Product dynamics and Trade liberalization: Evidence from the Korea-US FTA*

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Abstract

This study examines resource reallocation within firms by investigating how firms change their product portfolios in response to a fall in trade costs. Using Korean firm-product data, we show that firms experiencing large tariff reductions under the Korea-US free trade agreement are more likely to shrink their product scope. They not only decrease the number of products but also specialize their production in specific products. Furthermore, we show that those specific products are relatively more productive than others within firm by estimating a firm-product efficiency. Dropped and added products tend to be less efficient than incumbent products. However, given the sharp increase in added products' efficiencies after they enter, the above result may not indicate the low efficiency of new products, but rather the time needed to become organized and profitable. After considering the production distributions of incumbent products within firms, this study finds that firms tend to increase the proportion of efficient products in response to tariff reductions. In other words, firms allocate resources from less efficient products to more efficient ones.

Key words: Multi-product firms, Product mix, Product scope, Tariffs, KORUS FTA

JEL classification: F10, F15, L11, L25

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1. Introduction

Resource allocation is an important issue in economics, given the need to achieve economic growth under the constraint of exhaustible resources. Although product churning within firm takes place frequently and explains a large part of economic growth (Bernard et al., 2010; Goldberg et al., 2010), most studies focus on firm turnover within industry. However, considering that multi-product firms account for the majority of output in the Korean economy[1], this study examines product churning within firm rather than firm turnover within industry. Because of changes in product prices, marginal costs, and market competition due to shocks in trade costs, several researchers have studied how firms change their product scope when trade costs fall (Baldwin and Gu, 2009; Bernard et al., 2011; Berthou and Fontagn*é*, 2013*;* Iacovone and Javorcik, 2010). However, to examine which products are switched and expanded in firms (i.e., qualitative changes in the product mix) is important to understand the resource reallocation within firm as well as to investigate quantitative changes in product scope. Nevertheless, few studies examine the characteristics of dropped products by utilizing product sales as a proxy for product competence (Bernard et al., 2010; Liu, 2010; Ma et al., 2014). Furthermore, previous studies are silent about which products are added, grow, and shrink, although product churning includes all four activities: dropping and adding products as well as increasing and decreasing the production of incumbent products. Instead of the proxy variable, we estimate firm-product efficiency and explore whether firms increase the production of more efficient products by considering all churning activities. This study thus contributes to the literature by examining not only the changes in firms' product scope in response to the

[1] Although multi-product firms account for only 16% of Korean manufacturing firms, they are responsible for more than 70% of total output.

reduction in trade costs but also the relation between product churning and firm-product efficiency, a topic overlooked in previous studies.

To deepen our understanding of product churning patterns, this study investigates how Korean manufacturing firms react to a reduction in trade costs. In relation to the Korea-US Free Trade Agreement (KORUS FTA) of 2012[2], a large change occurred in the Korean trade environment that should have affected firms' resource reallocation. Given that the United States was Korea's second largest export market and third largest import market in 2011, the effects of KORUS FTA on Korean firms' product portfolios are expected to be larger than those of other FTAs in Korea[3]. Figure 1 shows the trend in average US tariff rates on Korean manufacturing imports (solid line) and the most-favored-nation tariff rate (dashed line) in 2008–2016. In 2011, the average US tariff rate for Korea was 3.5%. Under KORUS FTA, the tariff rate sharply decreased by 90% from 2011 to 2016, falling to 0.36%. In addition to the tariff reductions, both countries also eliminated any administrative fees for trade[4].

KORUS FTA is not only limited to the trade of goods; it also creates new market access to investment, telecommunications, express delivery, and legal consulting services[5].

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2 KORUS FTA took effect on March 15, 2012.

3 Following the FTA with Chile in 2004, Korea has actively agreed FTAs with several trade partners. By June 2018, Korea had signed 16 FTAs: Chile in 2004, Singapore in 2006, Ireland, Liechtenstein, Norway, and Switzerland in 2007, ASEAN (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam) in 2007, India in 2010, Peru in 2011, the United States in 2012, Turkey in 2013, Australia in 2014, Canada in 2015, China in 2015, New Zealand in 2015, Vietnam in 2015, the EU (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Spain, Slovakia, Slovenia, Sweden, and the United Kingdom) in 2015, and Colombia in 2016. Although Korea contracted an FTA in 2015 with China, the largest exporting and importing market for Korea, because of the lack of data after 2017, we do not examine the effects of the China-Korea FTA on firms' product churning in this study.

4 Article 2.10 describes this as follows: "*Neither Party require consular transactions, including related fees and charges… Neither Party may adopt or maintain a merchandise processing fee on originating goods*."

5 According to Article 11.3, the United States treats investments from Korea the same as those from in-state investors.

Furthermore, given that both China and Japan, which are the major competitors in exports to the United States, have not signed any FTAs with the United States, the effects of KORUS FTA on Korean firms seem to be large.

To assess how Korea's exports change in this period, we examine the export amount and number of exported products in 2011 and 2016 using data from the International Trade Centre. Table 1 reports the exports to Korea's top three export destinations in 2011 and to the world. Korea's exports to the United States show the highest increases in both the export amount and the number of exported products, highlighting the considerable effects of KORUS FTA on Korea's exports. Given the importance of the United States to Korean trade and substantial reduction in trade costs between the two countries in 2012, we therefore examine how Korean firms reassigned their product portfolios between 2011 and 2016[6].

Before investigating the qualitative changes within firms, we examine whether firms increase or decrease their product scope. Using Korean firm-product-level data, we investigate changes in the number of produced products and distribution of product sales within firms. After examining the quantitative changes in product portfolios, we examine the relation between product churning and firm-product efficiency. While previous studies explore the relation between the probability of dropping a product and that product's size (Bernard et al., 2010; Tan et al., 2015), we utilize firm-product efficiency by estimating the single- and multi-product production functions of Foster et al. (2008) and Dhyne et al. (2017), respectively. Furthermore, we contribute to the literature by examining the characteristics of not only the dropped product but also the added, growing, and shrinking products to consider the whole

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[6] The largest decline occurred in 2012 when KORUS FTA came into effect. However, since it takes time to reallocate products, we investigate changes in the product mix between 2011 and 2016.

process of product churning. Hence, with these estimated firm-product efficiencies, we investigate whether less efficient products are more likely to be switched and whether more efficient products show higher growth within firms. This study thus contributes to the literature by investigating the mechanism of product churning within firms in response to tariff reductions.

The results show that firms that experience larger tariff reductions are more likely to shrink their product scope by decreasing the number of produced products and focusing their production on specific products. The estimation results on firm-product efficiencies shed light on how firms reassign their inputs in response to falling trade costs. The results report that firms tend to drop and add relatively less efficient products. We additionally trace the efficiencies of added products and find a sharp increase in their efficiencies after they start to be produced. In other words, the former results show that it takes time for new products to become organized and profitable. Therefore, the low level of added products' efficiencies when they enter does not indicate that firms become less productive by adding new products. Among incumbent products, the sales of more efficient products and their share within firms rise when trade costs fall. Considering the churning in both switched and incumbent products, we find that firms are more likely to increase their output of efficient products as trade costs decrease. This finding indicates that firms tend to decrease their product scope in response to tariff reductions by shrinking and dropping less efficient products and reallocate resources from those products to more efficient ones.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data and summary statistics of the Korean firm-product data. Section 4 investigates the estimation of changes in firms' product scope and the relationship between firm-product efficiency and product churning in response to a reduction in trade costs. Section 5 concludes.

2. Literature

The literature on product churning has expanded with the availability of firm-product-level data as well as the growing importance of multi-product firms and product churning in economies. According to Bernard et al. (2010), 39% of US manufacturing firms produce more than two products and those firms account for 87% of manufacturing output. The prevalence and importance of multi-product firms have also been shown in developing countries such as India[7] (Goldberg et al., 2010). Given that more than half of all manufacturing firms add or drop products every five years (Bernard et al., 2010; Goldberg et al., 2010), active product churning is not limited to multi-product firms; single-product firms switch their product mix as well.

Given the effects of changes in trade costs on a product's prices, costs, and market competition, several studies have examined the response of firms to trade cost shocks. Most theoretical studies predict that firms decrease their product scope when trade costs fall (Bernard et al., 2011; Eckel and Neary, 2010; Mayer et al., 2011). Several empirical studies find evidence that supports the arguments from these models. Bernard et al. (2011) show that US manufacturing firms that experience above-median tariff reductions through the Canada-US FTA decrease their product scope relative to firms experiencing below-median reductions. The shrinkage of the product scope is also shown in small Canadian firms under the bilateral tariff

[7] Indian multi-product firms account for 47% of manufacturing firms and 80% of manufacturing output.

reduction between Canada and the United States (Baldwin and Gu, 2009)[8].

Studies of product churning examine how firms reallocate their resources when trade costs change. Several theoretical studies investigate the mechanism of firms' product churning decisions. Most predict that firms specialize in their most competent products in response to falling trade costs and increased competition in the domestic market (Bernard et al., 2011; Eckel and Neary, 2010; Mayer et al., 2011). Theoretical studies characterize production costs within firms by defining a core product as one that has the lowest marginal cost. According to the models, a firm's product scope expands from the core product, since the farther is the distance from the core product, the higher is the marginal cost. Therefore, as domestic market competition increases, firms are more likely to drop peripheral products that have the highest marginal cost. Several empirical studies find a tendency to skew production to the core product within firms and a higher exit rate for peripheral products (Bernard et al., 2010; Liu, 2010; Ma et al., 2014). As a proxy variable for a product's competence, they utilize relative product sales by assuming that the core product accounts for the largest proportion of sales within firms. However, the size does not precisely capture products' competence within firms, since low marginal costs in theoretical studies indicate high efficiencies as opposed to relatively large sales. Although products' size and efficiency may be positively related, researchers cannot identify whether a large size is driven by the high productivity or the large quantity of inputs. In other words, the relative size is a vague variable in that it cannot separate products that have low efficiencies and need many input resources from those having high efficiencies that need small input resources to produce one unit of the product. Investigating the efficiencies of

[8] However, since the reduction in trade costs increases both market competition in domestic countries and market access to foreign countries, the effects on firms' product scope differ according to a firm's productivity (Dhingra, 2013; Qiu and Zhou, 2013), a firm's export activity (Lopresti, 2016; Nocke and Yeaple, 2014), and the destination of products (Berthou and Fontagné, 2013; Iacovone and Javorcik, 2010).

churned products, thus, sheds light on how firms reallocate their resources and reorganize their product portfolios.

Different from previous research, this study measures firm-product efficiency and investigates whether the production volume of less efficient products shrunk when the United States decreased tariff rates on Korean imports. We measure firm-product efficiency using two methodologies: a single-product production function and a multi-product production function. For the estimation, firm-product-level input variables are needed but only firm-level input data are available. To capture the firm-product-level inputs, Foster et al. (2008) allocate firms' inputs to each product as a proportion of the product's revenue share and estimate the single-product production function. Instead of measuring the inputs for each product as a proportion of their sales share, Dhyne et al. (2017) control for other product sales within the same firms in a production equation and estimate the multi-product production function based on the models of Diewert (1973) and Lau (1976). Different from the single-product production function, the multi-product production function does not directly restrict the input information but considers the production of other products within the same firm. In the empirical estimation, we estimate both production functions and utilize two estimated firm-product efficiencies. With these estimated firm-product efficiencies, we then investigate whether dropped or added products have lower efficiency than incumbent products within the same firms. Furthermore, we examine whether efficient products grow or shrink under firms' product churning.

3. Data

To investigate product churning within firm, we utilize Korean plant-product data, the Mining and Manufacturing Survey (MMS) from Statistics Korea for 2008–2016 except for 2010 and

2015[9]. Statistics Korea annually surveys plants in Korean mining and manufacturing sectors with at least 10 workers. The MMS includes information on a plant's inputs, outputs, and firm identification number (ID). The output information contains a plant's total sales, a set of produced products, and the sales of each product. To control for a plant's global activity[10], we additionally utilize the plant's export data from the Korea Customs Service, because the information on the plant's export activity is not included in the MMS[11]. Although we utilize plant data, decisions about product portfolios and resource reallocation tend to be made at the firm level rather than the plant level. Therefore, we aggregate the plant information to the firm level by using the ID of the firms to which the plants belong.

Before introducing the empirical model, we briefly examine the characteristics of multi-product firms and product churning in Korea. We define a product based on the eight-digit KSIC (Korea Standard Industry Classification) categories. Four-digit and two-digit KSIC categories are used to define industry and sectors, respectively. For example, an industry of Handbags, Luggage, and Other Protective Cases (KSIC 1512) consists of eight product categories: Handbag (KSIC 15121101), Purse (KSIC 15121102), Briefcase (KSIC 15129101), Suitcase (KSIC 15129102), School bag (KSIC 15129103), Hiking bag (KSIC 15129104), Other bag (KSIC 15129109), and Case (KSIC 15129200). According to these definitions, Korean manufacturing consists of 24 sectors, 180 industries, and 2,139 products[12]. We define a firm that produces more than two products as a multi-product firm.

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[9] Statistics Korea did not publish the MMS in 2010 and 2015 when the Economic Census was carried out.

[10] Globalized firms tend to expand their product scope in response to changes in trade costs (Lopresti, 2016; Nocke and Yeaple, 2014).

[11] By combining the two data sets by matching the plant's ID, we can identify an exporting plant and control for that characteristic.

[12] In Bernard et al. (2010), US manufacturing is composed of 20 sectors, 455 industries, and 1,440 products according to SIC (Standard Industry Classification) categorization. They use the first five digits of the SIC to define a product.

By employing the abovementioned definitions, we examine the prevalence of multi-product, -industry, and -sector firms in 2008–2016 in Table 2. Multi-product firms account for only 16% of Korean manufacturing firms but produce 71% of manufacturing output. Hence, although the number of multi-product firms is small, they represent a large proportion of the Korean economy. The last column of Table 2 indicates that multi-product firms produce 2.66 products on average. Multi-industry and multi-sector firms account for only 10% and 6% of firms, but explain 59% and 49% of manufacturing output, respectively.

To see how firms organize their product mix, we examine the distribution of product sales within firms. In the last column of Table 3, we merge all firms producing more than 10 products into one group. The distribution of sales across products is skewed towards a firm's core product (i.e., the highest ranked product). The largest product accounts for more than 70% of sales for firms producing two products and that share decreases gradually to 40% for firms with nine products. The distribution of products except for the highest ranked one is relatively constant across the number of products produced by firms.

Table 4 shows the activeness of Korean manufacturing firms' product switching between 2011 and 2016 by separating firms into four groups. The sample is restricted to firms that survived in both 2011 and 2016. The first group, *None*, includes firms which neither add nor drop any products between 2011 and 2016. The *Drop only* and *Add only* groups contain firms that only drop or only add products, respectively. Lastly, firms that both add and drop products are classified into the *Both* group. In other words, the firms not included in the *None* group switch their product mix in these periods. Table 4 describes firms' product switching activity in the first row and the switching activity weighted by firms' output share in the second row. On average, 39% of Korean manufacturing firms switch their product portfolios between 2011 and 2016. Among all firms, 4.8% only drop products, 6.7% only add new products, and 27.5% both drop and add products during the study period. When we employ weights using the output share in the second row, the share of firms that switch their products, 77.6%, becomes much larger than that before weighted. The results in the second row indicate that firms with large output shares change their sets of products more actively than those with small output shares.

For the tariff data, we utilize the US tariff rates on Korean imports obtained from the US International Trade Commission. These tariff rates are reported using the eight-digit Harmonized Tariff Schedule of the United States (HTS-US) code. We aggregate these eight-digit tariff rates at the six-digit level using eight-digit US imports from Korea in 2011. For example, trunks, suitcases, vanity & attaché cases, occupational luggage, and similar containers (HTS 420212) consist of trunks, suitcases, vanity & attaché cases, occupational luggage, and similar containers *with an outer surface of* plastic (HTS 42021220), cotton (HTS 42021240), fibers (HTS 42021260), and textiles (HTS 42021280). The tariff rates on those eight-digit-level products in 2011 are 20%, 6.3%, 5.7%, and 17.6%, respectively. US imports for the four products from Korea in 2011 are valued at USD 62,000, 5,000, 10,000, and 105,000, respectively. Thus, the weighted average tariff rate for trunks, suitcases, vanity & attaché cases, occupational luggage, and similar containers (HTS 420212) in 2011 is about 17.5% ($= 20\%*\frac{62}{182} + 6.3\%*\frac{5}{182} + 5.7\%*\frac{10}{182} + 17.6\%*\frac{105}{182}$). Since the tariff rate from the US International Trade Commission and product data in the MMS are reported using two different classification codes (i.e., HTS and KSIC), we match these two classifications at the most disaggregated level, namely the five-digit KSIC level[13].

[13] Since the first six digits of the HTS code take the same form as those of the Harmonized System (HS) code, we match the six-digit HS code to the five-digit KSIC code.

Using the product-level tariff rate data, we measure the change in the firm-specific tariff rate as the sales-weighted tariff change placed on firm i between 2011 and 2016:

(1) $\Delta Tariff_i = \sum_g share_{ig}^{2011} * \Delta Tariff_g$

where $share_{ig}^{2011}$ is the share of the sales of goods g (at the five-digit level) by firm i in 2011. $\Delta Tariff_g$ (=$Tariff_g^{2016} - Tariff_g^{2011}$) represents the US tariff rate changes on Korean manufacturing imports for goods g between 2011 and 2016. Since the goods produced by firm i do not experience the same tariff changes and they have different degrees of importance within the firm, the weighted average tariff reductions capture the difference in changes well. On average, firms experience a -2.14 percentage point tariff rate change between 2011 and 2016 with a standard deviation of 2.80 percentage points. The largest tariff rate reduction faced by firms is -21.98 percentage points.

4. Empirical Evidence

4-1 Firms' Product Scope

This section examines the changes in the number of manufactured products and product diversification to assess how firms adjust their product scope in the period of KORUS FTA application. The diversification variable is measured as one minus the sum of the squared product sales share within firms[14] (Lopresti, 2016). This index captures not only the number of produced products but also the distribution of product sales in the product mix. In other

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[14] $Diversification_{it} = 1 - \sum_{p=1}^{P} \left(\frac{Sales_{pit}}{\sum_{p=1}^{P} Sales_{pit}} \right)^2$ where *i* is the firm, *t* is the year, and *p* (*p=1,…, P*) is the eight-digit-level product produced by firm *i*.

words, the diversification index increases when a firm diversifies its product mix by raising the number of products or widening the distribution of product sales. Equation (2) reports the estimation model for the changes in firms' product scope in response to tariff reductions:

(2) $\Delta Y_i = a_0 + a_1 \Delta Tariff_i + a_2\, ln(TFP_i) + a_3\, ln(L_i) + a_4\, ln(Age_i) + a_5 Export_i + a_6 Multi - product_i + a_7 \Delta IP_j + e_i$

The dependent variable, ΔY_i, is the change in the number of eight-digit-level products produced by firm *i* (or the change in the product diversification of firm *i*) between 2011 and 2016. If firm *i* reduces (increases) the number of products, then the dependent variable takes a negative (positive) value. $\Delta Tariff_i$ is the change in firm *i*'s specific tariff rate between 2011 and 2016. TFP_i is firm *i*'s value-added total factor productivity (TFP) measured by the Cobb–Douglas production function with a two-thirds labor share in 2011. L_i is the number of permanent workers and Age_i is the age of firm *i* in 2011. $Export_i$ and $Multi - product_i$ are dummy variables that take the value of 1 if firm *i* exports and produces more than two products in 2011, respectively; otherwise, they are 0. ΔIP_j is the change in import penetration between 2011 and 2016 in the four-digit-level industry *j* to which firm *i* belongs[15].

Table 5 presents the summary statistics of the explanatory variables. On average, firms experience -2.137 percentage point changes in the firm-specific tariff rate. The average number of permanent workers is 60 and mean value of firms' age is 15 years. About 35% of firms in the sample export and 19% manufacture more than two products in 2011. The mean change in the import penetration variable has a small negative value, implying that, on average, the

[15] $IP_j = (\frac{M_j}{M_j+Q_j})$, where M_j is the total value of Korean imports in the four-digit-level industry *j* and Q_j is total plant sales in industry *j*.

increase in import penetration is not severe.

Column (1) of Table 6 shows how firms change the number of their products in response to tariff reductions. The coefficient of the firm-specific tariff change variable is positive and statistically significant. This finding indicates that firms facing large tariff reductions are more likely to reduce the number of manufactured products. Column (2) reports the change in product diversification upon tariff reduction. The tariff change variable has a positive and significant coefficient as well. The result shows that firms experiencing large tariff reductions tend to specialize their production in specific products. Considering that the reduction in trade costs increases market competition in the home country, we can infer that firms focus on their competent products and drop less competent products. In the next section, we check whether firms drop less efficient products and specialize in more efficient products by estimating firm-product efficiency.

Table 6 shows that firms facing large tariff reductions are more likely to shrink their product scope by decreasing the number of products and focusing their production on specific products[16]. Since we utilize a sample of surviving firms between 2011 and 2016, we also conduct an additional estimation including exiting firms. The results are similar to those in Table 6[17]. For the results of the other variables in Table 6, the coefficients of firms' general characteristics show that large or young firms are more likely to expand their product scope. The coefficients of the TFP and export dummy variables do not have significant coefficients.

[16] Since tariff reductions induce heterogeneous effects on product scope by increasing both market competition in the domestic country and market expansion into foreign countries, we examine these different effects by interacting the tariff change variables and firms' TFP (Dhingra, 2013; Qiu and Zhou, 2013) or export dummy variables (Lopresti, 2016; Nocke and Yeaple, 2014). However, the interaction terms do not have statistically significant coefficients.

[17] The estimation is limited to the change in the number of products because the diversification index cannot be measured with one period's production information. The estimation result is available upon request.

The coefficients of the multi-product firm variables indicate that such firms tend to decrease their product scope relative to single-product firms[18]. Lastly, the changes in the import penetration variable do not significantly affect firms' product scope.

While Table 6 shows that Korean firms experiencing larger tariff reductions under KORUS FTA are more likely to narrow their range of production, one concern about examining the change in firms' product scope remains: if this phenomenon was shown before KORUS FTA, it would be unrelated to changes in trade costs. To handle this issue, we check the placebo effect by regressing the changes in product scope between 2008 and 2011 on the tariff changes between 2011 and 2016 (see Table 7). The coefficients of the tariff changes variable are not statistically significant, showing no pre-trends in firms' product scope. In the next section, we examine which products are dropped and added and which products grow and shrink within firms by using the estimated firm-product efficiencies.

4-2 Relation between Product Churning and Firm-Product Efficiencies

In this section, we first examine whether less efficient products are more likely to be switched and then assess whether the production of more efficient incumbent products grows within firms when trade costs fall. According to the model of Bernard et al. (2011), as trade costs change, firms reallocate their resources by dropping less efficient and adding more efficient products. Empirical studies utilize product relative sales as a proxy variable for product efficiency by assuming that the most competent product accounts for the largest share of sales

[18] If a single-product firm drops its product, it means that the firm exits the market. We check the estimation results by dividing the sample into two groups: single- and multi-product firms. The coefficients of tariff changes only reach statistical significance in multi-product firms.

within firms (Bernard et al., 2010; Liu, 2010; Ma et al., 2014). Since sales depend on not only the efficiency but also the quantity of inputs, this study instead utilizes the firm-product efficiencies estimated from the two production functions.

Generally, productivity is defined as a residual that cannot be explained by the input factors in the production function:

(3) $Y = f(X) \cdot e^{w}$

where Y is output, $f(\cdot)$ is the production function, X is the input factors, and w is productivity (which is unobservable). To measure firm-product efficiency, information on the input factors at the firm-product level is needed. The key challenge to estimating firm-product efficiencies is the lack of input information on each product. Hence, how to capture firm-product-level inputs is critical. One study measuring firm-product efficiency utilizes the product's output share to distribute the firm's input factors at the firm-product level. Foster et al. (2008) allocate firms' input to each product as a proportion of the product's revenue share. Following their method, we estimate the single-product production function below:

(4) $ln(y_{pi}) = \alpha_0^p + \alpha_l^p ln(sh_{pi} * l_i) + \alpha_k^p ln(sh_{pi} * k_i) + \alpha_m^p ln(sh_{pi} * m_i) + e_{pi}$

where y_{pi} is the output of product p in firm i; sh_{pi} represents the sales share of product p in firm i; l_i, k_i, and m_i are the labor, capital, and material inputs of firm i; e_{pi} is composed of the specification error, n_{pi}, and the efficiency shock, w_{pi}. By interacting the firm-level inputs with the share of product sales, we estimate the single-product production function and obtain the residuals, firm-product efficiency (w_{pi}). Since the number of observations for an eight-digit-level product mix is insufficient for the estimation, we pool observations at the three-digit level (83). In the empirical estimation, the dependent variable is product p's sales (y_{pi}). To manage the between-industry price differences, we divide product sales based on the two-digit industry Output Price Indexes from the Bank of Korea. Although we control for cross-industry price differences, revenue-based productivity may positively relate to prices and thus, demand (Foster et al., 2008; Syverson, 2011). However, since this study investigates the effects of a change in trade costs, which relates to the opening up of the market and demand shifts, we utilize revenue-based productivity rather than quantity-based productivity[19]. As the input factors, we use the number of full-time workers (l_i), tangible fixed assets (k_i), and material inputs (m_i) of firm *i*. k_i and m_i are deflated with the two-digit-level sector deflator from the Bank of Korea. Since the output information about dropped (added) products is only available in 2011 (2016), the efficiency estimation of dropped (added) products utilizes the input and output information from the 2011 (2016) data.

However, allocating inputs using the product sales share could be a restrictive assumption since input intensity may differ across products. Hence, in the next estimation, we do not restrict the inputs directly but rather control for the sales of other products within the same firms. This method of measuring firm-product efficiency follows Dhyne et al. (2017) by estimating the following multi-product production function:

(5) $$ln(y_{pi}) = \beta_0^p + \beta_l^p ln(l_i) + \beta_k^p ln(k_i) + \beta_m^p ln(m_i) + \beta_{-pi}^p ln(y_{-pi}) + e_{pi}$$

This function differs from the single-product production function because it eliminates the interacted product sales share and instead includes the sales of other products in the same firms. In multi-product firms, since the sales of product p depend on not only firm i's inputs but also other products' outputs, the estimation aggregates the sales of all other products in firm *i*

[19] It would be better to check whether our results are robust with quantity-based productivity. However, our data only report a product's sales and not a product's quantity or price.

excluding those of product p, y_{-pi}[20]. By utilizing the multi-product production function, this study estimates another firm-product efficiency value. We report the estimation results of multi-product production function in the Appendix since the signs of coefficient of the inputs and the sales of other products have to be checked in the estimation of the multi-product production function[21]. Tables A1 and A2 describe the results of the top 10 three-digit goods according to the number of firm-product observations in 2011 and 2016, respectively. All the coefficients of the input factors are positive, whereas those of the sales of other products are negative, because as the sales of other products increase, the proportion of input factors to product *p* decreases. In short, Tables A1 and A2 show that all the coefficients have the correct sign.

Using the estimated firm-product efficiencies, we investigate which products a firm drops or adds between 2011 and 2016 by estimating the model in equation (6):

(6) $D_{pi} = c_0 + c_1 Efficiency_{pi} + \gamma_j + \delta_i + \varepsilon_{pi}$

The dependent variable, D_{pi}, takes the value of 1 if the eight-digit-level product *p* of firm i is dropped (added) following sharp tariff reductions. $Efficiency_{pi}$ is the estimated firm-product efficiency of product p in firm i in 2011 (2016). We use the two efficiency variables estimated from the single- and multi-product production functions. Four-digit-level industry, γ_j, and firm, δ_i, fixed effects are employed to capture the unobservable effects of industry and firm. We utilize standard errors clustered at the eight-digit product level.

Columns (1) and (2) of Table 8 show the efficiency of dropped products relative to that of

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[20] Since we use a product's sales as the output variable, we divide sales by the output price index as well.
[21] According to the models of Diewert (1973) and Lau (1976), the sales of product *p* are non-decreasing in the input factors holding the sales of other products (-*p*) constant and non-increasing in the sales of other products (-*p*) holding the input factors constant.

incumbent products. The negative coefficient of the firm-product efficiency variable estimated by the single-product production function in column (1) indicates that a product with lower efficiency has a higher probability of being dropped from firms' product mix. The result in column (2) for the multi-product production function looks similar. Columns (1) and (2) thus show that firms tend to drop less efficient products among their product portfolios in response to falling trade costs. Columns (3) and (4) describe the relative efficiencies of added products. Both the efficiency variables report significantly negative coefficients, meaning that added products tend to have lower estimated efficiencies than incumbent products. However, the low efficiencies of added products do not coincide with the prediction of Bernard et al. (2011).

When we consider the time needed for new products to become organized and profitable, columns (3) and (4) of Table 8 may not imply that added products are less efficient than incumbent products. Thus, we trace the increase in the efficiency and output of added products. In Table 9, we regress the changes in efficiencies, the log of product sales, and the sales share between 2013 and 2016 on the added product dummy, which takes a value of 1 if a product is added between 2011 and 2013. The coefficients of this added product dummy variable in columns (1) and (2) indicate that they show a higher increase in efficiencies than incumbent products after they start to be produced. Columns (3) and (4) show that added products' outputs increase more sharply than those of incumbent products. Although added products seem to have lower efficiency than incumbent products as shown in Table 8, the efficiency of added products may be comparable with that of incumbent products when they are organized properly. In other words, firms may not become less productive by adding new products.

Since resource reallocation also occurs among incumbent products, we next examine the relation between firm-product efficiencies and the change in the proportion of incumbent products within firms (see columns (1)–(4) of Table 10). We regress the increase in products' importance within firms between 2011 and 2016 on firm-product efficiencies in 2016. A product's importance is measured by the log of product sales and product sales share within firms. The coefficients of the efficiency variables indicate the growth of more efficient products and shrinkage of less efficient products. Table 6 previously showed that firms facing large tariff reductions tend to specialize their production in specific products. Columns (1) to (4) suggest that those specific products may have high efficiencies relative to other products within firms. In other words, firms reassign their incumbent products by increasing the share of efficient products in response to tariff reductions.

Lastly, considering both switched and incumbent products, we investigate the relation between product churning and product efficiencies within firms in columns (5)–(8) of Table 10[22]. For the dependent variables, we utilize the growth in product sales and sales share. The growth variable is the ratio of the output changes between 2011 and 2016 to the mean of the two periods' values (Davis and Haltiwanger, 1992), since the switched products only have output information from one period. Thus, the dropped and added products have the values of -2 and 2, respectively. The positive coefficients of the efficiency variables in columns (5)–(8) indicate that firms increase the proportion of more efficient products by reallocating their resources from less efficient products when trade costs fall.

5. Conclusion

Following the conclusion of KORUS FTA, the United States decreased its tariff rate on Korean

[22] The efficiencies of dropped products are measured using 2011 data and those of added and incumbent products are measured using 2016 data.

manufacturing imports by 90% between 2011 and 2016. This study examines how firms adjust their product portfolios in response to such a reduction in trade costs using Korean firm-product data.

First, we find that firms experiencing large tariff reductions are more likely to narrow their product scopes by reducing the number of manufactured products and specializing their production in some products. After investigating the quantitative changes in firms' product mix, we examine the efficiencies of dropped, added, growing, and shrinking products. Our estimation results show that dropped and added products are less efficient than incumbent products. However, given the high increases in efficiency and output of added products after they start to be produced relative to those of incumbent products, the former results suggest that time is needed for new products to become organized and profitable. Among incumbent products, more efficient products show higher increases in sales and in their sales share within firms. Considering both switched and incumbent products, we find that firms reallocate their resources by increasing the sales and sales share of efficient products in response to tariff reductions.

This study contributes to the literature by examining the mechanism of product churning within firms using estimated firm-product efficiencies and by considering all product churning activities (i.e., dropping, adding, expanding, and shrinking products) in response to tariff reductions. The results suggest that firms adjust their product mix as well as reallocate their resources. In addition, the empirical results on firms' responses to a reduction in trade costs have policy-relevant contributions with regard to the rise in protectionism globally. Strengthened protectionism may induce firms to restructure their product mix in the opposite way from that when trade costs fall.

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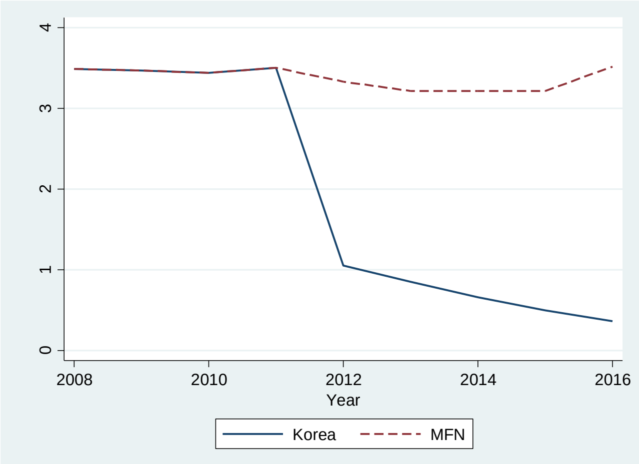
Figure 1. Trend in average US tariff rates, 2008–2016



Notes: Tariff rates are the average eight-digit (HTS)-level US tariff rates from the US International Trade Commission. Accessed May 10, 2018.

Table 1. Amount and number of exported products from Korea

To	United States	China	Japan	World
Amount of exports (US dollars, million)				
2011	56,421	134,185	39,679	555,208
2016	66,757	124,432	24,356	495,465
Growth	18%	-7%	-39%	-11%
Number of exported products (six-digit HS code)				
2011	3,047	3,646	3,375	4,514
2016	3,318	3,721	3,283	4,646
Growth	9%	2%	-3%	3%

Notes: Data from the International Trade Centre. Accessed October 19, 2018.

Table 2. Prevalence of multi-product, -industry, and -sector firms

Type of firm	Number of observations	Percentage of firms	Percentage of output	Mean products, industries, or sectors per firm
Multi-product	55,868	16.4	71.0	2.66
Multi-industry	34,498	10.2	59.1	2.31
Multi-sector	21,536	6.3	49.7	2.15

Notes: 2008–2009, 2011–2014, and 2016 data are used. 438,101 manufacturing firms. A product (industry or sector) is defined as the eight-digit (four- or two-digit) KSIC category. A multi-product (industry or sector) firm is a firm with more than two products (industries or sectors) in a year.

Table 3. Mean distribution of the product sales share within firms

		Number of products produced by a firm									
		1	2	3	4	5	6	7	8	9	10+
Average percentage of sales	1	100	71	59	52	49	45	44	45	40	30
	2		29	27	25	24	23	22	20	20	18
	3			14	14	14	14	13	12	13	13
	4				8	8	9	9	9	9	9
	5					5	6	6	6	7	7
	6						3	4	4	4	5
	7							2	3	3	4
	8								1	2	3
	9									1	2
	10+										1
Observations		247,028	31,605	9,473	3,311	1,361	626	327	145	66	390

Notes: 2008–2009, 2011–2014, and 2016 data are used. In the last column, all data are merged into one group for firms that produce more than 10 products.

Table 4. Product switching between 2011 and 2016

Firm activity (Observations)	None (17,476)	Drop only (1,362)	Add only (1,915)	Both (7,862)
Percentage of firms	61.0	4.8	6.7	27.5
Output-weighted percentage of firms	22.4	7.6	6.4	63.6

Notes: Continuing firms between 2011 and 2016 are used. The *None* group includes firms that neither add nor drop any products between 2011 and 2016. The *Drop only* and *Add only* groups contain firms that only drop or only add products, respectively. Firms that both add and drop products are classified into the *Both* group.

Table 5. Summary statistics of the explanatory variables

	Mean	Std. Dev.	Min	Max
ΔTariff	-2.137	2.802	-21.982	0.266
TFP	27.487	27.999	0.101	1314.559
L	60.094	698.882	1	87112
Age	14.594	9.751	1	86
Export	0.354	0.478	0	1
Multi-product	0.187	0.390	0	1
ΔIP	-0.00001	0.013	-0.040	0.333

Notes: $\Delta Tariff_i$ is the change in firm *i*'s specific tariff rate between 2011 and 2016. TFP_i is firm *i*'s value-added TFP measured by the Cobb–Douglas production function with a two-thirds labor share in 2011. L_i is the number of permanent workers and Age_i is the age of firm *I* in 2011. $Export_i$ and $Multi-product_i$ are dummy variables that take the value of 1 if firm *i* exports and produces more than two products in 2011, respectively; otherwise, they are 0. ΔIP_j is the change in import penetration between 2011 and 2016 in the four-digit-level industry *j* to which firm *i* belongs.

Table 6. Changes in product scope and tariff reductions

Variable	∆The number of products (1)	∆Diversification (2)
∆Tariff	0.005**	0.001**
	(0.002)	(0.0004)
ln(TFP)	0.008	-0.001
	(0.006)	(0.001)
ln(L)	0.100***	0.020***
	(0.011)	(0.001)
ln(Age)	-0.012**	-0.003*
	(0.006)	(0.002)
Export	-0.008	-0.001
	(0.010)	(0.002)
Multi-product	-0.505***	-0.169***
	(0.015)	(0.004)
∆IP	0.197	0.089
	(0.331)	(0.074)
Constant	-0.183***	-0.012
	(0.048)	(0.007)
Observations	28,489	28,489
R-squared	0.078	0.140

Notes: The dependent variable is the change in the number of eight-digit KSIC products produced by firm *i* (or the change in the product diversification of firm *i*) between 2011 and 2016. $\Delta Tariff_i$ is the change in firm *i*'s specific tariff rate between 2011 and 2016. TFP_i is firm *i*'s value-added TFP measured by the Cobb–Douglas production function with a two-thirds labor share in 2011. L_i is the number of permanent workers and Age_i is the age of firm *i* in 2011. $Export_i$ and $Multi-product_i$ are dummy variables that take the value of 1 if firm *i* exports and produces more than two products in 2011, respectively; otherwise, they are 0. ΔIP_j is the change in import penetration between 2011 and 2016 in the four-digit-level industry j to which firm i belongs. Numbers in parentheses are robust standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Placebo effect

Variable	∆The number of products (1)	∆Diversification (2)
∆Tariff	0.0001	0.0001
	(0.002)	(0.0003)
ln(TFP)	0.007	0.004***
	(0.005)	(0.001)
ln(L)	0.040***	0.017***
	(0.010)	(0.001)
ln(Age)	-0.018***	0.002
	(0.005)	(0.001)
Export	0.005	0.002
	(0.008)	(0.002)
Multi-product	-0.562***	-0.156***
	(0.013)	(0.003)
∆IP	0.699**	0.055
	(0.308)	(0.071)
Constant	-0.029	-0.049***
	(0.044)	(0.006)
Observations	30,458	30,458
R-squared	0.121	0.149

Notes: Dependent variables are changes in the number of products or the product diversification indices between 2008 and 2011. $\Delta Tariff_i$ is the change in firm i's specific tariff rate between 2011 and 2016. TFP_i is firm i's value-added TFP measured by the Cobb–Douglas production function with a two-thirds labor share in 2011. L_i is the number of permanent workers and Age_i is the age of firm *i* in 2011. $Export_i$ and $Multi-product_i$ are dummy variables that take the value of 1 if firm *i* exports and produces more than two products in 2011, respectively; otherwise, they are 0. ΔIP_j is the change in import penetration between 2011 and 2016 in the four-digit-level industry *j* to which firm *i* belongs. Numbers in parentheses are robust standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Efficiencies of the switched products

	Dropped products		Added products	
	(1)	(2)	(3)	(4)
Efficiency (Single)	-0.100***		-0.077***	
	(0.010)		(0.009)	
Efficiency (Multi)		-0.095***		-0.085***
		(0.008)		(0.008)
Constant	0.044	0.083	0.037	0.089
	(0.259)	(0.267)	(0.231)	(0.218)
Industry fixed effect	O	O	O	O
Firm fixed effect	O	O	O	O
Observation	30,363	30,363	31,328	31,328
R-squared	0.509	0.520	0.494	0.508

Notes: The dependent variable in columns (1) and (2) is 1 if a product is produced by a firm in 2011 but not produced in 2016 (in columns (3) and (4), this is 1 if a product is not produced by a firm in 2011 but produced in 2016) and it takes 0 if a product is produced both in 2011 and in 2016. *Efficiency (Single)* is the firm-product efficiency estimated by the single-product production function. *Efficiency (Multi)* is the firm-product efficiency estimated by the multi-product production function. All the columns include the four-digit-level industry and firm dummy variables. Numbers in parentheses are standard errors clustered at the eight-digit product level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9. Tracing the added products, 2013–2016

	Δ Efficiency (Single)	Δ Efficiency (Multi)	Δ ln(Sales)	Δ Sales share
	(1)	(2)	(3)	(4)
Added product	0.041	0.194***	0.229***	0.064***
	(0.068)	(0.083)	(0.087)	(0.018)
Constant	-0.622	-0.516	-0.272	0.007
	(0.385)	(0.757)	(0.863)	(0.259)
Industry fixed effect	O	O	O	O
Firm fixed effect	O	O	O	O
Observation	26,871	26,871	26,871	26,871
R-squared	0.673	0.639	0.606	0.039

Notes: The dependent variables are the changes in firm-product efficiencies, log of product sales, and product sales share between 2013 and 2016. The *Added product* variable is 1 if a product is not produced by a firm in 2011 but produced in 2013 and it takes 0 if a product is produced both in 2011 and in 2013. All the columns include the four-digit-level industry and firm dummy variables. Numbers in parentheses are standard errors clustered at the eight-digit product level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10. Product growth and efficiency

	Continuing products				All products			
	Growth in sales		Growth in the share of sales		Growth in sales		Growth in the share of sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Efficiency (Single)	0.636***		0.069***		0.160***		0.138***	
	(0.069)		(0.012)		(0.024)		(0.023)	
Efficiency (Multi)		0.565***		0.103***		0.112***		0.095***
		(0.043)		(0.011)		(0.020)		(0.020)
Constant	-1.357	-1.561	-0.299	-0.322	0.868	0.841	0.756	0.734
	(1.576)	(1.366)	(0.251)	(0.220)	(0.535)	(0.532)	(0.527)	(0.526)
Industry fixed effect	O	O	O	O	O	O	O	O
Firm fixed effect	O	O	O	O	O	O	O	O
Observation	26,517	26,517	26,517	26,517	50,457	50,457	50,457	50,457
R-squared	0.762	0.792	0.074	0.190	0.172	0.171	0.113	0.113

Notes: The sample in columns (1)–(4) consists of products produced both in 2011 and in 2016. Growth variables in columns (1)-(4) are measured by the log differences between 2011 and 2016. The growth variables in columns (5) and (6) are measured by the output changes between 2011 and 2016 divided by the mean of the two periods' values. *Efficiency (Single)* is the firm-product efficiency estimated by the single-product production function. *Efficiency (Multi)* is the firm-product efficiency estimated by the multi-product production function. For the efficiency of incumbent products, 2016 data are utilized. All the columns include the four-digit-level industry and firm dummy variables. Numbers in parentheses are standard errors clustered at the eight-digit product level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix

Table A1. Estimation results of the multi-product production function at the three-digit industry level in 2011

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	General Purpose Machinery	Plastic Products	Special-Purpose Machinery	Other Metal Products	Parts for Motor Vehicles	Other Food Products	Electrical Equipment	Other Chemical Products	Structural Metal Products	Cement, Lime, and Plaster
	291	222	292	259	303	107	281	204	251	233
l	0.149***	0.348***	0.284***	0.291***	0.251***	0.349***	0.091**	0.119**	0.207***	0.742
	(0.027)	(0.025)	(0.033)	(0.023)	(0.040)	(0.061)	(0.040)	(0.053)	(0.035)	(0.052)
k	0.072***	0.042***	0.050***	0.072***	0.109***	0.0001	0.055***	0.040	0.087***	0.046**
	(0.012)	(0.012)	(0.015)	(0.010)	(0.021)	(0.027)	(0.016)	(0.028)	(0.016)	(0.021)
m	0.680***	0.647***	0.594***	0.652***	0.614***	0.693***	0.718***	0.755***	0.713***	0.752***
	(0.017)	(0.016)	(0.019)	(0.014)	(0.025)	(0.042)	(0.026)	(0.030)	(0.022)	(0.029)
y_{-p}	-0.147***	-0.146***	-0.158***	-0.131***	-0.136***	-0.212***	-0.144***	-0.181***	-0.146***	-0.136***
	(0.004)	(0.003)	(0.004)	(0.003)	(0.005)	(0.009)	(0.005)	(0.007)	(0.005)	(0.007)
Observation	2,471	2,430	2,228	1,968	1,521	1,188	1,164	1,145	1,024	940

Notes: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A2. Estimation results of the multi-product production function at the three-digit industry level in 2016

	(1) General Purpose Machinery 291	(2) Plastic Products 222	(3) Special-Purpose Machinery 292	(4) Other Metal Products 259	(5) Parts for Motor Vehicles 303	(6) Other Food Products 107	(7) Other Chemical Products 204	(8) Electrical Equipment 281	(9) Structural Metal Products 251	(10) Cement, Lime, and Plaster 233
l	0.537***	0.722***	0.684***	0.583***	0.424***	0.467***	0.303***	0.522***	0.515***	0.284***
	(0.032)	(0.028)	(0.033)	(0.029)	(0.049)	(0.062)	(0.060)	(0.046)	(0.046)	(0.067)
k	0.062***	0.068***	0.057***	0.084***	0.233***	0.098***	0.165***	0.081***	0.145***	0.119***
	(0.015)	(0.014)	(0.016)	(0.013)	(0.029)	(0.034)	(0.031)	(0.021)	(0.022)	(0.028)
m	0.393***	0.324***	0.312***	0.397***	0.363***	0.398***	0.479***	0.342***	0.405***	0.560***
	(0.020)	(0.016)	(0.019)	(0.016)	(0.028)	(0.042)	(0.029)	(0.030)	(0.025)	(0.037)
y_{-p}	-0.151***	-0.140***	-0.155***	-0.131***	-0.154***	-0.188***	-0.161***	-0.145***	-0.139***	-0.153***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.010)	(0.008)	(0.006)	(0.007)	(0.008)
Observation	2,253	2,461	2,306	1,991	1,729	1,257	1,218	1,181	1,044	960

Notes: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.