Chapter 3

The Effects of Imported Intermediate Varieties on Plant Total Factor Productivity and Product Switching: Evidence from Korean Manufacturing

Yong-Seok Choi
Department of Economics, Kyung Hee University

Chin Hee Hahn
Korea Development Institute (KDI)

March 2010

This chapter should be cited as
Choi, Y.-S. and C. H. Hahn (2010), 'The Effects of Imported Intermediate Varieties on Plant Total Factor Productivity ad Product Switching: Evidence from Korean Manufacturing', in Hahn, C. H. and D. Narjoko (eds.), *Causes and Consequences of Globalization in East Asia: What Do the Micro Data Analyses Show?*. ERIA Research Project Report 2009-2, Jakarta: ERIA. pp.61-101.

CHAPTER 3

The Effects of Imported Intermediate Varieties on Plant Total Factor Productivity and Product Switching: Evidence from Korean Manufacturing

YONG-SEOK CHOI[1]
Department of Economics, Kyung Hee University

CHIN HEE HAHN[2]
Korea Development Institute (KDI)

By utilizing previously unexplored plant-product data on Korean manufacturing, and detailed import data during 1991~1998, this paper empirically investigates the role of imported intermediate varieties. Specifically, we investigated whether greater access to imported intermediate varieties enhanced plant total factor productivity and product switching behavior. First, as consistent with previous empirical studies using macro- and micro-data, we find that a plant that belongs to industries with higher imported intermediate variety growth experienced higher productivity growth. Secondly and perhaps more importantly, our empirical results suggest that increased imported intermediate varieties had a positive impact on stimulating the product-switching behavior of domestic plants. Since product-switching behavior (that is, simultaneously adding and dropping products) could be understood as a part of the continual process of "creative destruction" within plants, this result suggest that imported intermediate variety growth may be one of the channels through which resource reallocation within firms can be enhanced. Taking into account the fact that 68% of Korean plants (77% when weighted by shipments) are both adding and dropping products during our sample period, this finding is of greater empirical importance. Additionally, unlike a previous study for India, we found that imported intermediate variety growth has reduced the product scope (that is, the number of products) of domestic plants. Although this finding is not inconsistent with our finding related to product switching behavior, this suggests that imported intermediate variety growth may have different implications for industrial countries and developing countries.

---

[1] Associate Professor, Department of Economics, Kyung Hee University, choiy@khu.ac.kr
[2] Senior Research Fellow, Korea Development Institute, chhahn@kdi.re.kr

1. Introduction

There is wide agreement among trade and growth economists that international trade is one of the major conduits for knowledge spillovers across countries. Based on the endogenous growth models developed by Romer (1990) and Aghion and Howitt (1992), Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991) extended these frameworks into an open-economy context. In these macroeconomic models, international trade both in final goods and intermediate goods affects domestic productivity and economic growth through knowledge spillovers. For example, R&D activities or technology innovation abroad create new intermediate goods that are different from or better than existing ones and by importing these new intermediate goods, domestic producers can improve their production efficiency. Many empirical studies have found some evidence for this knowledge spillover effect through international trade by using either country-level data (Coe and Helpman, 1995) or industry-level data (Keller , 2002).

In recent years, developments in trade theory suggest that understanding the plant-level response to trade liberalization is crucial in understanding its impact on aggregate productivity and welfare (e.g., Melitz, 2003 and Bernard *et al.,* 2003). This theoretical development has prompted intense empirical scrutiny in examining the effect of imported intermediate goods on productivity with micro-level data.[1] All of these empirical studies, however, considered only the price effect of trade liberalization (i.e., cheaper imported intermediates due to tariff reduction) and few of them takes into

[1] The plant-level or firm-level analyses that emphasized the role of imported intermediate goods include Amiti and Konings (2007) for Indonesia, Kasahara and Rodrigue (2008) for Chile and Halpern *et al.* (2009) for Hungary.

account the variety growth effect of imported intermediate.[2] Feenstra (1994, 1999) has developed an empirically feasible methodology to measure input variety growth and has theoretically shown that greater input varieties can have a direct impact on total factor productivity. Thus, if domestic producers are able to access to greater imported intermediate varieties (due to trade liberalization) then we may expect that their productivity will be improved. This is the first hypothesis we would like to test in our empirical analysis, using Korean manufacturing data.

While the nexus between greater access to imported intermediate varieties and domestic productivity is of great importance on its own, this paper is also interested in more dynamic effect of trade liberalization through intermediate imports: the product switching behavior of domestic plants. Recently, Bernard *et al.* (2006, hereafter BRS, 2006) investigated this product switching (i.e., product adding and product dropping) behavior of US firms using firm-product data and they argued that, through product switching, the reassignment of resources takes place within surviving firms. They showed that 45% of US firms (accounting for 81% of US shipments) are both adding and dropping at least one product at the same time during 1972 ~ 1997.[3]

In explaining this observed phenomenon, they emphasized the interactions of firm and product attributes. For example, firm shocks such as the accumulation of R&D knowledge or the substitution of one management team for another may have an uneven effect across products. As a result, it is possible for the firms to add those products

---

[2] Goldberg *et al.* (2010) is the only exception. By using Indian data during 1990s they examined whether greater access to new intermediate imports has increased the number of products manufactured by firms.

[3] Korean plant-product data used in this paper shows a very similar pattern: 68.0% of firms (accounting for 76.9% of shipments) are both adding and dropping products during 1990~1998. More detailed analyses of product switching as well as economy-wide product creation and destruction in Korea with focus on exporting plants were conducted in a separate paper by Hahn (2010)

whose relative profitability has risen and at the same time to drop those products whose relative profitability has fallen (i.e., both product adding and dropping could take place within the firm at the same time). This active product switching behavior can enhance the resource reallocation process within the firm and thereby improve the firm's production efficiency.

Although they did not consider international trade explicitly in explaining product switching behavior, we think that imported intermediate variety growth can play an important role as well.[4] If a newly imported intermediate variety can enhance the relative profitability of some specific products and reduce that of other products, it is possible for domestic producers to reallocate their resources into more profitable products through product switching.[5] This constitutes our second hypothesis: whether and to what extent imported intermediate variety growth can explain the process of product switching within Korean manufacturing data. Because we believe that plant product switching (that is, both product adding and product dropping) behavior can be considered as a part of the continual process of "creative destruction" within plants, we think that this dynamic gain from new intermediate imports, if it exists, is of great empirical importance.

In sum, by utilizing previously unexplored plant-product data on Korean manufacturing and detailed import data during 1991~1998, this paper empirically investigates the above two hypotheses: whether increased access to new intermediate

[4] In another paper (BRS, 2009), the theoretical relation between trade liberalization and product switching behavior and its empirical validity for US was analyzed. But in that paper, the focus was the trade liberalization in the export market (that is, the Canadian market) and its effect on the product switching behavior of exporting firms (that is, US firms).

[5] New imported intermediate variety is not a firm-product-specific but product-specific shock. Although BRS (2006) emphasized firm-product-specific shocks in explaining US data, theoretically the product-specific shock as well can explain simultaneous adding and dropping behavior within firms. See BRS (2006) Section 5.1.

goods through imports had an impact on (i) plant productivity and (ii) product switching behavior. Although there are many empirical studies on the former as discussed above, to our knowledge there exists no study that investigated the latter.

During our sample period in 1991~1998, the Korean government implemented the second tariff reduction plan (Table 1). The average tariff rate in Korea was reduced from 20.6% in 1984 to 16.9% in 1988 by the first tariff reduction plan and through the second tariff reduction plan it was further reduced to 6.2% in 1994.[6] After the completion of this second tariff plan, Korea's import tariff saw little further change. This tariff reduction pattern could be seen in our data as well (Figure 1). In these figures, we see a sharp reduction of import tariffs during the early 1990s and afterwards the tariff rate stabilized. Then the natural question would be whether this tariff reduction during our sample period induced greater access to import variety? The simple fixed-effect model estimations in Table 2 show that, at least in the case of imported intermediate goods, the variety growth was related to tariff reduction especially during our sample period.[7]

Table 1. Trend of Tariff Rate in Korea (unit: %)

	1983	1st Tariff Reduction Plan		2nd Tariff Reduction Plan					1997	1999	2000
		1984	1988	1989	1990 ~1991	1992	1993	1994			
All	22.6	20.6	16.9	11.2	9.7	8.4	7.1	6.2	6.3	6.4	6.4
Raw Material	11.9	10.6	9.5	3.9	3.9	3.3	3.2	2.8	2.6	2.5	2.5
Intermediate	21.5	18.7	17.1	11.7	10.7	9.3	7.8	7.0	6.9	6.8	6.8
Final	26.4	24.7	18.9	13.3	11.2	9.4	7.9	7.1	6.8	7.0	7.0

Source: Chung and Ryu (2004).

6 See Chung and Ryu (2004) for more details about the backgrounds of these tariff reduction plans.

7 As we will explain in the next section, greater imported variety is represented by lower values of the dependent variables of these regressions. Thus the positive sign of the coefficient means that as tariff rate is decreased the imported variety growth is greater.

Figure 1. Tariff Rates on Imported Goods

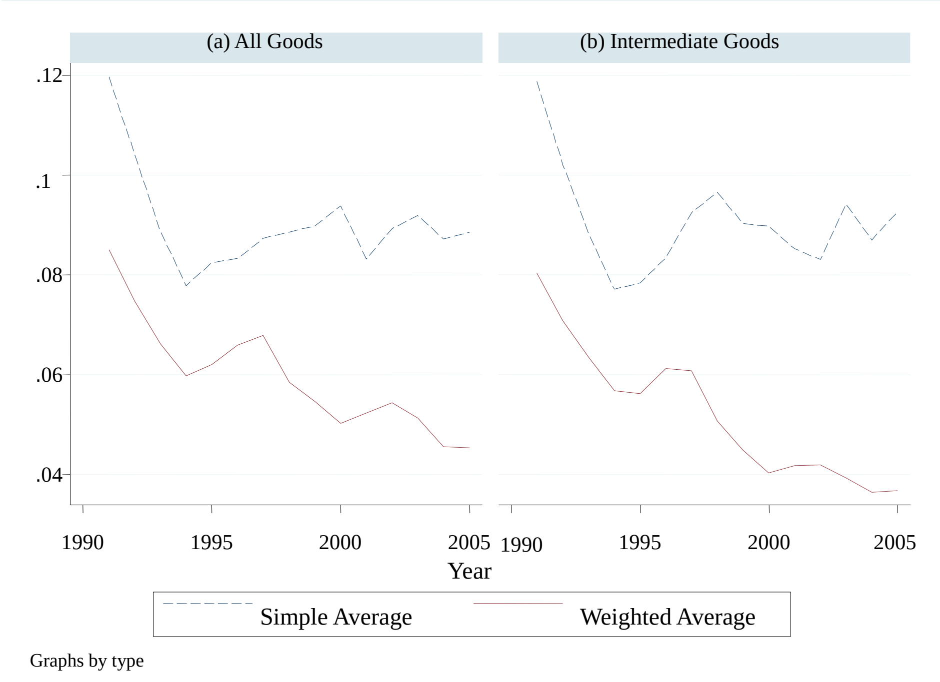


Table 2. Regression of Imported Varieties on Tariff Rate Change

Variables	Fixed Effect Estimation
(a) Variety Change of All Imported Goods: 1991~2005	
Tariff Change	0.010 (0.006)
Observation	1,525
R-Squared	0.014
(b) Variety Change of Imported Intermediate Goods: 1991~2005	
Tariff Change	0.016* (0.009)
Observation	1,243
R-Squared	0.019
(c) Variety Change of All Imported Goods: 1991~1998	
Tariff Change	0.046** (0.023)
Observation	557
R-Squared	0.020
(d) Variety Change of Imported Intermediate Goods: 19991~1998	
Tariff Change	0.115** (0.049)
Observation	452
R-Squared	0.035

Note: Heteroscedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively.

Our work is related to several strands of previous literature, beside the aforementioned ones. First, from the methodological perspective in measuring imported intermediate varieties, this paper is related to the theoretical and empirical studies such as Feenstra (1994) and Broda and Weinstein (2006a). They provided the methodology to measure imported varieties or intermediate input varieties at the level of each good or at the aggregated level in a monopolistic competition setting as in Krugman (1979). By using this methodology, Broda and Weinstein (2004, 2006a) directly estimated the impact of increased *imported variety* on aggregate welfare for the case of 20 countries during 1972~1997 and the US during 1972~2001. In these works, they showed that the globalization process has led to an increase of imported varieties which in turn reduced the import prices. This reduction of import prices due to the increase of import varieties represented the main source of gains from variety import.[8] We adopt this methodology in measuring imported intermediate varieties in our analysis.

Secondly, our work is directly related to a recent empirical work by Goldberg *et al.* (2010, henceforth GKPT, 2010). In this study, they investigated whether increased access to new imported intermediate varieties enabled firms to expand their *domestic product scope* (measured by the number of products manufactured by the firm).[9] Using Indian data in the 1990s, they found that there was an expansion of domestic product scope driven by increases in newly available imported input. While examining the domestic product scope can give us its own important implications, we think that analyzing product switching behavior rather than domestic product scope would be more relevant, considering the situation in Korea where a creative destruction

[8] Other studies that estimated the impact of imported variety on overall welfare include Arkolakis *et al.* (2008) for Costa Rica and Mohler and Seitz (2009) for 27 EU countries.
[9] In measuring imported intermediate varieties, they also used the methodology developed by Feenstra (1994) and Broda and Weinstein (2006a).

process through adding and dropping within plants prevails.[10]

Finally, our study is also related to the literature on direct tests of the endogenous growth model, where increased intermediate input variety improves productivity. Two more empirical studies are noteworthy. Feenstra *et al.* (1999) used industry level data from Korea and Taiwan; they showed that changes in *domestic input variety* have a positive and significant effect on total factor productivity.[11] On the other hand, in GKPT (2010) the effect of *imported input variety* was estimated to have a positive impact on total factor productivity in India, although their main interest lies on the impact on domestic product scope.

The rest of the paper is organized as follows. Section 2 presents our empirical framework where methodologies regarding the measurement of imported intermediate varieties and the product switching rate will be discussed including our regression specifications. Section 3 describes the data that are used in the paper. Section 4 discusses our empirical results and Section 5 concludes.

2. Empirical Framework

2.1. Measuring Imported Intermediate Varieties: Feenstra Price Index

In answering the research questions posited above, we first need to measure imported varieties. In doing so, we closely follow the methodologies developed by

---

[10] Suppose that due to newly available intermediate imports, a firm adds one product and at the same time drops another by reallocating resources more efficiently. In this situation, the measure of domestic product scope will be zero despite the existence of dynamic gains from intermediate imports, while our measure on product switching can capture this effect.

[11] Due to the limitation of the data, Feenstra *et al.* (1999) used export variety instead of domestic product variety in their work.

Feenstra (1994) and its applications in Broda and Weinstein (2006a). Feenstra (1994) showed that for any good m that continuously exists in two periods, the conventional import price index can be modified to account for the role of new import varieties as long as there exists some overlap in the varieties available between two periods, which has the following form.[12]

$$P_{mt}^{E} = P_{mt}^{C}\Lambda_{mt} \tag{1}$$

where P_{mt}^{E} is the exact price index of imported good m at time t when new (or extinct) varieties are taken into account, P_{mt}^{C} the conventional import price index and Λ_{mt} imported variety index (or lambda ratio in the literature). In turn, Feenstra (1994) showed that the conventional import price index and the imported variety index can be calculated by the following formula:

$$P_{mt}^{C} = \prod_{v \in I_m} \left(\frac{p_{mvt}}{p_{mvt-1}} \right)^{w_{mvt}} \tag{2}$$

$$\Lambda_{mt} = \left(\frac{\lambda_{mt}}{\lambda_{mt-1}} \right)^{\frac{1}{\sigma_m - 1}} \tag{3}$$

$$\text{where } \lambda_{mt} = \frac{\sum_{v \in I_m} p_{mvt} M_{mvt}}{\sum_{v \in I_{mt}} p_{mvt} M_{mvt}} \text{ and } \lambda_{mt-1} = \frac{\sum_{v \in I_m} p_{mvt-1} M_{mvt-1}}{\sum_{v \in I_{mt-1}} p_{mvt-1} M_{mvt-1}}$$

The conventional import price index (equation (2)) is the geometric mean of price changes (p) in individual variety (denoted by subscript v) weighted by ideal log-change

[12] The fact that only continuously produced goods in both periods can be taken into account is one of the limitations of Feenstra's methodology. This is because the impact of truly new good on an economy is presumably far greater than that of new variety. Thus, how to incorporate the impact of new (or extinct) good is thus important issue but beyond the scope of this paper. We leave this issue for future research.

weights (w_{mvt}).[13] This index can be calculated only when the specific variety exist in both periods (i.e., when $v \in I_m$ where I_m is the set of variety existing in both periods). Looking at the numerator of the imported variety index (equation (3)), λ_{mt} is the fraction of expenditure in the varieties that are available in both periods (i.e., $v \in I_m$) relative to the entire set of varieties available only in period *t* (i.e., $v \in I_{mt}$). This means that the higher the expenditure share of new varieties, the lower is λ_{mt} and the smaller is the exact price index relative to the conventional price index.[14] Thus, Λ_{mt} captures the gains from newly available imported variety.

Following the convention in the previous literature, an imported good (*m*) is defined according to HS (Harmonized System) codes and for each imported good a variety (*v*) is defined as the import of that good from a particular country. That is, it is assumed that for each HS category, imports are treated as differentiated across countries of supply (as in Armington (1969)).

Based upon the formula of the exact import price index for each imported good described above (equations (1)-(3)), Broda and Weinsten (2006a) developed the methodology on how to derive the aggregate exact import price index. That is, as long as two goods are available in two periods, the aggregate exact import price index with variety change is given by

---

13 These weights are computed as follows. $w_{mvt} = \frac{(s_{mvt} - s_{mvt-1})/(\ln s_{mvt} - \ln s_{mvt-1})}{\sum_{v \in M} \left[(s_{mvt} - s_{mvt-1})/(\ln s_{mvt} - \ln s_{mvt-1})\right]}$ where $s_{mvt} = \frac{p_{mvt} M_{mvt}}{\sum_{v \in M} p_{mvt} M_{mvt}}$.

14 In order to calculate Λ_{mt}, we need to have the estimate of elasticity of substitution between varieties of each imported good. Broda and Weinstein (2006b) estimated these elasticities at HS 3-digit level for 73 countries including Korea. In our empirical study, we directly adopted these estimates.

$$
\begin{aligned}
P_t^E &= P_t^C \Lambda_t \\
&= \prod_{m \in M} \left(P_{mt}^C\right)^{w_{mt}} \prod_{m \in M} \left(\Lambda_{mt}\right)^{w_{mt}} \\
&= \prod_{m \in M} \left(P_{mt}^E\right)^{w_{mt}}
\end{aligned}
\tag{4}
$$

where P_t^E, P_t^C and Λ_t denote aggregate exact price index, aggregate conventional price index and aggregate variety index for the set of all imported goods (*M*). The third equality in (4) implies that the aggregate exact price index is the geometric mean of the exact price index of each imported good (P_{mt}^E) where the weights (w_{mt}) are log-change ideal weights.[15]

If *M* is defined as the set of all imported goods, then equation (4) provides the decomposition of the aggregate exact price index into the aggregate conventional price index and the aggregate variety index. If *M* is defined as a narrower set of imported goods, for example the set of imported intermediate goods, then we can measure the exact price index and its two components of imported intermediate goods in the same way.

2.2. Measuring the Product Switching Rate

Suppose that two initially identical plants (plants A and B) added one more new product in their production line. But the *value* of plant A's new product is negligible compared to plant A's total value of production while that of plant B is significant. In

---

[15] Just like w_{mvt}, w_{mt} can be calculated as follows. $w_{mt} = \dfrac{(s_{mt} - s_{mt-1})/(\ln s_{mt} - \ln s_{mt-1})}{\sum_{m \in M} \left[(s_{mt} - s_{mt-1})/(\ln s_{mt} - \ln s_{mt-1})\right]}$

where $s_{mt} = \dfrac{p_{mt} M_{mt}}{\sum_{m \in M} p_{mt} M_{mt}}$.

this case, the economic importance of adding the new product is much higher for plant B. Therefore, in calculating the product switching rate, we need to take into account the value of production of each product.[16]

First, we use the following formula to measure product adding and product dropping rates for plant i:

$$PA_{it} = \frac{\sum_{d \in J_{it}} p_{idt} Q_{idt} - \sum_{d \in J_i} p_{idt} Q_{idt}}{\sum_{d \in J_{it}} p_{idt} Q_{idt}} = 1 - \frac{\sum_{d \in J_i} p_{idt} Q_{idt}}{\sum_{d \in J_{it}} p_{idt} Q_{idt}} \quad (5)$$

$$PD_{it} = \frac{\sum_{d \in J_{it-1}} p_{idt-1} Q_{idt-1} - \sum_{d \in J_i} p_{idt-1} Q_{idt-1}}{\sum_{d \in J_{it-1}} p_{idt-1} Q_{idt-1}} = 1 - \frac{\sum_{d \in J_i} p_{idt-1} Q_{idt-1}}{\sum_{d \in J_{it-1}} p_{idt-1} Q_{idt-1}} \quad (6)$$

where J_{it} or J_{it-1} denotes the set of products produced by plant i, either in year t or in year t-1. $J_i = J_{it-1} \cap J_{it}$ is the set of common products that are produced by plant i in both periods. And d, p and Q represent domestic product, its price and quantity, respectively. The numerator of the product adding rate in equation (5) measures the value of added product between year t-1 and t and the denominator is the value of production at time t. Suppose that a plant does nothing between two periods (no adding and no dropping). Then since $J_i = J_{it-1} = J_{it}$, both PA_{it} and PD_{it} will be zero.

Then we define the product switching rate as follows:

[16] In fact, this is why the value of new (or extinct) varieties is taken into account in equation (3) in measuring the variety change in imported goods.

$$PS_{it} = \frac{\left(\sum_{d\in J_{it}} p_{idt}Q_{idt} - \sum_{d\in J_i} p_{idt}Q_{idt}\right) + \left(\sum_{d\in J_{it-1}} p_{idt-1}Q_{idt-1} - \sum_{d\in J_i} p_{idt-1}Q_{idt-1}\right)}{0.5\left(\sum_{d\in J_{it}} p_{idt}Q_{idt} + \sum_{d\in J_{it-1}} p_{idt-1}Q_{idt-1}\right)}$$

$$= 2 - \frac{\left(\sum_{d\in J_i} p_{idt-1}Q_{idt-1} + \sum_{d\in J_i} p_{idt}Q_{idt}\right)}{0.5\left(\sum_{d\in J_{it}} p_{idt}Q_{idt} + \sum_{d\in J_{it-1}} p_{idt-1}Q_{idt-1}\right)} \quad (7)$$

The numerator reflects the value of added product (the first bracket) plus the value of dropped product (the second bracket) and the denominator the average production in period *t*-1 and *t*.

2.3. Empirical Specification

Having established the methodologies for measuring import varieties and domestic varieties, we now turn to our empirical specification to test our main hypotheses: whether imported intermediate variety has an impact (i) on a plant's total factor productivity and (ii) on a plant's product switching behavior.

In Section IV, we will run the following regressions.

$$\Delta \ln tfp_{it}^{k} = \alpha + \beta_1 P_{t-1}^{C,INT_k} + \beta_2 \Lambda_{t-1}^{INT_k} + \Gamma' X_{it-1}^{k} + \varepsilon_{it} \quad (8)$$

$$PS_{it}^{k} = \alpha + \beta_1 P_{t-1}^{C,INT_k} + \beta_2 \Lambda_{t-1}^{INT_k} + \beta_3 tfp_{it-1}^{k} + \Gamma' X_{it-1}^{k} + \varepsilon_{it} \quad (9)$$

$\Delta \ln tfp_{it}^{k}$ is the growth rate of total factor productivity of plant *i* in industry *k* at time *t* and PS_{it}^{k} the product switching rate of plant *i* in industry *k* at time *t* measured in the previous subsection. X_{it}^{k} is a vector of plant characteristics including size, age, capital intensity, skill intensity and R&D intensity. Because we do not have the data on the usage of imported intermediate goods at plant level, the conventional price index and variety index of imported intermediate goods has to be calculated at industry level, by utilizing the information from an input-output table following GKPT (2010). For example, in equation (8) $\Lambda_t^{INT_k}$ is the imported intermediate input variety index in industry k, measured by

$$\Lambda_t^{INT_k} = \sum_{l \in K} \theta_{lk} \Lambda_t^{INT_l} \tag{10}$$

where θ_{lk} is the input-output coefficient (the share of input l out of the value of industry k's total input) and $\Lambda_t^{INT_l}$ is the aggregated variety change index of industry l's imported intermediate input. The P_t^{C,INT_k} can be measured by the similar way.

In the regression equation (9), we added the level of total factor productivity tfp_{it}^k as an additional regressor. This was motivated by BRS (2006) where they showed that product switching behavior (especially product adding) is related to the firm's productivity. That is, they argue that the ability to enter and exit product markets flexibly may be due to the capability of the firms concerned. Thus, a more capable firm (with higher productivity) is more likely to be involved in more active product switching behavior due to the self-selection effect. Although in our study we are not directly assessing this self-selection effect, adding the level of total factor productivity seems to be a more appropriate empirical specification.

3. Data Description

3.1. Price and Variety Indices of Imported Intermediate Goods

The yearly data on Korean imports are taken from KCS (Korea Customs Service) at the10-digit level, but with a different HS code system for three periods: the import data during 1991~1995, during 1996~2001 and during 2002~2005 are categorized according to HS-1988, HS-1996 and HS-2002 code systems, respectively.[17] By using these data, we first constructed conventional price indices and lambda ratios following equations (2) and (3).

Since we are interested in the price and variety change of intermediate goods, we need to identify which HS codes are intermediate goods. By using the UN's BEC (Broad Economic Categories) code and the classification by Hummels *et al.* (1999), we divided each HS code into three types of imports: intermediate goods, consumption goods and capital goods. Once we identify which HS codes corresponds to the intermediate goods category of the BEC codes, we constructed industry-level price indices and lambda ratios by using equations (4) and (10).[18] That is, we aggregated each intermediate HS code's price indices and lambda ratios at industry level following equation (4) (as in Broda and Weinstein (2006a)) and then we applied an input-output coefficient from Korea's input-output table in order to calculate equation (10).

---

[17] Since the concordance matrix between different HS code system does not exist (between HS-1988 and HS-1996) or is incomplete (between HS-1996 and HS-2002), we calculated price and variety indices for each period given existing HS coding system. Therefore, we did not calculated these indices between 1995~1996 and 2001~2002.

[18] We have concordance matrices from each HS code to SITC 3 (provided by UN), from SITC3 to KSIC (Korea Standard Industrial Classification) (calculated by the authors) and from KSIC to IO table classification (provided by the Bank of Korea). By using these matrices we assigned one of the IO table industry classifications to each HS code.

3.2. Product Switching and Other Variables

All other variables are constructed by using the "Survey of Mining and Manufacturing" conducted by the KNSO (Korea National Statistical Office). This Survey covers all establishments with five or more employees in the mining and manufacturing sectors and contains necessary information to construct the variables used in this paper at plant level. Using this data, we calculated plant level total factor productivity and other control variables in equation (8) and (9).[19] Plant size is the natural logarithm of plant employment and plant age is the natural logarithm of a plant's operating years since establishment. Capital intensity is measured as the natural logarithm of per worker tangible fixed assets, while skill intensity is the ratio of non-production worker to production workers. R&D intensity is the ratio of R&D expenditure to total shipment value.

One of the variables that were not explored in the previous studies is the plant level product data: it contains the information about the value of shipments for each product category (based on KSIC classification) at plant level. By using this data, the product switching (adding and dropping) rate for each plant were calculated following equation (5) ~ (6). While we can calculate price indices and lambda ratios during the period between 1991~2005, we have plant product data only between 1990~1998. Thus, our regression analyses will use the panel data between 1991~1998.

---

[19] Plant total factor productivity is estimated using the chained-multilateral index number approach as developed in Good (1985) and Good *et al.* (1999). See Appendix 1 for more detail.

4. Results

4.1. Preliminary Analyses: Variety Changes in Korean Imports

Before we proceed to the main regression analyses, let us briefly describe the overall picture of the variety changes in Korean imports. Table 3-A provides a preliminary overview on the variety changes in all imported goods and Table 3-B in imported intermediate goods.

Table 3-A. Number of Goods and Varieties in Korean Imports: All Imported Goods

	Year	Number of HS categories	Median number of exporting countries	Average number of exporting countries	Total number of varieties
(a) 1991~1995 (in 10-digit HS-1988 code)					
Goods	1991	7,429	11	11.8	52,861
	1995	7,686 (3.5%)	13	14.5	65,423 (23.8%)
Common Goods 1991~1995	1991	7,035	11	11.8	51,244
	1995	7,035	13	14.6	62,374
1991 not in 1995	1991	394	10	10.9	1,617
1995 not in 1991	1995	651	10	12.4	3,049
(b) 1996~2001 (in 10-digit HS-1996 code)					
Goods	1996	7,786	13	14.6	66,786
	2001	8,035 (3.2%)	15	17.1	78,798 (18.0%)
Common Goods 1996~2001	1996	7,326	13	14.4	64,027
	2001	7,326	15	16.9	73,676
1996 not in 2001	1996	460	18	17.6	2,759
2001 not in 1996	2001	709	19	20.0	5,122
(c) 2002~2005 (in 10-digit HS-2002 code)					
Goods	2002	7,888	15	18.0	80,238
	2005	8,469 (7.4%)	16	19.3	88,899 (10.8%)
Common Goods 2002~2005	2002	7,597	16	18.0	79,244
	2005	7,597	16	19.4	81,768
2002 not in 2005	2002	291	12	14.9	994
2005 not in 2002	2005	872	16	18.6	7,131

Source: Korea Customs Service.
Note: The rates of increase of HS categories and varieties compared to each base year are in parentheses.

Table 3-B. Number of Goods and Varieties in Korean Imports: Imported Intermediate Goods

	Year	Number of HS categories	Median number of exporting countries	Average number of exporting countries	Total number of varieties
(a) 1991~1995 (in 10-digit HS-1988 code)					
Goods	1991	4,372	10	11.9	30,214
	1995	4,526 (3.5%)	12	14.1	36,116 (19.5%)
Common Goods 1991~1995	1991	4,166	10	11.8	29,444
	1995	4,166	12	14.2	34,590
1991 not in 1995	1991	206	11	12.7	770
1995 not in 1991	1995	360	10	12.6	1,526
(b) 1996~2001 (in 10-digit HS-1996 code)					
Goods	1996	4,579	13	14.3	37,512
	2001	4,722 (3.1%)	14	16.7	44,372 (18.3%)
Common Goods 1996~2001	1996	4,319	12	14.1	35,910
	2001	4,319	14	16.4	41,452
1996 not in 2001	1996	260	20	19.1	1,602
2001 not in 1996	2001	403	20	21.4	2,920
(c) 2002~2005 (in 10-digit HS-2002 code)					
Goods	2002	4,564	15	17.2	44,037
	2005	4,918 (7.8%)	16	18.2	48,104 (9.2%)
Common Goods 2002~2005	2002	4,404	15	17.2	43,458
	2005	4,404	16	18.2	44,261
2002 not in 2005	2002	160	16	18.3	579
2005 not in 2002	2005	514	15	17.9	3,843

Source: Korea Customs Service.
Note: The rates of increase of HS categories and varieties compared to each base year are in parentheses.

If we look at panel (a) of Table 3-A, we can see that during 1991~1995, the number of imported goods (i.e. 10-digit HS categories) increased from 7,429 to 7,686. That is, the number of *imported goods* has increased merely by 3.5%. However, the median number of exporting countries has increased from 11 to 13, which resulted in a substantial increase in the number of *imported varieties* (goods x country pair): from 52,861 to 65,423 (around 23.8%-increase). The same pattern can be found when we look at figures in the subsequent periods (panels (b) and (c)) and in the case of imported intermediate goods (Table 3-B).

In order to see how substantial the variety changes are in Korean imports, we do a similar exercise only for the number of varieties in Table 4. In panel (a), we can see that in 1991, the number of all imported varieties was 52,861, among which 17,406 varieties (32.9%) disappeared in 1995. On the other hand, out of 65,423 imported varieties in 1995, 45.8% did not exist in 1991. That is, a large portion of varieties was both disappearing and newly imported, while the share of disappearing varieties was consistently lower than that of newly imported varieties. And again, the same pattern emerges in the case of the varieties of intermediate imports and in other periods.

Table 4. Number of Varieties in Korean Imports: All and Intermediate Varieties

	Year	Number of varieties (goods-country pair)	
		All Imports	Intermediate Imports
(a) 1991~1995 (in 10-digit HS-1988 code)			
Varieties	1991	52,861 (100.0)	30,214 (100.0)
	1995	65,423 (100.0)	36,116 (100.0)
Common Varieties 1991~1995	1991	35,455 (67.1)	20,422 (67.6)
	1995	35,455 (54.2)	20,422 (56.5)
1991 not in 1995	1991	17,406 (32.9)	9,792 (32.4)
1995 not in 1991	1995	29,968 (45.8)	15,694 (43.5)
(b) 1996~2001 (in 10-digit HS-1996 code)			
Varieties	1996	66,786 (100.0)	37,512 (100.0)
	2001	78,798 (100.0)	44,372 (100.0)
Common Varieties 1996~2001	1996	44394 (66.5)	25352 (67.6)
	2001	44394 (56.3)	25352 (57.1)
1996 not in 2001	1996	22,392 (33.5)	12,160 (32.4)
2001 not in 1996	2001	34,404 (43.7)	19,020 (42.9)

(Table 4. *Continued*)

(c) 2002~2005 (in 10-digit HS-2002 code)			
Varieties	2002	80,238 (100.0)	44,037 (100.0)
	2005	88,899 (100.0)	48,104 (100.0)
Common Varieties 2002~2005	2002	55130 (68.7)	30699 (69.7)
	2005	55130 (62.0)	30699 (63.8)
2002 not in 2005	2002	25,108 (31.3)	13,338 (30.3)
2005 not in 2002	2005	33,769 (38.0)	17,405 (36.2)

Source: Korea Customs Service.
Note: The values in parentheses are the share out of all varieties in the corresponding years.

However, all these figures in all these tables used only count data in calculating imported varieties. As pointed out in Section II and in Broda and Weinstein (2006a), if a large number of new varieties takes a small market share, the changes in imported varieties described above may overestimate the importance of new varieties.

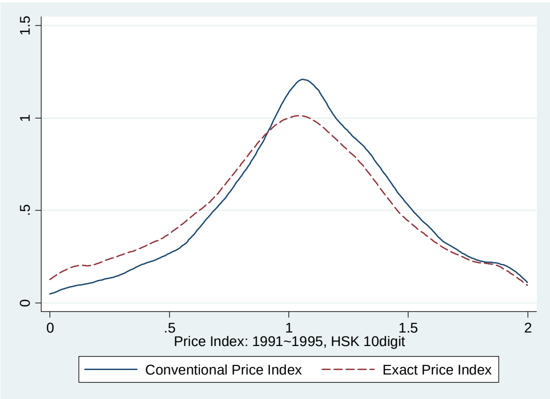
In order to appropriately take this issue into account, we need to rely on Feenstra's methodology. Figure 2 shows the distribution of the conventional price index and the exact price index for all imported goods and imported intermediate goods (calculated by using equations (2) and (3)). If the distribution of exact price is positioned to the left of the conventional price index, it means that the variety-adjusted prices for imports fell due to the variety growth (that is, due to lower lambda ratios). In both cases, the contribution of imported variety growth seems to be most substantial during the period of 1991~1995 and it was reduced as we move into later periods.[20]

[20] The reason why this variety effect is most significant in the early 1990s seems to be clear from Table 1 and Figure 1 as discussed in Section I. The import tariff reduced rapidly during the early 1990s after which the tariff rate was fairly stable.

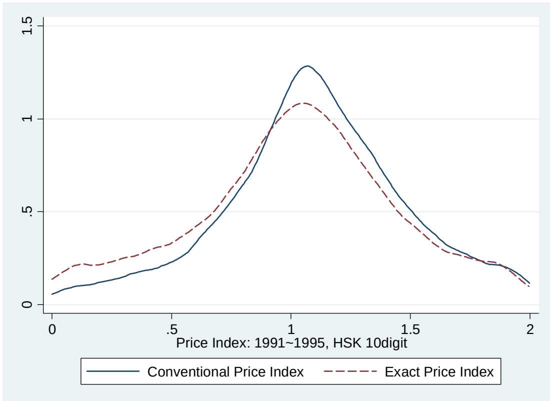
Figure 2. Distribution of Conventional and Exact Price Indices

(a) All Imported Goods | **(b) Imported Intermediate Goods**

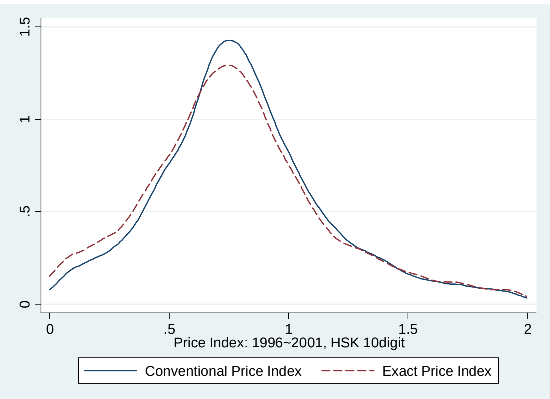
< 1991~1995 >



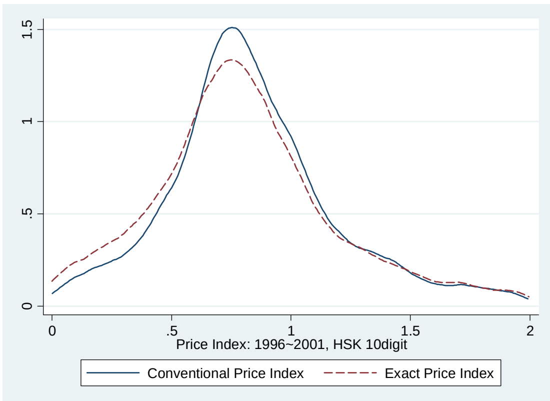
< 1991~1995>



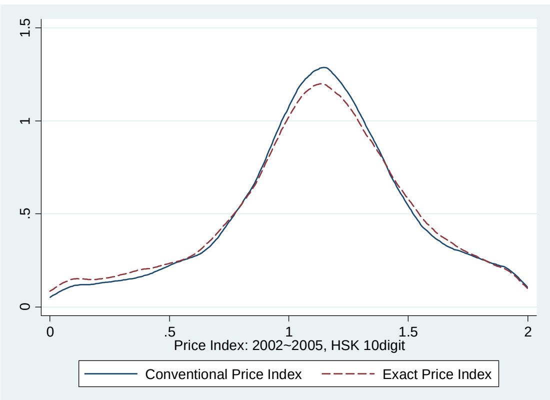
< 1996~2001 >



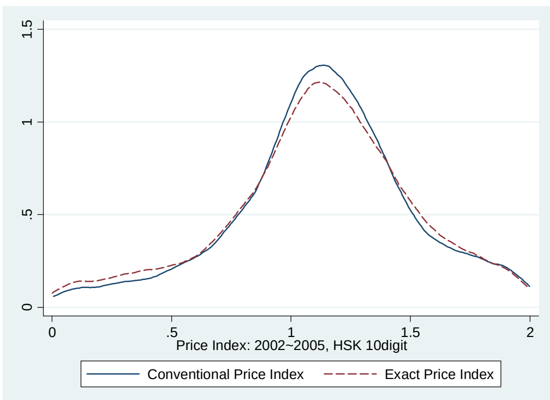
< 1996~2001 >



< 2002~2005 >



< 2002~2005 >



This distribution was drawn from the calculated conventional and exact price for each good (that is, for each 10-digit HS code). Now, by using equation (4) as in Broda and Weinstein (2006a), we can also calculate the aggregated exact price index and its two components (conventional price index and lambda ratio), which are shown in Table 5. During 1991~1995 and 1996~2001, the variety growth of all imported goods had the impact of lowering the conventional import price index by 3% (lambda ratio = 0.97). This implies that the variety growth effect has reduced the import price by 0.8%-points per annum. It is worthwhile to note two things about this figure. First, as mentioned before, this lambda ratio of 0.97 is an aggregated measure for all goods. Thus it may be useful to know how these lambda ratios vary across industries. We recalculated them for each industry following Korea's IO table classification and its descriptive statistics are in Table 6.[21] We can see that the cross-industry variation of the lambda ratios is not small, for example, with standard deviation of 0.292 for all imported goods and 0.664 for imported intermediate goods during the period of 1991~1995.

Second, comparing these results with other studies may be useful as well, in order to understand the relative magnitude of the variety growth effect in Korea. Other country studies that used a similar methodology include Broda and Weinstein (2006a) for US during 1972~2001 and GKPT (2010) for India during 1989~1997. As expected, the imported variety growth effect in India was most substantial because they experienced substantial trade reform during the sample period. The lambda ratio for all goods was 0.688 during the sample period (3.2%-points decrease of import price per annum) and that for intermediate goods were 0.624 (4.7%-points decrease of import

[21] Using equation (4), we can calculate the aggregated lambda ratios for any industrial or commodity classification. We used Korea's IO table classification here because this numbers will be used for our regression analyses in the next subsection.

price per annum). In the case of US (Broda and Weinstein (2006a)), the variety adjusted price for imports fell around 1.4% points per annum during 1972~1988 and 0.8% points per annum during 1990~2001. Thus the magnitude of the impact of imported variety in Korea during 1990s is very similar to the case of the US.[22]

In sum, although the imported variety growth effect at aggregate level in Korea during our sample period was not as great as in countries like India, the magnitude was similar to other industrial countries and its cross-industry variation was not small.

Table 5. Exact Price Indices and its Components

Periods	Commodity	Conventional Price Index (1)	Lambda Ratio (2)	Exact Price Index (1) x (2)
(a) 1991~1995 (in 10-digit HS-1988 code)	All Imported Goods	1.20	0.97	1.16
	Imported Intermediate Goods	1.25	0.96	1.21
(b) 1996~2001 (in 10-digit HS-1996 code)	All Imported Goods	0.91	0.97	0.89
	Imported Intermediate Goods	0.85	0.99	0.85
(c) 2002~2005 (in 10-digit HS-2002 code)	All Imported Goods	1.38	1.01	1.40
	Imported Intermediate Goods	1.26	1.00	1.26

22 In addition, Mohler and Seitz (2009) calculated the lambda ratios for 27 EU countries during 1999~2008. They showed that "newer" and smaller member states exhibit lower lambda ratio. The estimated median lambda ratio was 0.99 for France, Germany, Austria and Portugal and 0.98 for UK, Italy, Belgium and Netherlands and 0.97 for Denmark, Finland and Sweden. The country that gained most from imported variety was Latvia (0.79).

Table 6. Descriptive Statistics of Lambda Ratios

Periods	Statistics	Lambda Ratios with IO Table Industry Classification	
		All Goods	Intermediate Goods
(a) 1991~1995	Percentiles 5	0.681	0.554
	Median	0.975	0.983
	Mean	0.956	1.019
	Percentiles 95	1.148	1.343
	Std. Dev.	0.292	0.663
	N. observations	141	115
(b) 1996~2001	Percentiles 5	0.869	0.758
	Median	0.992	0.991
	Mean	0.995	1.012
	Percentiles 95	1.098	1.204
	Std. Dev.	0.177	0.335
	N. observations	141	115
(c) 2002~2005	Percentiles 5	0.924	0.881
	Median	1.002	1.000
	Mean	0.999	0.993
	Percentiles 95	1.051	1.054
	Std. Dev.	0.051	0.094
	N. observations	141	115

4.2. Regression Results

4.2.1. Regression of TFP Growth

In this subsection, we first report the regression results of equation (8) with panel data.[23] One problem that might arise in estimating equation (8) is the potential reverse causality problem: that is, plants with higher total factor productivity may have higher demand for imported intermediate varieties rather than the other way around. In order to reduce this reverse causality problem, we regress the plants' TFP growth rate on lagged independent variables with one-year lag. The first two columns in Table 7 show the results of this regression. In both cases (with and without other control variables) the coefficients on the lambda ratio have negative sign, and are significant. Note that the lower the lambda ratio the higher the imported variety growth effect.

[23] All the results are panel data regression with plant-specific fixed-effect and year dummies are included as well to observe year-specific shocks. As mentioned earlier, in our regression analyses, we used only the data from 1991~1998 due to data limitation.

Thus, this implies that plants with higher variety growth in imported intermediates experienced higher TFP growth.

Table 7. Regression of TFP Growth

Variables	Fixed Effect Estimation		2-Step GMM Estimation	
	(1)	(2)	(3)	(4)
Lambda Ratio	-0.020**	-0.021**	-0.103***	-0.091***
	(0.009)	(0.009)	(0.036)	(0.034)
Conventional Price Index	0.025***	0.025***	0.036*	0.028
	(0.009)	(0.009)	(0.019)	(0.018)
Size		0.068***		0.096***
		(0.005)		(0.007)
Age		-0.001		-0.001*
		(0.001)		(0.000)
Capital Intensity		0.060***		0.072***
		(0.002)		(0.003)
Skill Intensity		0.001**		0.001
		(0.000)		(0.000)
R&D Intensity		0.001**		0.001
		(0.000)		(0.000)
Plant fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes
Weak Instruments			255.7	256.2
Hansen J-statistic			3.405	3.524
[p-value]			0.182	0.172
Observation	80,327	80,319	33,648	33,646
R-Squared	0.017	0.054	0.017	0.066

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively. Instruments in GMM estimation are initial number of input varieties in 1991, initial input tariff rate and a lagged lambda ratio at each industry level.

However the estimated coefficient on the conventional price index is significantly positive, which is somewhat puzzling. Note that the conventional price index is a measure of price change of continuously imported intermediate varieties. If this continuously imported variety is of the same quality between two periods, a price reduction in this continuous variety will reduce the unit cost of production and thus improve productivity. In this situation, we expect the coefficient on the conventional price index to be negative. On the other hand, if the quality of this continuously imported variety is upgraded so that a higher price is charged, it is also possible to expect a positive sign for the coefficient on the conventional price index. A recent study by Fukao and Ito (2009) provided empirical evidence on this interpretation. By using Japan's micro-level data (Census of Manufactures) and trade statistics, they found that commodities with higher prices are of higher quality and more human capital-intensive. Given this interpretation, higher priced intermediate input with higher quality can improve a plant's productivity. However, since we do not have precise information about how the quality of the continuously imported intermediate goods has evolved, we need to be careful in interpreting this result.

Taking lags on independent variables may not be enough to control for the endogeneity problem of imported intermediate variety.[24] In order to treat this problem more seriously, we estimated equation (8) using a 2-step GMM technique by using various instruments. The set of instruments for the lambda ratio was the 1991 levels of number of intermediate input varieties, the 1991 level of input tariff and a lagged value of the lambda ratio in each industry.[25] These results are shown in column (3) and (4) in Table 7. In these two specifications, the instruments provide a good fit in the first stage with *F*-statistics (the Kleibergen-Paap statistic) being well above the critical values listed in Stock and Yogo (2005), which means that tests for weak instruments were passed. And over-identification tests were passed as well with *p*-values of Hansen's *J*-statistic of 0.182 and 0.172, respectively.

The estimated coefficients on the lambda ratio remain negative but with higher

---

[24] The conventional price index is unlikely to be subject to the endogeneity problem because our import data contains tariff-exclusive prices.

[25] The input tariff for each industry was calculated as a weighted average of the output tariff. Here, the weights are once again based on the input-output coefficient. The output tariff for each industry, in turn, is a weighted average of actual tariff of each HS-code that belongs to intermediate goods category.

significance level and larger magnitude after the GMM technique was adopted. Thus, even after treating the potential endogeneity problem of the lambda ratio, the impact of imported intermediate variety growth on productivity survives. Note that the coefficient on the conventional price index becomes insignificant with full specification (column (4)). Thus our estimation results confirm that plants that belongs to industries with higher imported intermediate variety growth experienced higher TFP growth.

The estimated coefficients on other control variables could be interpreted in an economically sensible way as well. Other things being equal, the TFP growth rate is higher if plants are larger in size, younger and with higher capital and R&D intensity (although the coefficients on the last two variables are not significantly different from zero in column (4)). Now we turn to the regression results of product switching behavior.

4.2.2. Regression of Product Switching Rate

In estimating (9), we face the same endogeneity problem as before: plants may decide to introduce new products for any reasons unrelated to trade, which can result in the increase of demand for imported intermediates. Since the first stage regression of TFP growth with 2-step GMM specification fits well, we continue to use the same set of instrumental variables to reduce the endogeneity problem in these regressions as well.[26] The results are shown in columns (1) ~ (3) of Table 7.[27] As discussed earlier in Section II, in order to capture the selection-effect as in BRS (2006), we added TFP level

[26] Just like TFP growth regressions, all tests for weak instrument and over-identification tests were passed in all our regressions.

[27] In this table, all of the regressions are estimated using a 2-step GMM with instrumental variables. If we run the regression without taking into account the endogeneity problem, all the coefficients on lambda ratios, conventional price indices and the TFP level are significantly estimated as well as reported in Appendix 2.

as a regressor. This will capture the plants' ability to enter and exit product markets flexibly. As we can see in columns (2) and (3), this selection-effect exists in our data (significantly positive coefficient on TFP level).

Table 8. 2-Step GMM Regression of Product Switching Rate

Variables	All Plants			Multi-Product Plants		
	(1)	(2)	(3)	(4)	(5)	(6)
Lambda Ratio	-0.533***	-0.513***	-0.510***	-0.591***	-0.582***	-0.584***
	(0.174)	(0.176)	(0.178)	(0.187)	(0.188)	(0.190)
Conventional Price Index	0.405***	0.408***	0.407***	0.429***	0.434***	0.436***
	(0.103)	(0.103)	(0.104)	(0.125)	(0.126)	(0.127)
TFP level		0.054**	0.053*		0.074**	0.073**
		(0.027)	(0.027)		(0.037)	(0.037)
Size			0.026			0.027
			(0.026)			(0.036)
Age			-0.001			-0.001
			(0.002)			(0.002)
Capital Intensity			-0.017			-0.004
			(0.012)			(0.016)
Skill Intensity			-0.000			-0.000
			(0.001)			(0.001)
R&D Intensity			-0.001			-0.001
			(0.001)			(0.001)
Plant fixed effects	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Weak Instruments	289.4	277.8	274.8	248.6	242.9	244.0
Hansen J-statistic	1.781	1.065	1.048	1.936	1.228	1.111
[p-value]	0.410	0.587	0.592	0.380	0.541	0.574
Observation	31,528	30,867	30,792	16,121	15,796	15,747
R-Squared	0.003	0.003	0.003	0.005	0.006	0.006

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively. Instruments in GMM estimation are initial number of input varieties, initial input tariff rate and a lagged lambda ratio at each industry level.

In the case of the imported variety growth effect, we have similar results to those of the previous TFP growth regression. Other things being equal, the lower the lambda ratios (i.e., the greater the imported intermediate variety growth effects) the higher the product switching rates. This means that when a plant is exposed to higher imported intermediate variety growth, it is more likely to be involved in a simultaneous process of product adding and dropping. If we understand this product switching behavior as being part of the resource reallocation process within a plant, our results suggest that higher imported intermediate variety growth is one of the channels through which this resource reallocation process can be enhanced.

Next, we divide our sample into two subgroups (single-product plants and multi-product plants) and then run the same regression for multi-product plants only (columns (4) ~ (6)). A single-product plant is defined as a plant which produces only one product during the sample period. Thus, by definition, their switching rates can take only zero or two. On the other hand, in the case of multi-product plants, their adding and dropping rates take continuous values between zero and two. Thus, the product switching behavior of these single-product plants should be estimated with different specifications (such as logit or probit models). Thus we excluded these single-product plants from the sample in columns (4) ~ (6). In addition to this econometric issue, there exist other economic reasons why we estimated only for multi-product plants. First, around 80% of total shipments can be explained by multi-product plants during 1990~1998 in our sample and thus these plants' switching behaviors are of greater importance than those of single-product plants.[28] Second, since the focus of the recent theoretical and empirical research lies on the behavior of multi-product firms (such as BRS (2006, 2009)), analyzing this sub-group separately may be helpful in understanding this issue.

Nevertheless, the regression results for multi-product plants do not change very much compared with those for all plants. Plants' product switching behavior is more active if they experience greater access to imported intermediate varieties and

[28] In the case of the US, multi-product firms' share of total output is 91%. See BRS (2006).

(potentially) a higher quality of existing intermediate goods. In this case as well, the selection-effect does exist (a significantly positive coefficient on TFP level). Overall then, our regression results imply that imported intermediate variety has an impact on product switching behavior of the Korean plants through a resource reallocation process.

4.3. Additional Results

4.3.1. Regression of Product Adding and Dropping Rates

Since the product switching rate contains collected information on both product adding and product dropping rates, we can run separate regressions for these variables which are shown in Table 9. As noted earlier and analyzed in Hahn (2010), our plant-product data shows that 68.0% of plants (accounting for 76.9% of shipments) are both adding and dropping products simultaneously during 1990~1998. In fact, the correlation between the product adding and product dropping rate is around 0.85 in our sample. In addition, the correlation between the product switching rate and the product adding rate is 0.96 and that between the product switching rate and product dropping rate 0.95.

Given that a large proportion of plants are both adding and dropping products simultaneously and that the correlations among switching, adding and dropping rates are high, it is no surprise to find that the regression results in Table 9 are very similar to those in Table 8. In Korea, greater access to imported variety boosts both product adding and product dropping simultaneously.

Table 9. 2-Step GMM Regression of Product Adding and Dropping Rates: Multi-Product Plants

Variables	Dependent: Product Adding Rate			Dependent: Product Dropping Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
Lambda Ratio	-0.245**	-0.215**	-0.216**	-0.349***	-0.366***	-0.365***
	(0.099)	(0.099)	(0.101)	(0.100)	(0.100)	(0.102)
Conventional Price Index	0.175***	0.166**	0.167**	0.266***	0.276***	0.275***
	(0.066)	(0.066)	(0.066)	(0.067)	(0.068)	(0.068)
TFP level		0.041**	0.041**		0.037*	0.037*
		(0.019)	(0.019)		(0.019)	(0.019)
Size			-0.003			0.027
			(0.019)			(0.019)
Age			-0.000			0.000
			(0.001)			(0.001)
Capital Intensity			-0.006			0.000
			(0.009)			(0.009)
Skill Intensity			-0.000			0.000
			(0.000)			(0.000)
R&D Intensity			-0.001			-0.000
			(0.001)			(0.001)
Plant fixed effects	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Weak Instruments	254.5	248.3	249.1	249.9	243.8	244.7
Hansen J-statistic	1.421	0.692	0.579	2.191	1.627	1.601
[p-value]	0.491	0.707	0.749	0.334	0.443	0.449
Observation	16,327	15,996	15,947	16,335	16,012	15,961
R-Squared	0.005	0.005	0.006	0.005	0.005	0.006

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively. Instruments in GMM estimation are initial number of input varieties, initial input tariff rate and a lagged lambda ratio at each industry level.

4.3.2. Regression of Product Scope

Our final regression is to investigate the relation between product scope change (as measured by the growth rate of number of products) and imported intermediate variety growth as in GKPT (2010). Table 10 shows the results. Whether or not single-product plants are excluded from the regression does not affect the regression results. However, our results are in sharp contrast to those in GKPT (2010), which analyzed the case of India. In GKPT (2010), the coefficient on the lambda ratio was estimated to be negative. Thus their interpretation was that greater access to new imported intermediate varieties resulted in an increase in the number of products (i.e., the product scope) of plants.

Table 10. 2-Step GMM Regression of Product Scope Change

Variables	All Plants			Multi-Product Plants		
	(1)	(2)	(3)	(4)	(5)	(6)
Lambda Ratio	0.178*	0.233**	0.238**	0.250*	0.325**	0.330**
	(0.104)	(0.101)	(0.101)	(0.144)	(0.139)	(0.140)
Conventional Price Index	-0.106*	-0.123**	-0.125**	-0.166*	-0.196**	-0.196**
	(0.056)	(0.055)	(0.055)	(0.092)	(0.092)	(0.092)
TFP level		0.031**	0.033**		0.060**	0.064**
		(0.014)	(0.014)		(0.026)	(0.026)
Size			-0.040***			-0.077***
			(0.014)			(0.027)
Age			0.000			0.000
			(0.001)			(0.001)
Capital Intensity			-0.007			-0.014
			(0.006)			(0.012)
Skill Intensity			-0.000			-0.000
			(0.000)			(0.001)
R&D Intensity			0.000			0.000
			(0.000)			(0.001)
Plant fixed effects	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Weak Instruments	289.4	277.8	274.8	248.6	242.9	244.0
Hansen J-statistic	2.919	1.901	2.069	2.873	1.695	1.854
[p-value]	0.232	0.387	0.355	0.238	0.429	0.396
Observation	31,528	30,867	30,792	16,121	15,796	15,747
R-Squared	0.001	0.001	0.001	0.001	0.001	0.003

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively. Instruments in GMM estimation are initial number of input varieties, initial input tariff rate and a lagged lambda ratio at each industry level.

But in the case of Korea, the coefficient on the lambda ratio was positively estimated in Table 10, which means that greater access to new imported intermediate varieties induced a reduction of product scope. What brings about this difference between India and Korea? One plausible explanation might be that these two countries are at different stages of economic development. In an early stage of economic reform accompanied by trade liberalization (the sample period of India in GKPT (2010)), greater access to imported intermediate variety is more likely to expand the number of products of domestic producers. But as the economy is maturing in its economic development (the sample period of Korea in this paper), it is also possible for domestic producers to reallocate their resources into more profitable products rather than just to expand the number of products. Although we do not have direct evidence to support this explanation, we think that it is consistent with our findings in the previous regressions.

5. Summary and Concluding Remarks

By utilizing previously unexplored plant-product data on Korean manufacturing and detailed import data during 1991~1998, this paper empirically investigates the role of imported intermediate varieties. Specifically, we examined whether greater access to imported intermediate varieties enhanced plants' total factor productivity and product switching behavior. First, as consistent with previous empirical studies using macro- and micro-data, we find that plants that belong to industries with higher imported intermediate variety growth experienced higher productivity growth.

Secondly and perhaps more importantly, our empirical results suggest that increased imported intermediate varieties had a positive impact on stimulating the product switching behavior of domestic plants. Since product switching behavior (that is, simultaneously adding and dropping products) could be understood as a part of the continual process of "creative destruction" within plants, this result suggest that imported intermediate variety growth may be one of the channels through which resource reallocation within firms can be enhanced. Taking into account the fact that 68% of Korean plants (77% when weighted by shipments) are both adding and dropping products during our sample period, this finding is of greater empirical importance.

Additionally, unlike the previous study for India, we found that imported intermediate variety growth has reduced the product scope (that is, the number of products) of domestic plants. Although this finding is not inconsistent with our finding related to product switching behavior, it suggests that imported intermediate variety growth may have different implications for industrial countries and developing countries.

However, there are many other important issues that were not included in this paper but are necessary to consider in order to better understanding the precise mechanisms of these channels. For example, whether intermediate imports from advanced countries had different impacts from those from developing countries? What are the characteristics of the added product and the dropped product in this process? Do they really represent a creative destruction process? These are the areas for future research.

References

Aghion, Philippe and Peter Howitt (1992) “A Model of Growth through Creative Destruction.” *Econometrica* 60, no. 2: 323-51.

Amiti, Mary and Jozef Konings (2007) “Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia.” *American Economic Review* 97, no. 5: 1611-1638.

Arkolakis, Costas, Svetlana Demidova, Peter J. Klenow an Andres Rodriguez-Clare (2008) “Endogenous Variety and the Gains from Trade.” *American Economic Review: Papers and Proceedings* 98, no.2: 444-450.

Armington, Paul (1969) “A Theory of Demand for Products Distinguished by Place of Origin.” *IMF Staff Papers* 16, no.1: 159-78.

Bernard, Andrew, Jonathan Eaton, Bradford Jensen and Samuel Kortum (2003) “Plants and Productivity in International Trade.” *American Economic Review* 93, no.4: 1268-1290.

Bernard, Andrew, Stephen Redding and Peter Schott (2006) “Multi-Product Firms and Product Switching.” NBER Working Paper No. 12293. Cambridge, MA: National Bureau of Economic Research.

Bernard, Andrew, Stephen Redding and Peter Schott (2009) “Multi-Product Firms and Trade Liberalization.” CES Working Paper No. 09-21.

Broda, Christian and David Weinstein (2004) “Variety Growth and World Welfare.” *American Economic Review: Papers and Proceedings* 94, no.2: 139-144.

Broda, Christian and David Weinstein (2006a) “Globalization and the Gains from Variety.” *Quarterly Journal of Economics* 121, no.2: 541-585.

Broda, Christian and David Weinstein (2006b) “From Groundnuts to Globalization: A Structural Estimate of Trade and Growth.” NBER Working Paper, No. 12512. Cambridge, MA: National Bureau of Economic Research.

Chung, Jaiho and Ryu Duck-Hyun (2004) “Industry Structure and Effective Tariff Rates in Korea.” *Policy Report* 04-03, Korea Institute of Public Finance.

Coe, David and Elhanan Helpman (1995) “International R&D Spillovers.” *European Economic Review* 39, no.5: 859-887.

Feenstra, Robert (1994) "New Product Varieties and the Measurement of International Prices." *American Economic Review* 84, no.1: 157-177.

Feenstra, Robert, Dorsati Madani, Tzu-Han Yang and Chi-Yuan Liang (1999) "Testing Endogenous Growth in South Korea and Taiwan." *Journal of Development Economics* 60: 317-341.

Fukao, Kyoji and Keiko Ito (2009) "Vertical Intra-Industry Trade, Unit Values of Commodities and Factor Contents: An Empirical Analysis Based on Micro-Data of the Census of Manufactures." *mimeo*.

Goldberg, Pinelopi, Amit Khandelwal, Nina Pavcnik and Petia Topalova (2010) "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India." forthcoming in *Quarterly Journal of Economics*.

Good, David H. (1985) "The Effect of Deregulation on the Productive Efficiency and Cost Structure of the Airline Industry." *Ph.D. diss*., University of Pennsylvania.

Good, David, Ishaq Nadiri, and Robin Sickles (1999) "Index number and factor demand approaches to the estimation of productivity." In *Handbook of applied econometrics*. Vol. 2, Microeconometrics, ed. H. Pesaran and P. Schmidt, 14–80. Oxford: Blackwell.

Grossman, Gene and Elhanan Helpman (1991) *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Hahn, Chin Hee (2010) "Does Exporting Promote New Product Introduction?: An Empirical Analysis of Plant-Product Data on the Korean Manufacturing Sector." *mimeo*.

Halpern, László, Miklós Koren and Adam Szeidl (2009) "Imported Inputs and Productivity." *mimeo*.

Hummels, David, Jun Ishii and Kei-Mu Yi (1999) "The Nature and Growth of Vertical Specialization in World Trade." Staff Reports 72, Federal Reserve Bank of New York.

Kasahara Hiroyuki and Joel Rodrigue (2008) "Does the Use of Imported Intermediates Increase Productivity? Plant-level Evidence." *Journal of Development Economics* 87: 106-118.

Keller, Wolfgang (2002) “Trade and the Transmission of Technology.” *Journal of Economic Growth* 1: 5-24.

Krugman, Paul (1979) “Increasing Returns, Monopolistic Competition and International Trade.” *Journal of International Economics* 9, no.4: 469-479.

Melitz, Mark (2003) “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity.” *Econometrica* 71: 1695-1725.

Mohler, Lukas and Michael Seitzb (2009) “The Gains from Variety in the European Union.” MPRA Paper No. 17589.

Rivera-Batiz, Luis and Paul Romer (1991) “Economic Integration and Endogenous Growth.” *Quarterly Journal of Economics* 106, no.2: 531-55.

Romer, Paul (1990) “Endogenous Technological Change.” *Journal of Political Economy* 98, no.5, S71-S102.

Stock, James, and Motohiro Yogo (2005) “Testing for Weak Instruments in Linear IV Regression.” In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, ed. Donald Andrews and James Stock, 80–108. New York: Cambridge University Press.

Appendix 1. Measurement of Plant Total Factor Productivity

Plant total factor productivity is estimated using the chained-multilateral index number approach as developed in Good (1985) and Good *et al.* (1999). It uses a separate reference point for each cross-section of observations and then chain-links the reference points together over time. The reference point for a given time period is constructed as a hypothetical firm with input shares that equal the arithmetic mean input shares and input levels that equal the geometric mean of the inputs over all cross-section observations. Thus, the output, inputs, and productivity level of each firm in each year are measured relative to the hypothetical firm at the base time period. This approach allows us to make transitive comparisons of productivity levels among observations in a panel data set.[1]

Specifically, the productivity index for firm i at time t in our study is measured in the following way:

$$\ln TFP_{it} = \left(\ln Y_{it} - \overline{\ln Y_{it}}\right) + \sum_{\tau=2}^{t}\left(\overline{\ln Y_{\tau}} - \overline{\ln Y_{\tau-1}}\right) - \left\{\sum_{n=1}^{N}\frac{1}{2}\left(S_{nit} + \overline{S_{nt}}\right)\left(\ln X_{nit} - \overline{\ln X_{nt}}\right) + \sum_{\tau=2}^{t}\sum_{n=1}^{N}\frac{1}{2}\left(\overline{S_{n\tau}} + \overline{S_{n\tau-1}}\right)\left(\overline{\ln X_{nt}} - \overline{\ln X_{nt-1}}\right)\right\}$$

where Y, X, S, and TFP denote output, input, input share, TFP level, respectively, and symbols with upper bar are corresponding measures for hypothetical firms. The subscripts τ and n are indices for time and inputs, respectively. In our study, the year 1990 is the base time period.

[1] Good *et al.* (1999) summarize the usefulness of chaining multilateral productivity indices succinctly. While the chaining approach of Tornqvist-Theil index, the discrete Divisia, is useful in time series applications, where input shares might change over time, it has severe limitations in cross-section or panel data where there is no obvious way of sequencing the observations. To the contrary, the hypothetical firm approach allows us to make transitive comparisons among cross-section data, while it has an undesirable property of sample dependency. The desirable properties of both chaining approach and the hypothetical firm approach can be incorporated into a single index by chained-multilateral index number approach.

As a measure of output, we used the gross output (production) of each plant in the Survey deflated by the producer price index at disaggregated level. As a measure of capital stock, we used the average of the beginning and end of the year book value capital stock in the Survey deflated by the capital goods deflator. As a measure of labor input, we used the number of workers, which includes paid employees (production and non-production workers), working proprietors and unpaid family workers. Here, we allowed for the quality differential between production workers and all the other types of workers. The labor quality index of the latter was calculated as the ratio of non-production workers' and production workers' average wage of each plant, averaged again over the entire plants in a year. As a measure of intermediate input, we used the "major production cost" plus "other production cost" in the Survey. Major production cost covers costs arising from materials and parts, fuel, electricity, water, manufactured goods outsourced and maintenance. Other production cost covers outsourced services, such as advertising, transportation, communication and insurance. The estimated intermediate input was deflated by the intermediate input price index.

We assumed constant returns to scale so that the sum of factor elasticity equals to one. Labor and intermediate input elasticity for each plant are measured as average cost shares within the same plant-size class in the five-digit industry in a given year. Thus, factor elasticity of plants is allowed to vary across industries and size classes and over time. Here, plants are grouped into three size classes according to the number of employees: 5-50, 51-300, and over 300.

Appendix 2. Fixed Effect Estimation Results

Table A-1. Fixed Effect Estimation of Switching and Adding Rates

Variables	Dependent Variable: Switching Rate			Dependent Variable: Adding Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
Lambda Ratio	-0.107***	-0.117***	-0.117***	-0.043***	-0.047***	-0.047***
	(0.018)	(0.018)	(0.018)	(0.009)	(0.009)	(0.009)
Conventional Price Index	0.189***	0.200***	0.201***	0.090***	0.095***	0.095***
	(0.027)	(0.027)	(0.027)	(0.014)	(0.014)	(0.014)
TFP level		0.026*	0.025*		0.015**	0.015**
		(0.014)	(0.014)		(0.007)	(0.007)
Size			-0.014			-0.019***
			(0.013)			(0.006)
Age			0.001			0.000
			(0.001)			(0.000)
Capital Intensity			-0.010*			-0.009***
			(0.006)			(0.003)
Skill Intensity			0.000			-0.000
			(0.000)			(0.000)
R&D Intensity			-0.000			-0.000
			(0.001)			(0.000)
Plant fixed effects	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Observation	96,881	95,098	94,798	100,410	98,596	98,182
R-Squared	0.004	0.004	0.004	0.006	0.006	0.006

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively.

Table A-2. Fixed Effect Estimation of Dropping Rate and Product Scope

Variables	Dependent Variable: Dropping Rate			Dependent Variable: Product Scope		
	(1)	(2)	(3)	(4)	(5)	(6)
Lambda Ratio	-0.056***	-0.061***	-0.061***	0.024***	0.024***	0.025***
	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)
Conventional Price Index	0.090***	0.095***	0.096***	-0.010	-0.013	-0.012
	(0.014)	(0.014)	(0.014)	(0.013)	(0.013)	(0.013)
TFP level		0.031***	0.031***		0.026***	0.026***
		(0.007)	(0.007)		(0.007)	(0.007)
Size			-0.003			-0.028***
			(0.007)			(0.007)
Age			0.000			-0.000
			(0.000)			(0.001)
Capital Intensity			-0.004			-0.005*
			(0.003)			(0.003)
Skill Intensity			0.000			-0.000
			(0.000)			(0.000)
R&D Intensity			0.000			0.000
			(0.000)			(0.000)
Plant fixed effects	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Observation	99,753	97,940	97,630	96,881	95,098	94,798
R-Squared	0.002	0.002	0.003	0.002	0.002	0.002

Note: Heteroskedasticity-consistent robust standard errors are in parentheses. *, **, and *** denote that the estimated coefficients are significant at 10%, 5% and 1% level, respectively.