0.033*** (0.012)	-0.032*** (0.012)
	im*93	-0.095*** (0.015)	-0.095*** (0.015)	-0.084*** (0.013)	-0.084*** (0.013)
	im*94	-0.077*** (0.015)	-0.077*** (0.015)	-0.068*** (0.013)	-0.067*** (0.013)
	im*95	-0.035** (0.015)	-0.035** (0.015)	-0.017 (0.013)	-0.016 (0.013)
	im*96	-0.015 (0.015)	-0.014 (0.015)	0.010 (0.013)	0.012 (0.014)
	im*97	-0.035** (0.016)	-0.034** (0.016)	-0.038*** (0.014)	-0.036** (0.015)
	bi*92	0.001 (0.012)	0.001 (0.012)	0.002 (0.009)	0.001 (0.009)
	bi*93	0.007 (0.011)	0.006 (0.011)	0.009 (0.009)	0.007 (0.009)
	bi*94	0.012 (0.011)	0.009 (0.011)	0.013 (0.009)	0.010 (0.010)
	bi*95	0.047*** (0.011)	0.046*** (0.011)	0.060*** (0.010)	0.056*** (0.010)
	bi*96	0.062*** (0.011)	0.059*** (0.011)	0.065*** (0.010)	0.061*** (0.010)
	bi*97	0.045*** (0.011)	0.042*** (0.011)	0.035*** (0.010)	0.030*** (0.011)
	Industry	YES	YES	YES	YES
	Year	YES	YES	YES	YES
	R	0.421	0.421	0.243	0.243
	N	310,900	310,900	108,310	108,310

TABLE A2— REGRESSION RESULTS WITH DIFFERENT METHODS (CONT'D)

[2. SECOND PERIOD]

		Perpetual Inventory Method		Fixed effect Model	
		Model 7	Model 8	Model 9	Model 10
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
2nd period	ex	-0.106*** (0.009)	-0.103*** (0.009)	-0.027** (0.013)	-0.028** (0.013)
	im	-0.202*** (0.014)	-0.183*** (0.014)	0.036 (0.027)	0.035 (0.027)
	bi	-0.102*** (0.008)	-0.105*** (0.008)	-0.029** (0.013)	-0.029** (0.013)
	exit	-0.179*** (0.003)	-0.179*** (0.006)	-0.016*** (0.003)	-0.012** (0.006)
	exit_ex		-0.016* (0.010)		-0.015 (0.010)
	exit_im		-0.110*** (0.014)		-0.010 (0.016)
	exit_bi		0.019*** (0.007)		-0.001 (0.008)
	ex*03	0.002 (0.012)	0.002 (0.012)	0.013 (0.009)	0.015 (0.009)
	ex*04	0.004 (0.012)	0.004 (0.012)	0.020** (0.009)	0.022** (0.009)
	ex*05	0.012 (0.012)	0.012 (0.012)	0.021** (0.009)	0.024** (0.009)
	ex*06	0.023* (0.012)	0.022* (0.012)	0.024*** (0.009)	0.028** (0.010)
	ex*07	0.054*** (0.012)	0.053*** (0.012)	0.043*** (0.010)	0.047*** (0.010)
	im*03	0.001 (0.018)	0.003 (0.018)	-0.020 (0.013)	-0.018 (0.014)
	im*04	0.051*** (0.019)	0.049*** (0.019)	0.016 (0.014)	0.017 (0.014)
	im*05	0.058*** (0.018)	0.058*** (0.018)	0.038*** (0.014)	0.040*** (0.015)
	im*06	0.042** (0.018)	0.039*** (0.018)	0.017 (0.014)	0.020 (0.015)
	im*07	0.068*** (0.018)	0.063*** (0.009)	0.027* (0.015)	0.030* (0.015)
	bi*03	0.025*** (0.009)	0.025*** (0.009)	0.017** (0.007)	0.017** (0.007)
	bi*04	0.061*** (0.009)	0.061*** (0.009)	0.041*** (0.007)	0.041*** (0.007)
	bi*05	0.085*** (0.009)	0.085*** (0.009)	0.046*** (0.007)	0.046*** (0.007)
	bi*06	0.069*** (0.009)	0.070*** (0.009)	0.030*** (0.007)	0.031*** (0.007)
	bi*07	0.077*** (0.009)	0.077*** (0.009)	0.021*** (0.007)	0.021*** (0.008)
	Industry	YES	YES	YES	YES
	Year	YES	YES	YES	YES
	R	0.352	0.353	0.042	0.042
	N	308,808	308,808	99,779	99,779

TABLE A2— REGRESSION RESULTS WITH DIFFERENT METHODS (CONT'D)

[3. THIRD PERIOD]

		Perpetual Inventory Method		Fixed effect Model	
		Model 7	Model 8	Model 9	Model 10
		Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
3rd period	ex	-0.037*** (0.012)	-0.045*** (0.012)	-0.025 (0.020)	-0.023 (0.020)
	im	-0.179*** (0.014)	-0.185*** (0.014)	0.034 (0.027)	0.034 (0.027)
	bi	-0.011 (0.010)	-0.015 (0.010)	0.001 (0.016)	0.001 (0.016)
	exit	-0.160*** (0.004)	-0.194*** (0.012)	-0.040*** (0.005)	-0.060*** (0.014)
	exit_ex		0.049*** (0.014)		0.040** (0.016)
	exit_im		0.039** (0.018)		0.014 (0.021)
	exit_bi		0.028** (0.013)		0.010 (0.016)
	ex*13	-0.029** (0.012)	-0.027 (0.012)	-0.015* (0.009)	-0.018** (0.009)
	ex*14	-0.021* (0.012)	-0.017 (0.012)	-0.001 (0.009)	-0.005 (0.009)
	ex*16	0.003 (0.013)	0.005 (0.013)	0.030*** (0.009)	0.023** (0.009)
	ex*17	0.028** (0.013)	0.035*** (0.017)	0.053*** (0.009)	0.049*** (0.009)
	im*13	-0.009 (0.013)	-0.008 (0.017)	0.003 (0.012)	0.002 (0.012)
	im*14	-0.023 (0.017)	-0.020 (0.018)	0.009 (0.012)	0.008 (0.012)
	im*16	0.006 (0.017)	0.008 (0.018)	0.055*** (0.013)	0.053*** (0.013)
	im*17	0.011 (0.018)	0.017 (0.018)	0.056*** (0.013)	0.055*** (0.013)
	bi*13	-0.035*** (0.018)	-0.034*** (0.012)	-0.028*** (0.008)	-0.029*** (0.008)
	bi*14	-0.019 (0.012)	-0.016 (0.012)	-0.020** (0.009)	-0.021** (0.009)
	bi*16	-0.003 (0.012)	-0.001 (0.012)	-0.001 (0.009)	-0.003 (0.009)
	bi*17	0.039*** (0.012)	0.044*** (0.012)	0.033*** (0.009)	0.032*** (0.009)
	Industry	YES	YES	YES	YES
	Year	YES	YES	YES	YES
	R	0.349	0.349	0.061	0.061
	N	270,010	270,010	100,056	100,056

Note: 1) Figures in the parentheses denote the standard deviation, 2) Statistical significance levels: *** p<0.01, ** p<0.05 and * p<0.1.

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