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Import Penetration and Technological Changes in U.S. Manufacturing Industries

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Abstract

In this study, we estimated the effects of foreign imports on the technological changes that take place within U.S. manufacturing firms. We constructed a two-period model, assuming that there are differences between domestic and foreign firms in R&D costs and the marginal costs of production before R&D. Through the use of various measures, we confirmed that imports have a positive effect on the technological changes within U.S. firms.

JEL Classification : F14 ; O31 ; O51.
Keywords : technological change, import penetration, cost differences.

1 Introduction

Many researchers have discussed how firms respond to increases in import competition due to trade liberalization and other factors. Some firms manage to exist in industries subject to suffering enormous import competition. These firms might engage in more technological improvements to enhance their competitiveness or fewer technological improvements to accommodate increased imports.

An empirical study by Scherer and Huh (1992) estimates the effects of import competition on R&D investments and the number of innovations at U.S. firms. Using micro data on 308 U.S. manufacturing firms from 1971 to 1987, they regress a standardized index of R&D on import and net export indices. According to their results, import competition has an adverse effect on the R&D/total sales ratio.

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Bertschek (1995) estimates the effects of imports on innovations by German firms. Her study uses panel data on 1,270 manufacturing firms in West Germany from 1984 to 1988, including indicator variables of innovations, production/activity variables at individual firms, and indicators of the globalization of the German economy. Besides the import effects, she also estimates the effect of exports and foreign direct investments. Using a probit estimation, she finds that imports have a positive effect on the innovations of German firms.

Lawrence (1998) uses a slightly different method to estimate the effect of import competition on technological change in U.S. firms. Using data on the manufacturing industries from the late 1970s and the 1980s, he regresses the total factor productivity (TFP) on R&D intensity, industry concentration, measures of import competition, and the interaction of industry concentration with import competition. The results are mixed, depending on the measures of import competition (import prices/quantities) and the estimation methods (OLS/instrumental variables) used.

In a related study, Coe and Helpman (1995) focus on technological spillovers among developed countries. They explore the effects of domestic and foreign R&D on the TFP of 21 OECD countries and Israeli from 1971 to 1990. Their results indicate that foreign R&D has a greater spillover effect on the TFPs of countries with higher imports/GDP ratios. Although their data are aggregated, their results suggest a strong link between technological change in developed countries and R&D capital stocks, both domestic and foreign through imports. However, as their study focuses on the role of foreign imports in transmitting foreign technologies to a country, they do not consider any strategic effect of a country's R&D through foreign trade, a factor that could discourage R&D in other countries even when international R&D spillovers take effect.

This article estimates the effect of imports and other factors on the technological change that take place in U.S. manufacturing industries. Our regression equation is derived from the market equilibrium of a two-period model of R&D competition between domestic and foreign firms based on Spencer and Brander (1983), focusing on R&D competition in period one and quantity competition in period two. From this model, we derive a regression equation reflecting the effects of three factors-(1) foreign imports, (2) domestic shipment, and (3) an indicator of cost advantage to U.S. firms-on technological change and investments in technology.

This article uses three direct/indirect measures of technological change: five-factor TFP, the ratio of R&D to total sales, and investments in computers. In contrast to previous empirical studies on innovation/technological change, which have tended to rely solely on direct measures such as the number of patents or number of innovations, this article uses both direct and indirect measures. We have several reasons for taking this approach. First, direct measures of innovation/technological change could be arbitrary, and therefore poor at reflecting the true technological change (Symeonidis 1996). Second, the two indirect measures of technological change used in this study are commonly used by researchers to estimate the effects of technological change on the relative wages of skilled workers in the U.S.[1] Third, the use of various types of technology measures helps us assess the robustness of our results.

The remainder of this article is arranged into three sections. Section 2 discusses the two-period model. Section 3 presents our regression equation, data, and results. Section 4 addresses conclusions and possible extensions.

2 Model

In this section, we formulate the decision problems of domestic and foreign firms to establish a hypothesis to test. Our model is based on the two-period model of R&D competition introduced by Spencer and Brander (1983). Suppose that there are two firms, one domestic (D) and one foreign (F), producing the same product, and that the foreign firm exports all of its output to the domestic market, thereby nullifying any foreign demand to highlight the import penetration effect. In period one, they make R&D investments that lower their marginal costs of production. In period two, they perform quantity competition with decreased marginal costs due to their R&D investments.

Assuming a linear demand function and a quadratic R&D cost function (implying decreasing returns to R&D investment), the profit maximization problem for firm $i=D, F$ is

$$\max_{q_i} \Pi_i = [A - q_D - q_F]q_i - (B_i - x_i)q_i - \delta_i x_i^2, \tag{1}$$

where q_i and x_i are firm i's output and R&D investment respectively. Note that x_i units of R&D investments are assumed to decrease the constant marginal cost, B_i, by the same units. While there actually is no reason to believe that these cost-decreasing effects of R&D are the same for both firms, we assume this for simplicity. Further, we believe that the difference in the effect of R&D is at least partially captured by the difference in R&D costs.

1) See Bartel and Sicherman (1999).

This article does not assume the international R&D spillovers discussed by Coe and Helpman (1995). For simplicity, we assume that $\delta_F = 1$ and $\delta_D = \delta > 0$. We also assume that $B_D = \theta B_F$ where $\theta > 0$.

We solve the firms' problems by backward induction. In period two, each firm maximizes its profits with respect to its output. From the first order conditions, the reaction function for firm $i = D, F$ is

$$q_i = \frac{A - q_j - (B_i - x_i)}{2},\ j \neq i. \tag{2}$$

Solving these reaction functions (2) yields the equilibrium output of firm $i = D, F$ in period two:

$$q_i = \frac{A - 2(B_i - x_i) + (B_j - x_j)}{3},\ j \neq i. \tag{3}$$

Substituting the equilibrium output in period two (equation 3) into the domestic firm's profits (1) gives its objective function in period one:

$$\Pi_D = \frac{[A + (1 - 2\theta)B_F + 2x_D - x_F]^2}{9} - \delta x_D^2. \tag{4}$$

Similarly, the foreign firm's objective function in period one is

$$\Pi_F = \frac{[A - (2 - \theta)B_F + 2x_F - x_D]^2}{9} - x_F^2. \tag{5}$$

The first order condition with respect to R&D gives the reaction function for the domestic firm:

$$x_D = \frac{2[A + (1 - 2\theta)B_F - x_F]}{9\delta - 4}, \tag{6}$$

and similarly for the foreign firm:

$$x_F = \frac{2[A - (2 - \theta)B_F - x_D]}{5}. \tag{7}$$

From the reaction function for domestic firm (6), an increase in the foreign firm's R&D investment due to factors other than those discussed below, described as an outward shift of the foreign firm's reaction function decreases the R&D investment of the domestic firm.[2)]

$$\frac{\partial x_D}{\partial x_F} = \frac{-2}{9\delta - 4} < 0. \tag{8}$$

Solving the reaction functions (6) and (7) yields the equilibrium R&D investment of the domestic firm,

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2) We assume that $\delta \geq \frac{2}{3}$ for the profits and R¥&D investments of both firms are positive.

$$x_D^* = \frac{2A+(6-8\theta)B_F}{15\delta-8}, \tag{9}$$

and that of the foreign firm.

$$x_F^* = \frac{2[A(3\delta-2)+B_F(2+3\delta(\theta-2))]}{15\delta-8}. \tag{10}$$

We can see the effects of exogenous factors on the domestic firm's equilibrium R&D investment by comparative statics. First, the effect of market size parameter, A, is positive.

$$\frac{\partial x_D^*}{\partial \mathrm{A}} = \frac{2}{15\delta-8} > 0. \tag{11}$$

Second, the effect of an increase in the foreign firm's marginal cost (e.g. an increase in the price of oil), B_F, an effect that also increases the marginal cost of domestic firm, $B_D = \theta B_F$, depends on the value of the marginal-cost difference parameter, θ.

$$\begin{aligned} \frac{\partial x_D^*}{\partial B_F} = \frac{6-8\theta}{15\delta-8} &> 0 \text{ if } \theta < \frac{3}{4} \\ &< 0 \text{ if } \theta > \frac{3}{4}. \end{aligned} \tag{12}$$

This change is prompted by the intuitive assumption that more cost advantage induces more R&D investment for the domestic firm, enabling it to capture more rent. A smaller θ means a greater cost advantage for the domestic firm with its marginal cost. In this model, θ of $\frac{3}{4}$ works as a threshold for the domestic firm.

Third, an increase in the domestic firm's parameter of relative marginal cost, θ, decreases the domestic firm's R&D investment.

$$\frac{\partial x_D^*}{\partial \theta} = \frac{-8B_F}{15\delta-8} < 0. \tag{13}$$

Finally, as in the case with the marginal-cost difference parameter θ, an increase in the R&D-cost difference parameter δ decreases the domestic firm's R&D investment.

$$\frac{\partial x_D^*}{\partial \delta} = \frac{-15[2A+(6-8\theta)B_F]}{(15\delta-8)^2} < 0. \tag{14}$$

From equations (12), (13), and (14), we can see that any kind of cost advantage for the domestic firm can increase its R&D investment.[3)]

3) we develop a model of price competition with product differentiation focusing on tariffs, for use as a proxy for the cost advantage to U.S. firms (not shown in this article). This model brings about the same result: a positive effect of tariffs on domestic R&D.

3 Empirical Findings

3.1 Estimated Equation

Based on the model developed in the last section, we estimate the following equation.

$$\begin{aligned} Technology = \alpha_1 + \alpha_2 \cdot & \underset{(+)}{Market\ Size} \\ & + \alpha_3 \cdot \underset{(+)}{Cost\ Advantage} + \alpha_4 \cdot \underset{(-)}{Imports} + \varepsilon. \end{aligned} \tag{15}$$

The signs of the effects predicted by our model are in parentheses. *Technology* is a measure of technological change or a quantity of investment in technology. *Market Size* is the proxy for demand parameter A in our model, hence the coefficient α_2 is the partial derivative of equilibrium domestic R&D with respect to A (equation 11). *Cost Advantage* represents cost advantage to U.S. firms in either production or R&D. A greater *Cost Advantage* implies either a smaller θ (smaller marginal cost borne by the domestic firm relative to the foreign marginal cost) or a smaller δ (smaller R&D cost borne by the domestic firm relative to the foreign R&D cost) in our model. The coefficient α_3 is the partial derivative of equilibrium domestic R&D with respect to θ (equation 13) or δ (equation 14).

Imports is foreign imports of the product, a variable that captures the effect of an exogenous increase in imports (due to an increase in subsidies by a foreign government, for instance). The coefficient α_4 is the effect of an outward shift of a foreign firm's reaction curve on domestic R&D, $\frac{\partial x_D}{\partial x_F}$ (equation 8), times the effect of an increase in foreign production, i.e. imports, on the foreign R&D ($\frac{\partial x_F}{\partial q_F}$ described by equation 3). $\frac{\partial x_F}{\partial q_F} = \frac{2}{3} > 0$, hence the sign of α_4 is equal to the sign of $\frac{\partial x_F}{\partial x_D}$, which is expected to be negative in our model. ε is the error term.

3.2 Data

To estimate the regression equation, we use the following variables of U.S. manufacturing industries at the four-digit SIC level. For *Technological Change* we use three kinds of proxies separately: (1) five-factor TFP from the NBER Manufacturing Industry Productivity Database, (2) the ratio of expenditures on R&D investments to total sales from the

National Science Foundation (NSF), and (3) investments in computers from the Census of Manufactures. Variable (1) is a proxy for technological change itself while variables (2) and (3) are quantities of investments in technology.

As a proxy for *Market size,* we use the value of shipments from the NBER Manufacturing Industry Productivity Database. To capture the degree of cost advantage to domestic firms (proxy for *Cost Advantage*), we use the tariff rates from the U.S. Imports and Exports Data provided by the Center for International Data at UC Davis (http://data.econ.ucdavis.edu/international/). A higher tariff on imports of a good would increase the costs of foreign firms virtually by increasing the price of the imports. Finally, we use the dollar value of imports from the U.S. Imports and Exports Data (*Imports*).

Table 1 shows the descriptive statistics. Columns 2 to 5 show the averages, standard errors, minimums and maximums of the variables for all samples. A total of 2,484 observations are incorporated (covering 207 four-digit SIC industries during the sample years from 1977 to 1988). There are large variations across industries for shipments, imports, and investments in computers. Columns 6 to 8 show the average of each variable in three different years (1977, 1982, and 1988). As most of these variables have an upward trend, [all but the TFP (no trend) and tariff rate (downward trend)], it is worthwhile to control for them.

As investments in computers are estimated every five years, the missing values for all

Table 1 Descriptive Statistics.

Variable/Statistics	Mean 1977-88	Standard Error	Min	Max	Mean 1977	Mean 1982	Mean 1988
Value of Shipments (Unit: 1 million dollars)	6112.031	12353.100	161.400	215056.100	4109.777	6090.778	7755.686
Value of Imports (Unit: 1 million dollars)	606.913	1457.549	0.974	21187.540	279.677	500.844	1013.939
Tariff Rate	5.831	5.838	0.000	33.645	7.034	5.897	4.422
Five-Factor TFP (1987=1.000)	0.974	0.109	0.427	1.993	0.976	0.950	1.013
R&D/Sales Ratio	1.946	1.976	0.200	12.400	1.633	1.988	2.147
Investments in Computers (Unit: 1 million dollars)	7.807	17.912	0.040	222.460	2.396	6.462	14.219
Investments in Computers per Employee (Unit: 1 million dollars)	0.141	0.221	0.002	3.909	0.043	0.115	0.257

Note
Number of Observations=2484 (207 SIC four-digit Industries × 12 Years).

Table 2 SIC Four-Digit Manufacturing Industries used For Estimation

SIC	Industry Name	SIC	Industry Name
20	FOOD AND KINDRED PRODUCTS	25	FURNITURE AND FIXTURES
2011	MEAT PACKING PLANTS	2511	WOOD HOUSEHOLD FURNITURE
2013	SAUSAGES AND OTHER PREPARED MEATS	2512	UPHOLSTERED HOUSEHOLD FURNITURE
2022	CHEESE, NATURAL AND PROCESSED	2514	METAL HOUSEHOLD FURNITURE
2023	CONDENSED AND EVAPORATED MILK	2515	MATTRESSES AND BEDSPRINGS
2026	FLUID MILK	2521	WOOD OFFICE FURNITURE
2032	CANNED SPECIALTIES	2522	METAL OFFICE FURNITURE
2033	CANNED FRUITS AND VEGETABLES	2531	PUBLIC BUILDING & RELATED FURNITURE
2035	PICKLES, SAUCES, AND SALAD DRESSING	2542	METAL PARTITIONS AND FIXTURES
2037	FROZEN FRUITS AND VEGETABLES	2591	DRAPERY HARDWARE & BLINDS & SHADES
2038	FROZEN SPECIALTIES	2599	FURNITURE AND FIXTURES, NEC
2041	FLOUR AND OTHER GRAIN MILL PRODUCTS	26	PAPER AND ALLIED PRODUCTS
2043	CEREAL BREAKFAST FOODS	2611	PULP MILLS
2044	RICE MILLING	2621	PAPER MILLS, EXCEPT BUILDING PAPER
2048	PREPARED FEEDS, NEC	2631	PAPERBOARD MILLS
2051	BREAD, CAKE, AND RELATED PRODUCTS	2653	CORRUGATED AND SOLID FIBER BOXES
2052	COOKIES AND CRACKERS	2655	FIBER CANS, DRUMS & SIMILAR PRODUCT
2062	CANE SUGAR REFINING	27	PRINTING AND PUBLISHING
2079	SHORTENING AND COOKING OILS	2711	NEWSPAPERS
2084	WINES, BRANDY, AND BRANDY SPIRITS	2721	PERIODICALS
2086	BOTTLED AND CANNED SOFT DRINKS	2731	BOOK PUBLISHING
2095	ROASTED COFFEE	2741	MISCELLANEOUS PUBLISHING
2097	MANUFACTURED ICE	2752	COMMERCIAL PRINTING, LITHOGRAPHIC
2098	MACARONI AND SPAGHETTI	2754	COMMERCIAL PRINTING, GRAVURE
2099	FOOD PREPARATIONS, NEC	2761	MANIFOLD BUSINESS FORMS
21	TOBACCO PRODUCTS	2771	GREETING CARD PUBLISHING
2131	CHEWING AND SMOKING TOBACCO	2782	BLANKBOOKS AND LOOSELEAF BINDERS
22	TEXTILE MILL PRODUCTS	28	CHEMICALS AND ALLIED PRODUCTS
2211	EAVING MILLS, COTTON	2813	INDUSTRIAL GASES
2221	WEAVING MILLS, SYNTHETICS	2816	INORGANIC PIGMENTS
2241	NARROW FABRIC MILLS	2819	INDUSTRIAL INORGANIC CHEMICALS, NEC
2251	WOMEN'S HOSIERY, EXCEPT SOCKS	2821	PLASTICS MATERIALS AND RESINS
2252	HOSIERY, NEC	2833	MEDICINALS AND BOTANICALS
2253	KNIT OUTERWEAR MILLS	2834	PHARMACEUTICAL PREPARATIONS
2254	KNIT OUTERWEAR MILLS	2841	SOAP AND OTHER DETERGENTS
2257	CIRCULAR KNIT FABRIC MILLS	2842	POLISHES AND SANITATION GOODS
2258	WARP KNIT FABRIC MILLS	2843	SURFACE ACTIVE AGENTS
2262	FINISHING PLANTS, SYNTHETICS	2844	TOILET PREPARATIONS
2281	YARN MILLS, EXCEPT WOOL	2851	PAINTS AND ALLIED PRODUCTS
2282	THROWING AND WINDING MILLS	2865	CYCLIC CRUDES AND INTERMEDIATES
2295	COATED FABRICS, NOT RUBBERIZED	2869	INDUSTRIAL ORGANIC CHEMICALS, NEC
23	APPAREL AND OTHER TEXTILE PRODUCTS	2873	NITROGENOUS FERTILIZERS
2311	MEN'S AND BOYS' SUITS AND COATS	2874	PHOSPHATIC FERTILIZERS
2321	MEN'S AND BOYS' SHIRTS AND NIGHTWEA	2879	AGRICULTURAL CHEMICALS, NEC
2329	MEN'S AND BOYS' CLOTHING, NEC	2891	ADHESIVES AND SEALANTS
2337	WOMEN'S AND MISSES' SUITS AND COATS	2893	PRINTING INK
2339	WOMEN'S AND CHILDREN'S UNDERGARMENT	2895	CARBON BLACK
2369	CHILDREN'S OUTERWEAR, NEC	2899	CHEMICAL PREPARATIONS, NEC
2386	LEATHER AND SHEEP LINED CLOTHING	29	PETROLEUM AND COAL PRODUCTS
2387	APPAREL BELTS	2911	PETROLEUM REFINING
2392	HOUSE FURNISHINGS, NEC	2951	PAVING MIXTURES AND BLOCKS
2393	TEXTILE BAGS	2992	LUBRICATING OILS AND GREASES
2396	AUTOMOTIVE AND APPAREL TRIMMINGS	30	RUBBER AND MISC. PLASTICS PRODUCTS
2399	FABRICATED TEXTILE PRODUCTS, NEC	3069	FABRICATED RUBBER PRODUCTS, NEC
24	LUMBER AND WOOD PRODUCTS	31	LEATHER AND LEATHER PRODUCTS
2421	SAWMILLS AND PLANING MILLS, GENERAL	3111	LEATHER TANNING AND FINISHING
2431	MILLWORK	3143	MEN'S FOOTWEAR, EXCEPT ATHLETIC
2434	WOOD KITCHEN CABINETS	3144	WOMEN'S FOOTWEAR, EXCEPT ATHLETIC
2435	HARDWOOD VENEER AND PLYWOOD	3149	FOOTWEAR, EXCEPT RUBBER, NEC
2436	SOFTWOOD VENEER AND PLYWOOD	3171	WOMEN'S HANDBAGS AND PURSES
2449	WOOD CONTAINERS, NEC	3199	LEATHER GOODS, NEC
2451	MOBILE HOMES		
2452	PREFABRICATED WOOD BUILDINGS		
2499	WOOD PRODUCTS, NEC		

Table 2 SIC Four-Digit Manufacturing Industries used For Estimation

(continued)

SIC	Industry Name	SIC	Industry Name
32	STONE, CLAY, AND GLASS PRODUCTS	36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT
3221	GLASS CONTAINERS	3621	MOTORS AND GENERATORS
3229	PRESSED AND BLOWN GLASS, NEC	3631	HOUSEHOLD COOKING EQUIPMENT
3231	PRODUCTS OF PURCHASED GLASS	3634	ELECTRIC HOUSEWARES AND FANS
3241	CEMENT, HYDRAULIC	3639	HOUSEHOLD APPLIANCES, NEC
3271	CONCRETE BLOCK AND BRICK	3641	ELECTRIC LAMPS
3272	CONCRETE PRODUCTS, NEC	3643	CURRENT-CARRYING WIRING DEVICES
33	PRIMARY METAL INDUSTRIES	3644	NONCURRENT-CARRYING WIRING DEVICES
3312	BLAST FURNACES AND STEEL MILLS	3645	RESIDENTIAL LIGHTING FIXTURES
3321	GRAY IRON FOUNDRIES	3646	COMMERCIAL LIGHTING FIXTURES
3341	SECONDARY NONFERROUS METALS	3651	RADIO AND TV RECEIVING SETS
3351	COOPER ROLLING AND DRAWING	3652	PHONOGRAPH RECORDS
3353	ALUMINUM SHEET, PLATE, AND FOIL	3661	TELEPHONE AND TELEGRAPH APPARATUS
3354	ALUMINUM EXTRUDED PRODUCTS	3671	ELECTRON TUBES, RECEIVING TYPE
3357	NONFERROUS WIRE DRAWING & INSULATIN	3674	SEMICONDUCTORS AND RELATED DEVICES
34	FABRICATED METAL PRODUCTS	3675	ELECTRONIC CAPACITORS
3429	HARDWARE, NEC	3676	ELECTRONIC RESISTORS
3433	HEATING EQUIPMENT, EXCEPT ELECTRIC	3677	ELECTRONIC COILS AND TRANSFORMERS
3441	FABRICATED STRUCTURAL METAL	3678	ELECTRONIC CONNECTORS
3442	METAL DOORS, SASH, AND TRIM	3679	ELECTRONIC COMPONENTS, NEC
3443	FABRICATED PLATE WORK (BOILER SHOPS	3691	STORAGE BATTERIES
3444	SHEET METAL WORK	3699	ELECTRICAL EQUIPMENT & SUPPLIES, NE
3452	BOLTS, NUTS, RIVETS, AND WASHERS	37	TRANSPORTATION EQUIPMENT
3462	IRON AND STEEL FORGINGS	3713	TRUCK AND BUS BODIES
3465	AUTOMOTIVE STAMPINGS	3715	TRUCK TRAILERS
3469	METAL STAMPINGS, NEC	3728	AIRCRAFT EQUIPMENT, NEC
3494	VALVES AND PIPE FITTINGS	3732	BOAT BUILDING AND REPAIRING
35	INDUSTRIAL MACHINERY AND EQUIPMENT	38	INSTRUMENTS AND RELATED PRODUCTS
3511	TURBINES AND TURBINE GENERATOR SETS	3822	ENVIRONMENTAL CONTROLS
3519	INTERNAL COMBUSTION ENGINES, NEC	3823	PROCESS CONTROL INSTRUMENTS
3523	FARM MACHINERY AND EQUIPMENT	3824	FLUID METERS AND COUNTING DEVICES
3524	LAWN AND GARDEN EQUIPMENT	3825	INSTRUMENTS TO MEASURE ELECTRICITY
3531	CONSTRUCTION MACHINERY	3829	MEASURING & CONTROLLING DEVICES, NE
3532	MINING MACHINERY	3841	SURGICAL AND MEDICAL INSTRUMENTS
3533	OIL FIELD MACHINERY	3842	SURGICAL APPLIANCES AND SUPPLIES
3537	INDUSTRIAL TRUCKS AND TRACTORS	3843	DENTAL EQUIPMENT AND SUPPLIES
3541	MACHINE TOOLS, METAL CUTTING TYPES	3861	PHOTOGRAPHIC EQUIPMENT AND SUPPLIES
3544	SPECIAL DIES, TOOLS, JIGS & FIXTURE	39	MISCELLANEOUS MANUFACTURING INDUSTRIES
3545	MACHINE TOOL ACCESSORIES	3944	GAMES, TOYS, AND CHILDREN'S VEHICLE
3549	METALWORKING MACHINERY, NEC	3949	SPORTING AND ATHLETIC GOODS, NEC
3552	TEXTILE MACHINERY	3951	PENS AND MECHANICAL PENCILS
3554	PAPER INDUSTRIES MACHINERY	3991	BROOMS AND BRUSHES
3555	PRINTING TRADES MACHINERY	3993	SIGNS AND ADVERTISING DISPLAYS
3559	SPECIAL INDUSTRY MACHINERY, NEC	3999	MANUFACTURING INDUSTRIES, NEC
3561	PUMPS AND PUMPING EQUIPMENT		
3562	BALL AND ROLLER BEARINGS		
3563	AIR AND GAS COMPRESSORS		
3564	BLOWERS AND FANS		
3566	SPEED CHANGERS, DRIVES, AND GEARS		
3567	INDUSTRIAL FURNACES AND OVENS		
3568	POWER TRANSMISSION EQUIPMENT, NEC		
3569	GENERAL INDUSTRIAL MACHINERY, NEC		
3579	TYPEWRITERS AND OFFICE MACHINES, NEC		
3585	REFRIGERATION AND HEATING EQUIPMENT		
3586	MEASURING AND DISPENSING PUMPS		
3589	SERVICE INDUSTRY MACHINERY, NEC		
3592	CARBURETORS, PISTONS, RINGS, VALVES		
3599	MACHINERY, EXCEPT ELECTRICAL, NEC		

but three years (1977, 1982, and 1987) are linearly interpolated to increase the sample size. For example, if the investments in computers in an industry were one million dollars in 1977 and six million dollars in 1982, the values linearly interpolated are two million dollars in 1978, three million dollars in 1979, four million dollars in 1980, and five million dollars in 1981, respectively. The values in 1992 are also used for this linear interpolation. For investments in computers, we also show the results with the dollar value of investments per employee to control for the possible firm-size effect.

To our knowledge, there is no good price index for computer that takes the improvements in quality into account. The U.S. Bureau of Labor Statistics (BLS) has estimated the price index for personal computers and workstations since 1992, but this index cannot be used to adjust our variables since it falls outside the sample period for our data. We use the log values of shipments, imports, and investments in computers for standardization. Deflating these variables by CPI before taking the log does not substantially change the results.

Table 2 lists the industries covered by our panel data set. To make the panel balanced, 207 out of 450 SIC four-digit industries are used for our analysis. Although more than half of the industries are omitted from the data set, Table 2 shows that all two-digit industries are covered without extreme diffrences in numbers of four-digit industries included in each of two-digit classification.

3.3 Estimated Results

Table 3 shows the estimated regression equations. The estimated equation by ordinal least squares (OLS) and that controlled for industry fixed effects are shown for each of technological change measure. First, the value of industry shipments, our proxy for *Market Size,* has positive effects on all of the technological change variables but R&D by OLS. This is consistent with our model, and the use of the domestic demand (=shipments-net exports) does not change the result. The negative effect on R&D could be due to the definition of the variable; as the sales value in the denominator is highly correlated with the shipment value. However, the sign becomes positive when we control for the industry fixed effects.

The effects of tariffs, our proxy for the *Cost Advantage* of U.S. firms, are negative by OLS. By industry fixed-effect estimation, the effects are mixed. This result does not support either the hypothesis from our model very much or, in terms of trade policies, the

Table 3　Effects of Imports on Technological Changes.

Dependent /Independent Variables	5-Factor TFP		R&D/sales Ratio		log (investments in computers) (million dollars)		log (investments in computers per worker)	
	OLS	Fixed Effect	OLS	Fixed Effect	OLS	Fixed Effect	OLS	Fixed Effect
log (shipments)	0.007**	0.151**	−0.159**	0.212**	0.842**	0.883**	0.110**	0.128*
	(0.002)	(0.010)	(0.044)	(0.058)	(0.022)	(0.062)	(0.020)	(0.063)
tariff rate	−0.002**	−0.003**	−0.051**	0.019**	−0.019**	0.005	−0.051**	0.004
	(0.0003)	(0.001)	(0.007)	(0.006)	(0.003)	(0.007)	(0.003)	(0.007)
log (imports)	0.002	−0.012**	0.237**	0.016	0.110**	0.017	0.072**	0.025
	(0.002)	(0.005)	(0.028)	(0.031)	(0.014)	(0.014)	(0.013)	(0.034)
constant	0.924**	−0.123	2.194**	2.194**	−6.980**	−7.051**	−4.505**	−4.827**
	(0.020)	(0.073)	(0.352)	(0.352)	(0.175)	(0.456)	(0.162)	(0.457)
Year Dummies								
1978	N.S.	N.S.	N.S.	N.S.	0.215	0.234	0.277	0.281
1979	N.S.	−0.027	N.S.	N.S.	0.298	0.329	0.418	0.436
1980	N.S.	−0.052	N.S.	N.S.	0.357	0.403	0.537	0.582
1981	−0.021	−0.065	N.S.	N.S.	0.377	0.436	0.634	0.693
1982	−0.032	−0.075	N.S.	0.293	0.443	0.518	0.734	0.822
1983	−0.024	−0.070	N.S.	0.313	0.737	0.828	1.087	1.190
1984	N.S.	−0.062	N.S.	0.335	0.826	0.948	1.233	1.368
1985	N.S.	−0.067	N.S.	0.481	0.958	1.099	1.401	1.557
1986	−0.022	−0.076	N.S.	0.597	1.053	1.212	1.529	1.705
1987	N.S.	−0.054	N.S.	0.539	1.054	1.227	1.554	1.754
1988	0.024	−0.052	N.S.	0.401	1.081	1.261	1.628	1.834
adjusted R^2	0.036	0.148	0.057	0.299	0.568	0.667	0.404	0.695

Notes
1. Number of observations＝2484 (207 SIC 4-digit Industries×12 years (1977-88)).
2. Standard errors are in parentheses. N.S. for year dummies stands for "not significant"
3. *＝Statistically significant at 5% level. **＝1% level. N.S. for year dummies stands for "not significant."
4. Values of investments in computers are linearly interpolated for all years but 1982 and 1987.

so-called infant industry argument that a protective trade policy increases domestic technological change and output. Tariffs might only partially reflect the cost difference between U.S. and foreign firms. Further, the lobbies of U.S. manufacturers might have influenced the tariff rates. If such was the case, higher tariffs or other trade barriers resulting from the lobbies might have decreased the incentive of U.S. firms' to pursue technological change. Even though the average of U.S. tariff rates steadily declined during the sample period (clearly shown in Table 1), the potential endogeneity of tariffs cannot be ruled out. However, the effect for R&D/sales ratio is positive with industry fixed effects. Although the effect of R&D on costs or innovation is not deterministic in reality, this result is consistent with our model.

Imports have positive effects on the technological change of U.S. manufacturing firms (though the effect on TFP is not statistically significant) by OLS. However, by industry fixed-effect estimation, the effect is not significant for any of technology variables except for TFP (significantly negative). Without year dummies, the effect of imports are positive even with industry fixed effects (not shown in the table). However, as seen in the table, the year dummies are significant and are necessary to be included.

The effects of year dummies are shown if they are statistically significant at least five-percent level.[4] The year-dummy coefficients for computer variables show clear upward trend of these variables. One might argue that this trend is due to linear interpolation for the computer variables. However, the coefficients do not increase at the same rate as the year goes. Also, the per capita investments increases but the increases changes year by year. The coefficient for R&D/sales ratio also has a upward trend from 1982 except for 1987 and 1988. On the other hand, the coefficients for TFP shows cycle, possibly due to U. S. business cycle.

We seek to determine whether the effects have time lags for each of the regressions. The results with lagged independent variables (not shown here) suggest that the effect of time lag is not serious.

In Table 4, we used the ratio of imports to domestic shipments as the measure of import penetration. This measure might reflect the extent of how foreign imports have pressed

Table 4 Effects of Import Penetration on Technological Changes.

Dependent /Independent Variables	5-Factor TFP		R&D/sales Ratio		log (investments in computers) (million dollars)		log (investments in computers per worker)	
	OLS	Fixed Effect	OLS	Fixed Effect	OLS	Fixed Effect	OLS	Fixed Effect
log (shipments)	0.008**	0.147**	−0.012	0.248**	0.911**	0.856**	0.149**	0.131*
	(0.002)	(0.010)	(0.042)	(0.055)	(0.021)	(0.060)	(0.019)	(0.060)
tariff rate	−0.002**	−0.003**	−0.046**	0.019**	−0.016**	0.005	−0.049**	0.004
	(0.0004)	(0.001)	(0.007)	(0.006)	(0.003)	(0.007)	(0.003)	(0.007)
import penetration	0.001	0.013	−0.048	0.078	−0.026	−0.122**	−0.091	−0.043
	(0.006)	(0.007)	(0.111)	(0.041)	(0.055)	(0.044)	(0.051)	(0.045)
constant	0.923**	−0.145	2.053**	−0.434	−7.043**	−6.756**	−4.494**	−4.739**
	(0.020)	(0.075)	(0.365)	(0.436)	(0.181)	(0.468)	(0.167)	(0.470)
Year Dummies								
1978	N.S.	−0.017	N.S.	N.S.	0.238	0.243	0.293	0.288
1979	N.S.	−0.031	N.S.	N.S.	0.329	0.343	0.440	0.446
1980	N.S.	−0.057	N.S.	N.S.	0.393	0.421	0.563	0.594
1981	N.S.	−0.072	N.S.	N.S.	0.424	0.460	0.669	0.708
1982	−0.031	−0.081	N.S.	0.288	0.496	0.542	0.773	0.838
1983	−0.022	−0.079	N.S.	0.308	0.805	0.859	1.137	1.211
1984	N.S.	−0.074	N.S.	0.329	0.921	0.990	1.303	1.397
1985	N.S.	−0.081	0.486	0.475	1.069	1.146	1.483	1.590
1986	N.S.	−0.092	0.591	0.590	1.179	1.265	1.624	1.743
1987	N.S.	−0.071	0.531	0.529	1.186	1.287	1.655	1.795
1988	0.027	−0.070	0.409	0.389	1.219	1.326	1.733	1.877
adjusted R^2	0.035	0.147	0.029	0.300	0.557	0.668	0.397	0.695

Notes
1. Number of observations=2484 (207 SIC 4-digit Industries × 12 years (1977-88)).
2. Standard errors are in parentheses.
3. *=Statistically significant at 5% level. **=1% level. N.S. for year dummies stands for "not significant."
4. Values of investments in computers are linearly interpolated for all years but 1982 and 1987.
5. Import penetration=imports/shipment.

4) Standard errors are omitted to save the space.

U.S. manufacturing firms more than the value of imports. However, the estimated effects are not very different from those in Table 3.

4 Conclusions and Extensions

In this article, we attempt to estimate the effect of import penetration on technological change within U.S. firms. Based on the hypotheses derived from our newly developed model of R&D competition, we estimate a regression equation of technological change variables on imports, a market size variable, and a parameter representing cost differences between U.S. and foreign firms.

Our estimates show that the market size has a positive effects on the technological changes that take place in U.S. manufacturing industies while tariff rates have mixed effects. we find that either imports or the ratio of the imports to the domestic shipments have mixed effects on technological change.

Our results can be extended in several other directions. We could explore more issues of estimation and model specification. First, our estimates do not include any measure of foreign direct investments. Bertschek (1995) suggest that in the former West Germany, foreign direct investments were an important factor as well as a form of international trade that influenced innovation within domestic firms' innovation.

Second, introducing the possibility of exit by either domestic or foreign firms would make the model more realistic and change its predictions. We attempt to introduce the possibility of exit in our model by giving a first-move advantage to the domestic firm. However, in our model, a domestic firm benefits more from the accommodation of foreign imports than inducement for the exit of a foreign firm by large R&D investment, as the latter does not change the main results.

References

[1] Bartel, A. P. and N. Sicherman, 1999, Technological change and wages: an interindustry analysis, Journal of Political Economy 107, 285-325.

[2] Bertschek, I., 1995, Product and process innovation as a response to increasing imports and foreign direct investment, Journal of Industrial Economics 43, 341-357.

[3] Coe, D. T. and E. Helpman, 1995, International R&D spillovers, European Economic Review 39, 859-887.

[4] Lawrence, R. Z., 2000, Does a kick in the

pants get you going or does it just hurt? The impact of international competition on technological change in US manufacturing, in: R. C. Feenstra, ed., The impact of international trade on wages, (University of Chicago Press) 197-219.

[5] Mookherjee, D. and D. Ray, 1991, On the competitive pressure created by the diffusion of innovations, Journal of Economic Theory 54, 124-47.

[6] Scherer, F. M. and K. Huh, 1992, R&D reactions to high-technology import competition, Review of Economics and Statistics 74, 202-212.

[7] Spencer, B. J. and J. A. Brander, 1983, International R&D rivalry and industrial strategy, Review of Economic Studies 50, 707-722.

[8] Symeonidis, G., 1996, Innovation, firm size and market structure: Schumpeterian hypotheses and some new themes, OECD Economic Studies 27, 35-70.

[9] Wood, A., 1995, How trade hurt unskilled workers, Journal of Economic Perspectives 9, 57-80.

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