

EMPIRICAL STUDY OF EXCHANGE RATE PASS-THROUGH: THE EFFECT OF RIVAL EXCHANGE RATES

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This article tests the strategic behaviors among exporting firms with simultaneous estimation techniques using 7-digit TSUSA data. Exchange rate pass-through is estimated, and the effect of the rival exchange rate is emphasized. Also, I demonstrate the problem associated with tests which use trade-weighted exchange rate. Pass-through rates are significantly different across source countries and products. While the own exchange rate pass-through tends to be related positively with market share, firms that have small market shares often pass through for the fluctuation of rival exchange rate. Particularly, some exporters who have small market shares may pass through the change of rival exchange rate but not the change of own exchange rate. Most importantly, this research highlights the importance of market structure in exchange rate pass-through studies.

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I. INTRODUCTION

Exporting firms based in different countries have faced notably large fluctuations in currency values, particularly since the advent of floating exchange rates. In an export market, the major uncertainty may result from the change of exchange rate. Exchange rate changes are usually perceived as cost shocks for a foreign firm producing in its home country and selling in its export market. When the exchange rate changes, the firm may choose to pass the cost shock into its selling prices; it is called exchange rate pass-through.

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During the last two decades, there have been over 50 published empirical studies on exchange rate pass-through (PT). Over half of the studies employed an aggregate approach. However, the aggregate approach raises the concern of possible aggregation bias in the pass-through estimates, especially given the fact that studies such as Feenstra (1989), Feinberg (1989), Kasa (1992) and Athukorala and Mennon (1994) found significant differences in pass-through rates across industries, possibly reflecting differences in demand and cost conditions. Thus exchange rate-price relationships cannot be meaningfully studied without referring to disaggregated data. Studies using disaggregated data in sectors or industries, which is still a very high level of aggregation, also often face a proxy bias. Previous studies have frequently relied on price proxies such as import or export unit values. Alterman (1991) emphasized the bias introduced into estimates of pass-through as a result of measurement errors inherent in price proxies.

Existing empirical research has documented several stylized facts about pass-through. While Kreinin (1977), Spitaeller (1980), Khosla and Teranishi (1989), and Knetter (1989) found that PT behavior differs across source countries, Feenstra (1989), Feinberg (1989), Kasa (1992), and Knetter (1993) found significant differences in PT rates across industries or product categories. However, there is little disaggregated research attempting to formally explain inter-industry differences in PT.

Incomplete pass-through is a common and pervasive phenomenon across a wide range of countries. Much of the literature explains the incomplete PT with an imperfect competition model. Although there are many empirical studies estimating imperfect competition model, those were tested with aggregate data. This mismatch should be of concern if the industry and aggregate data behave differently.

This line of research has paid little attention to the differences of competition situation across destination countries and commodities. There is no literature giving an attention to strategic interaction with other foreign rivals (e.g., how the existence of other foreign rivals and the movement of rival countries' exchange rates affect on pass-through). The existing exchange rate pass-through (PT) literature is based on an imperfect competition model of a foreign firm and a domestic firm, including only a bilateral exchange rate. However, if other foreign firms exist in the market, the foreign firm's pricing behavior will be affected by rival countries' exchange rates through the strategic interaction. Intuitively, the firm with small market share may choose their price depending on rival's price rather than its own exchange rate. In an export market, an exporter may often face other foreign firms rather than domestic firms as major rivals. Indeed, in some markets, a domestic firm does not exist. Even when domestic firms exist, the substitutability between imported goods is often much higher than the one between an imported good and a domestic good. Thus, rival exchange rates may have a significant effect on the firm's price decision through the strategic interaction. The importance of strategic interaction in an export market was

recognized by Goldberg and Knetter (1997; p1265).

This research is different from earlier empirical studies in several regards. First, this study employs the disaggregated data at the finest level. The 7-digit level TSUSA (Tariff Schedule of the United States Annotated) data that I use here contains over 16,000 product categories. The result of the tests, for the market of specific commodities, will be freer from the aggregation bias mentioned above and better matched with imperfect competition model. Furthermore, the disaggregated data should also enable more accurate estimation of the time-lags involved in the transmission of exchange rate changes to prices (Hopper & Mann, 1989). The use of such micro-level data may shift the emphasis of the study to the level of the firm and make the study useful to international marketers as they determine their pricing strategies. However, this study will also generate some implications at the macro-level that will be further explained in the results section.

Second, this research emphasizes the role of strategic behavior among foreign firms in a market by expanding the data sample to include two or three major exporting countries that compete in a common export (U.S.) market in the same industries. The competition structure differs across destination markets as well as across industries or goods. The different exchange rate PT may result from the differences in the degree and structure of competition across destination markets as well as the difference in destination-specific demand for the good. Furthermore, the existence of the foreign rivals and the movement of rival countries' exchange rates may be an explanation for inter-industry differences in PT. The particular attention of this empirical study is focused on the effect of rival exchange rates. Actually, in price decision, the rival's exchange rate may have a much affect on the firm's decision as its own exchange rate. For example, a Korean exporter of electronic goods will be sensitive to the value of Japanese currency.

II. THE IMPERFECT COMPETITON MODEL

This paper considers a heterogeneous oligopoly with price strategies. There are n firms based in different source countries.¹ Therefore, each firm faces a different exchange rate. Each firm i exports the differentiated good i to a destination market (say U.S.), respectively. The foreign spot prices of the destination currency are denoted by e_i (foreign country i 's currency/\$). The destination currency prices of the imported varieties of a differentiated product are denoted by p_i . I will treat rival prices' vector as P_{-i} . Then, I can write

¹ Here, I exclude the US domestic firms in this competition because domestic data that match 7-digit TSUSA commodity categories are not available. I implicitly assume that the substitutability among imported goods is much higher than the one between an imported good and a domestic good. Indeed, in the international export market, an exporter may face other foreign firms rather than domestic firms as major rivals. Patriotism may also help the model justification.

import demand as $q_i(p_i, P_{-i}, Z)$, where Z denotes a vector of all variables shifting demand. The foreign firms maximize expected profits in own currency, treating P_{-i} as exogenous.² I assume that its pricing decision must be made before the exchange rate is known with certainty. As discussed by Baron (1976), McKinnon (1979), and Giovannini (1988), the foreign firms then face a decision as to which currency to use in announcing its price. I will not analyze this problem, but rely on the fact that 85 percent of U.S. imports are invoiced in dollars.³ Since my empirical work deals with this market, I simply assume that the foreign firms set their price in the destination market currency (\$). I also assume that the cost functions in the foreign currency are separable in quantity and input prices so that it can be written as $\varphi_i(q_i)\phi_i(W_i)$ and marginal cost is $\varphi'_i(q_i)\phi_i(W_i)$, where q_i is the output of good i , and W_i is vector of firm i 's input factor prices. The foreign firms' profit maximization problem can be written as:

$$\underset{p_i}{\text{Max}} E[e_i p_i q_i(p_i, P_{-i}, Z) - \varphi_i(q_i)\phi_i(W_i)] \quad (1)$$

where $i = 1, 2, \dots, n$ and E denotes expected value. I assume that variables other than the exchange rate are non-random. Letting $s_i = E[e_i]$ denotes the expected exchange rate, equation (1) can be rewritten as:⁴

$$\underset{p_i}{\text{Max}} [s_i p_i q_i(p_i, P_{-i}, Z) - \varphi_i(q_i)\phi_i(W_i)] \quad (2)$$

The first-order condition for (2) is:

$$\varphi'_i(q_i)\phi_i(W_i) = s_i p_i \left\{ 1 - \frac{1}{\eta_i} \right\} \quad (3)$$

where $\eta_i = -\frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i}$ denotes the (positive) elasticity of demand for firm i .

Rearranging equation (3) yields a markup model of price determination which prevails in previous empirical studies in this field, (e.g., Athukorala, 1991; Athukorala & Menon, 1994; Hooper & Mann, 1989).

$$p_i = mk_i \cdot mc_i / s_i \quad (4)$$

² Thus, I assume that the foreign firms act as Bertrand competitor. However, my generalized empirical model that can match conjectural variation behavior is independent of this assumption.

³ See Hamada and Horiuchi (1987).

⁴ This certainty-equivalent structure to the firms' problems would not arise if the import prices were set in the foreign currency; see Giovannini (1988).

where $mk_i = \left(1 - \frac{1}{\eta_i}\right)^{-1}$. The typical exporting firm sets an export price (p_i) in importer currency (\$) at a markup (mk_i) over its marginal cost of production (mc_i). If perfect competition prevails ($\eta_i = \infty$), then price is equal to marginal cost, and pass-through is perfect.

Assuming that $\left[\varphi_i''(q_i) \frac{\partial q_i}{\partial p_i} \phi_i(W_i) - s_i \frac{\partial r_i}{\partial p_i}\right] \neq 0$, where $r_i = p_i \left(1 - \frac{1}{\eta_i}\right)$, I can convert (3) to obtain the pricing equation:

$$p_i = \pi_i(s_i, \phi_i(W_i), P_{-i}, Z) \quad (5)$$

III. THE ECONOMETRIC MODEL

Differently from other oligopoly empirical studies in exchange rate pass-through, I estimate a system of equations to see the effect of rival exchange rate. Since most studies approximate the competitor prices as a domestic price or a trade weighted price, and regard the competitor prices as an independent variable, only a single equation estimation method could be used. However, these estimations hide the effect of rival's exchange rate fluctuation and are both biased (i.e., the effect of own exchange rate is overstated) and inconsistent as well known.

To test the effect of rival's exchange rate change, I use a log-linear specification for equation (5) which is a variant of Feenstra's (1989) model.⁵

$$\ln p_{it} = \alpha_{i0} + \alpha_{i1} \ln y_t^{us} + \alpha_{i2} \ln s_{it} + \alpha_{i3} \ln \phi_i(W_{it}) + \sum_{j=1, j \neq i}^n \beta_{ij} \ln p_{jt} + \varepsilon_{it} \quad (6)$$

where ε_{it} is a random error. The vector of variables shifting demand (Z) is represented by the economic activity of destination country (y_t^{us}). The demand function corresponding to the specification (6) can be obtained by assuming constant pass-through and solving the resulting differential equation.⁶

To estimate equation (6) I must specify how the expected exchange rate and the cost function in input price are determined. I assume the expected exchange rate is a log-linear function of the lagged spot exchange rates (or $\ln s_t = \sum_{g=0}^k \lambda_g \ln e_{t-g}$). The current quarterly-average exchange rate is included

⁵ Feenstra(1989) estimated just a single equation with instrumental variables because he did not consider strategic behavior between exporters.

⁶ Totally differentiating (3), I obtain $(dp_i/ds_i)(s_i/p_i) = -1/[(\varphi_i'' q_i/\varphi_i')\eta_i + (\partial r_i/\partial p_i)(p_i/r_i)]$. For example, to obtain a pass-through elasticity of $-1/2$ set $\varphi_i'' = 0$ and $(\partial r_i/\partial p_i)(p_i/r_i) = 1 + (p_i^2/r_i \eta_i^2)(\partial \eta_i/\partial p_i) = 2$. Then the solution is obtained as $q_i = (k_i/p_i) - q_i^0$, where $q_i^0 > 0$ and $k_i > 0$ can depend on P_{-i} and y^{us} . By choosing $k_i = (P_{-i})^e (y^{us})^f$, and solving for the optimal price, I obtain a log-linear specification as (6). The demand curves leading to a constant pass-through unequal to $-1/2$ are more complex.

to reflect information received by firms within a quarter which is then immediately reflected in prices. If unit of time is small, such as monthly or weekly, then omitting the current spot rate will be appropriate. The coefficients λ_g would depend on the time-series properties of exchange rate. For example, if the spot rate follows a random walk, then rational expectations would be formed with $\lambda_1 = 1$ and $\lambda_g = 0$ for $g \neq 1$.

I assume that each firm uses two inputs, labor and capital. Firms are assumed to minimize the unit cost of production by choosing the best combination of labor and capital. The cost function in input price ($\phi_i(W_{it})$) is given by a Cobb-Douglas cost function. The time trend is used to capture the effects of productivity change: $\ln \phi_i(W_{it}) = \ln a_{i0} + a_{i1} \ln wg_{it} + a_{i2} \ln in_{it} + f_{i0} + f_{i1}t + f_{i2}t^2 + \xi_{it}$. Where wg_{it} and in_{it} are prices of labor and capital at time t for each firm i , and $f_{it} = f_{i0} + f_{i1}t + f_{i2}t^2$ is a time trend. Then the estimating simultaneous equations are derived as:

$$\ln p_{it} = c_{i0} + c_{i1}t + c_{i2}t^2 + \alpha_{i1} \ln y_t^{us} + \sum_{j=1, j \neq i}^n \beta_{ij} \ln p_{jt} + \sum_{g=0}^k \gamma_{ig} \ln e_{it-g} + \delta_{i1} \ln wg_{it} + \delta_{i2} \ln in_{it} + \varepsilon_{it} \quad i, j = 1, 2 \dots n \quad (7)$$

where $c_{i0} = \alpha_{i0} + \alpha_{i3}(\ln a_{i0} + f_{i0})$, $c_{i1} = \alpha_{i3}f_{i1}$, $c_{i2} = \alpha_{i3}f_{i2}$, $\gamma_{ig} = \alpha_{i2}\lambda_{ig}$, $\delta_{is} = \alpha_{i3}a_{is}$ and $\sum_{g=0}^k \lambda_{ig} = 1$ is assumed.

I have n equations with n firms' oligopoly market and estimate n simultaneous equations as a system (3SLS).⁷ The equations in the system are identified.⁸ Equation (7) can be written as:

$$\begin{bmatrix} 1 & -\beta_{12} & \cdots & -\beta_{1n} \\ -\beta_{21} & 1 & \cdots & -\beta_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ -\beta_{n1} & \cdots & \cdots & 1 \end{bmatrix} \cdot \begin{bmatrix} \ln p_1 \\ \ln p_2 \\ \vdots \\ \ln p_n \end{bmatrix} = \begin{bmatrix} J_1 + \sum_{g=0}^k \gamma_{1g} \ln e_{1t-g} \\ J_2 + \sum_{g=0}^k \gamma_{2g} \ln e_{2t-g} \\ \vdots \\ J_n + \sum_{g=0}^k \gamma_{ng} \ln e_{nt-g} \end{bmatrix} \quad (8)$$

⁷ Although full information maximum likelihood (FIML) is theoretically favorable, since three stage least squares (3SLS) does not require a normality assumption, it is a frequently used method for relatively small samples as in this data.

⁸ Kelejian and Oates (1989) demonstrate that the necessary condition for identification in a simultaneous equations system in which endogenous variables enter nonlinearly is $A_{1i} \geq A_{2i}$. Where A_{1i} = number of predetermined variables appearing in the model but not appearing in the i th equation and A_{2i} = number of endogenous variables appearing as a regressor in the i th equation. In this system, $A_{1i} = (n-1)(2+k)$ and $A_{2i} = n-1$.

where $J_i = c_{i0} + c_{i1}t + c_{i2}t^2 + \alpha_{i1} \ln y^{us} + \delta_{i1} \ln wg_i + \delta_{i2} \ln in_i + \varepsilon_i$. The interest of estimation is the time pattern of the coefficients γ_{ig} , which indicate the rate at which exchange rate changes are passed through to import prices. To reduce the erratic behavior of the coefficient estimates, I will use a second-order polynomial lag on γ_{ig} , so that $\gamma_{ig} = a + bg + cg^2$. For $k=4$, I can readily calculate that $\sum_{g=0}^k \gamma_{ig} = 5a + 10b + 30c$. The responsiveness of export price in \$ (p_i) to change in own bilateral exchange rate (e_i) and the effect of rivals' exchange rates changes on export price in \$ (p_i) are calculated from:

$$\begin{bmatrix} \ln p_1 \\ \ln p_2 \\ \vdots \\ \ln p_n \end{bmatrix} = \begin{bmatrix} 1 & -\beta_{12} & \cdots & -\beta_{1n} \\ -\beta_{21} & 1 & \cdots & -\beta_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ -\beta_{n1} & \cdots & \cdots & 1 \end{bmatrix}^{-1} = \begin{bmatrix} \sum_{g=0}^k \gamma_{1g} \ln e_{1t-g} \\ \sum_{g=0}^k \gamma_{2g} \ln e_{2t-g} \\ \vdots \\ \sum_{g=0}^k \gamma_{ng} \ln e_{nt-g} \end{bmatrix}$$

For example, for $n=2$, while $\frac{\sum \gamma_{1g}}{1 - \beta_{12}\beta_{21}}$ measures the responsiveness of export price in \$ (p_1) to change in own bilateral exchange rate (e_1), $\frac{\beta_{12} \sum \gamma_{2g}}{1 - \beta_{12}\beta_{21}}$ scales the effect of rival exchange rates changes (e_2) on export price in \$ (p_1).

Alternative specifications:

I also consider several alternative specifications. First, I may also estimate the reduced form of (7). To see only the effect of rival's exchange rate change, the structural form estimation is not necessary required. The reduced form for each firm i will be:

$$\ln p_t = v_{0t} + v_1 \ln y_t^{us} + \sum_{j=1}^n v_{2j} \ln wg_{jt} + \sum_{j=1}^n v_{3j} \ln in_{jt} + \sum_{j=1}^n \sum_{g=0}^k v_{4jg} \ln e_{j,t-g} + \mu_t \quad (9)$$

While $\sum_{g=0}^k v_{4ig}$ measures the effect of export price in \$ (p_i) to change in bilateral exchange rate (e_i), $\sum_{j \neq i}^n \sum_{g=0}^k v_{4jg}$ scales the effect of rival's exchange rate changes on export price in \$ (p_i).

Second, I shall eliminate the lagged exchange rates in (7) and (9), and only current exchange rates are used as independent variables. This modification will be justified by rational expectations. However, the inclusion of lagged values of exchange rate variable may not be based on the expectation of exchange rates. The reason for including lagged exchange rate is that there are certain

institutional lags (such as transport time and reporting lags) that could delay the impact of an exchange rate change on prices. Another reason is that there may be a reluctance on the part of sellers to pass-through all of a major fluctuation immediately. Spreading the pricing response over time might make the price changes (especially increases) somewhat more palatable to prospective buyers.

IV. DATA DESCRIPTION

I estimate the US import market for specific industries or goods. The use of highly disaggregated data is motivated by the fact that individual commodities differ with regard to demand, cost conditions and competition situations, and estimates at the aggregate level tend to mask such differences. For specific commodities, the U.S. import data (q_{it} , p_{it} and $q_{it}p_{it}$) are obtained by commodity by country of origin on annual base from the U.S. Department of commerce, Bureau of the Census. The TSUSA data at the 7-digit level in the present study are compiled at the finest level of aggregation available in publicly distributed trade statistics. However, publicly distributed annual data may not be desirable for this research because of low frequency.

Fortunately, I could get the unpublished TSUSA monthly data at the 7-digit level from Dr. William R. Smith (the author of "Exchange Rates and Prices: The Case of United States Imports"). He kindly provided 112 product data covering from January of 1978 through December of 1988. Although the TSUSA contains over 16000 product categories, Smith (1996) chose 112 products through several sample selection criteria⁹: (1) choose products whose total import values are during 1988 of at least \$75 million, (2) remove products whose total import value are zero in 1978, (3) remove heterogeneous product categories, (4) remove products whose quantities are expressed in different quantity measures at different times or by different importers, (5) excluded by initial examination for price heterogeneity, etc. The time period was chosen for some reasons including (1) exchange rates of most major US trading partners were floating, (2) many important traded products, such as certain types of electronics, were not produced in earlier time period, (3) since 1990, the 7-digit categories were changed to 10 digit.

The distinguishing feature of this data is that the import prices are genuine prices that are free from well-known limitations as price proxies. However, we have to regard all foreign firms that are based in the same country as a representative firm (or firms of the same country are identical) because of data limitations. In reality, pass-through can be different among companies because they have different cost structure, production methods, and productivity. Since these firms are affected by the same bilateral exchange rate, I expect that it do

⁹ See Smith (1996; p 66-75) for detail.

not affect this test too seriously. In choosing commodity markets, I added some additional rule to Smith (1996)'s. First, I choose goods imported from only a few countries, to avoid monopoly or perfect competition market. Next, I change the monthly data to quarterly to reduce some data problems (order-delivery lag, etc.). I also remove goods that have any zero value through the whole sample period (i.e., quarter one of 1978 through quarter four of 1988). Finally, I remove products that its major exporters are Brazil, Hong Kong, Malaysia, Philippines, Singapore, Taiwan and Thailand. For these countries, wage and/or interest rate data are not available for the whole sample period.¹⁰ After implementing these criteria, I am left with 20 product markets to test. Other data are available on quarterly basis from International Financial Statistics, IMF.

y^{us} = real GDP of U.S. (as a proxy of economic activity of U.S.).

wg_i = wage index of country i .

in_i = interest rate of country i . Due to availability for a whole sample period, different interest rates across countries are used (treasury bill rates for Canada, Mexico and U.K.; discount rates for Korea; money market rates for other countries).

e_i = exchange rate of country i (exporter i currency/\$).

V. ESTIMATION RESULTS AND DISCUSSION

While there is no generally accepted technique for choosing the length for a polynomial lag, I experimented with a lag length of 3 and 4 quarters, but the results were quite similar. It seems that the estimation of 3SLS does not have any advantage compared to the reduced form estimation in viewing the effect of exchange rates, because economic theory tells us that reduced form parameters are the long-run multipliers associated with the model. However, in the over-identified case, the pass-through estimates from 3SLS are biased, but consistent and more efficient than those from the reduced form (Kennedy; 1992, p. 168).¹¹

In the over-identified case, 3SLS estimates are restricted by structural parameters while reduced estimations are an unrestricted regression. Furthermore, we, from 3SLS, can see the coefficients for structural forms and figure out the

¹⁰ Smith (1996)'s study included these countries because his model does not employ any other variable except exchange rates and prices.

¹¹ Following the suggested means, I tested the over-identifying restrictions. In the case of using polynomial lagged exchange rates, derived reduced form estimates are superior to OLS reduced form estimates in 13 markets (beer, wall paper, electrodes, steel pipe, steel wire stand, diesel engine, front-end loaders, chainsaws, shavers, spark plugs, relays, eyeglasses, and silver halide paper). In the case of using only spot exchange rates, derived reduced form estimates are superior to OLS reduced form estimates in 10 markets (wall paper, benzene, electrodes, steel pipe, steel wire stand, front-end loaders, chainsaws, relays, silver halide paper, and grand pianos).

economical meanings.¹² To increase the degree of freedom T^2 or interest rate terms that are not employed by most researchers were removed if the coefficients were not statistically significant.

Results for the twenty U.S. import products are reported in Table I. For each product the table reports the pass-through of own exchange rate and rival exchange rates from both 3SLS estimates and reduced form estimates. The countries included in the model are the major exporters. Also, average market shares during whole sample period are reported. For example, in the beer market, Netherlands' exporter passes 92.6% of own exchange rate fluctuation to their export price in U.S. dollar while Germany exporter pass 24.5% of the fluctuation of Netherlands' exchange rate. Other PTs are not statistically significant. The average market shares in the beer import market of U.S. are 22% for Canada, 15% for Germany, and 44% for Netherlands.

Both estimations show significant normal pass-through¹³ for rival exchange rate as well as own exchange rate in most product markets. With 3SLS estimation, I can see that 27 exporters from 19 commodity markets show significant pass-through for own exchange rate while 12 exporters from 10 commodity markets show significant pass-through for rival exchange rates. It supports the conventional wisdom that exporters capable of price adjustment pass cost shocks induced by exchange rate fluctuations to their export prices. Only two exporters have perverse pass-through behavior for own exchange rate. Reduced form estimation also indicates that 18 exporters from 15 commodity markets show significant normal pass-through for own exchange rate while 14 exporters from 12 commodity markets show significant normal pass-through for rival exchange rates. Like other literature the exchange rate pass-through varies quite significantly across industries or source countries. However, we can see PT of higher than 100% for some exporters in some markets. This is puzzling. I might have to recognize this model is not fit well for commodity markets in which pass-through is greater than one beyond standard error. The simplicity of the model may preclude a clear interpretation of the effect of exchange rate changes on import prices. First, other omitted factors (or firm specific factors) that are systematically related to exchange rates may change elasticities over time. Second, there is no attempt to control for the U.S. domestic good prices of close substitutes. Finally, it is possible that aggregation could bias the coefficients. Even though the 7-digit level TSUSA is compiled at the finest level of aggregation available, it is still not free from the problem of aggregation. If there is heterogeneity within a product, changes in the composition of exports may be correlated with exchange rates if the elasticities of demand for varieties differ.

¹² Other coefficients than PT are not reported here because there are too many coefficients from 45*4 equations. Although some coefficients are not significant statistically, resulting in relatively weak support, there is little that is adverse to economic sense.

¹³ In my model, normal pass-through will be negative pass-through for both own and rival exchange rates.

[Table I] Exchange rate pass-through, with polynomial lagged exchange rates^{1,2}

Product (TSUSA#)	Source country	Market Share	3SLS			Reduced form		
			Own exchange rate	Rival1 exchange rate	Rival2 exchange rate	Own exchange rate	Rival1 exchange rate	Rival2 exchange rate
Beer 1670515	Canada	22%	-0.217 (0.176)	0.041 (0.082)	-0.062 (0.112)	-0.701* (0.415)	-1.543 (1.140)	1.605 (1.131)
	Germany	15%	0.071 (0.135)	-0.035 (0.043)	-0.245* (0.143)	-0.293 (0.641)	0.062 (0.234)	0.115 (0.636)
	Netherlands	44%	-0.926*** (0.086)	-0.031 (0.044)	0.036 (0.072)	-1.168* (0.639)	-0.746*** (0.235)	0.307 (0.644)
Wall paper 2560500	Canada	38%	-1.820** (0.751)	0.538 (0.418)	-0.152 (0.140)	-1.212** (0.603)	-0.031 (0.397)	-0.245 (0.169)
	Korea	12%	-0.984 (0.816)	0.374 (1.434)	0.377 (0.286)	-0.974 (0.668)	0.570 (1.015)	0.422 (0.284)
	UK	18%	0.278 (0.202)	-0.455 (0.943)	-0.342 (0.500)	0.480 (0.321)	0.041 (1.148)	-0.630 (0.756)
Benzene 4011000	Canada	30%	0.577 (2.445)	-0.117 (0.716)		0.450 (1.406)	0.774 (0.630)	
	Japan	15%	-0.143 (0.874)	0.565 (2.395)		0.330 (0.569)	0.209 (1.270)	
Hydroxide 4210800	Canada	53%	-3.776*** (0.646)	0.175 (0.294)		-3.946*** (0.980)	0.776** (0.309)	
	Japan	13%	-1.751*** (0.541)	-6.398*** (1.708)		0.769 (0.874)	-7.967*** (2.770)	
Polybutad rubber 4461516	Canada	46%	-1.143*** (0.411)	-1.045*** (0.297)		-1.222** (0.584)	-0.509** (0.257)	
	Japan	25%	-0.862*** (0.3090)	-1.366*** (0.463)		-0.447 (0.205)	-1.733*** (0.466)	
Electrodes 5176100	Canada	5%	-0.576 (7.851)	1.212 (1.342)		6.816 (4.543)	1.082 (1.695)	
	Japan	66%	-0.648** (0.309)	0.084 (1.153)		-0.711*** (0.254)	0.001 (0.681)	
Steel pipe 6103955	Canada	51%	-2.100** (0.209)	-0.024 (0.205)		-1.987*** (0.294)	-0.045 (0.184)	
	Canada	40%	-0.620*** (0.138)	-0.966*** (0.236)		-0.276 (0.198)	-0.901*** (0.317)	
Steel wire stand 6421110	Italy	10%	0.299 (0.324)	-0.465 (0.390)		0.476 (0.344)	-0.836* (0.510)	
	Japan	41%	-0.635* (0.345)	0.242 (0.273)		-0.912* (0.509)	0.359 (0.343)	

Note: 1. Standard errors are shown in parentheses. Statistical significance is based on asymptotic t-ratios:

*** at the 1 percent level, ** at the 5 percent level, * at the 10 percent level.

2. Rival 1 and rival 2 are ordered alphabetically. For example, in the beer market, the rival 1 of Germany is Canada, and the rival 2 of Germany is Netherlands.

[Table I] Continued

Product (TSUSA#)	Source country	Market Share	3SLS			Reduced form		
			Own exchange rate	Rival1 exchange rate	Rival2 exchange rate	Own exchange rate	Rival1 exchange rate	Rival2 exchange rate
Diesel engine 6604260	Germany	18%	-0.808** (0.372)	0.335 (0.490)	0.176 (0.300)	-0.932 (0.845)	-1.655 (1.276)	-1.478 (0.952)
	Japan	25%	0.804 (1.141)	-0.782 (0.731)	0.345 (0.575)	-2.053 (1.614)	1.405 (1.068)	1.236 (1.204)
	UK	37%	0.447 (0.667)	-0.693 (0.662)	0.521 (0.771)	1.464 (2.039)	0.993 (1.809)	-1.652 (2.733)
Motor vehicle Pumps 6609702	Germany	23%	0.302 (0.612)	-1.314 (0.993)		-2.744 (1.996)	3.266 (2.912)	
	Japan	43%	-1.527** (0.720)	0.170 (0.361)		-0.825 (2.046)	-0.249 (1.403)	
Front-end Loaders 6640720	Canada	37%	-4.265*** (1.264)	-0.844* (0.432)		-4.508** (1.797)	-2.135** (1.050)	
	Japan	29%	2.331** (0.941)	-1.519 (1.251)		1.141 (1.254)	-4.279** (2.146)	
Chainsaws 6747025	Germany	31%	-0.970*** (0.198)	0.032 (0.057)	0.144 (0.134)	-0.989** (0.386)	0.889 (0.577)	-0.057 (0.416)
	Japan	17%	0.323 (0.445)	-1.126** (0.428)	0.419 (0.284)	1.770 (1.067)	-0.613 (0.713)	-0.981 (0.769)
	Sweden	31%	0.528 (0.307)	-0.998*** (0.328)	0.054 (0.092)	0.724 (0.454)	-1.402*** (0.421)	0.230 (0.630)
Shavers 6835020	Japan	11%	-0.872*** (0.228)	-0.008 (0.178)		-0.932 (0.875)	0.552 (0.559)	
	Netherlands	73%	-0.624*** (0.179)	0.404 (0.207)		-0.788* (0.422)	0.642 (0.661)	
Spark plugs 6836060	Germany	37%	-0.347*** (0.091)	0.135 (0.156)		-0.561** (0.243)	-0.039 (0.397)	
	Japan	52%	-0.410*** (0.169)	0.074 (0.063)		-0.347 (1.649)	-0.002 (0.397)	
Relays 6859034	Japan	29%	0.089 (0.278)	-0.005 (0.050)		0.412 (0.296)	-0.249** (0.127)	
	Mexico	33%	-0.173** (0.076)	-0.033 (0.103)		-0.104 (0.090)	0.024 (0.209)	
Power cable 6880465	Canada	50%	-2.068*** (0.618)	-0.217*** (0.076)		-2.622*** (0.736)	-0.226*** (0.071)	
	Mexico	12%	-0.984*** (0.248)	-0.967 (1.615)		-0.802*** (0.291)	-4.525 (3.023)	
Tractors 6923406	Germany	35%	-1.027*** (0.296)	0.138 (0.230)		-0.220 (0.441)	0.114 (0.888)	
	UK	35%	-1.301 (1.655)	-1.226* (0.688)		0.012 (2.192)	-0.529 (1.090)	

[Table I] Continued

Product (TSUSA#)	Source country	Market Share	3SLS			Reduced form		
			Own exchange rate	Rival1 exchange rate	Rival2 exchange rate	Own exchange rate	Rival1 exchange rate	Rival2 exchange rate
Eyeglasses 7084720	Fance	21%	-0.266 (0.278)	-0.105 (0.185)	0.023 (0.068)	2.812 (1.742)	-3.826** (1.705)	1.098 (1.159)
	Italy	24%	-1.066*** (0.322)	0.008 (0.106)	0.198 (0.208)	-4.196* (2.380)	2.697 (2.432)	0.072 (1.618)
	Japan	15%	0.332 (0.312)	0.089 (0.129)	-0.498* (0.285)	0.079 (1.132)	2.102 (1.702)	-2.638 (1.666)
Silver halide paper 7233030	Germany	21%	-0.622** (0.282)	0.370 (0.353)		-0.577** (0.240)	0.349 (0.323)	
	Japan	55%	0.745** (0.313)	-0.477** (0.235)		0.664** (0.287)	-0.404* (0.213)	
Grand pianos 7250320	Japan	64%	-0.381*** (0.109)	0.029 (0.069)		-0.357* (0.219)	-0.011 (0.212)	
	Korea	24%	0.083 (0.181)	-0.211 (0.139)		0.078 (0.218)	-0.666** (0.224)	

This research manifests the importance of rival exchange rate effect. The 3SLS estimation indicates that 12 exporters from 10 commodity markets passed-through significantly for rival exchange rates, while reduced form estimation indicates that 14 exporters from 12 commodity markets show significant normal pass-through for rival exchange rates. Many studies have ignored the rival's behavior without considering strategic interaction in a market. In some empirical studies, the effect of rival exchange rate is partially reflected by rival prices (usually domestic good price). However, there exists simultaneous bias problem because it fails to capture the strategic interaction. A major and indeed important factor for exchange rate PT has simply been missed. This finding will also generate an implication to studies with aggregated data. In export price pass-through studies, an export price is affected not only by own trade weighted exchange rate but also by rival exchange rates in each destination market.

Another interesting finding is that, in 3SLS estimation, 5 exporters from 4 markets (Germany in beer market, Japan and Sweden in chainsaws market, U.K. in Tractors markets, and Japan in eyeglasses market) did not show pass-through behaviors for own exchange rate but show significant pass-through behavior for rival exchange rate. This finding is more obvious in the reduced form estimation which indicates 8 exporters from 8 markets (Japan in hydroxide, Japan in steel pipe, Italy in steel wire stand, Sweden in chainsaws, Japan in front-end loaders, Japan in relay, France in eyeglasses, Korea in Grand piano) are affected by rival exchange rate but not by own exchange rate. The more interesting thing is the fact that these exporters have relatively small market shares and affected by the exchange rate of exporters who have the largest market shares. These

exporters may have strong trends to follow a rival's price (price follower). To match with a market leader price, these firms may try to offset price changes in the local currency induced by own cost shock (e.g., exchange rate fluctuation). This finding may reveal that the own exchange rate pass-through tends to be related positively with the market share. Also, this finding emphasizes the importance of the game structure in studying exchange rate pass-through.

Finally, this study gives an interesting implication to an import pass-through study in both aggregated data and disaggregated data. In the import pass-through study, most previous studies used a trade weighted exchange rate. However, this study shows that, with the 3SLS estimation, 10 product markets' (i.e., beer, wall paper, electrodes, steel wire stand, motor vehicle pumps, chainsaws, relays, tractors, eyeglasses, grand pianos) prices are affected by only the exchange rate of the country which has the largest market share. Meanwhile, trade weighted exchange rates may be used as a good proxy in only 6 markets (i.e., hydroxide, polybutadiene rubber, steel pipe, shavers, spark plugs, power cable), considering that all exchange rates affect on prices. Reduced form estimations also indicate that 10 product markets' prices are affected by only the exchange rate of the country which has the largest market share while trade weighted exchange rates seem to work in only 3 markets. Only, if all firms have considerable market powers, pass-through estimation with trade weighted exchange rate may be unbiased.

I also estimated equation (7) and (9) with only the current exchange rate rather than polynomial distributed lagged exchange rate. Because of restricted space, I do not report the all results here. However, the main findings from the original estimation with polynomial distributed lag are not vulnerable to the length of exchange rates.

With the 3SLS estimation, 23 exporters from 17 commodity markets show significant pass-through for own exchange rate while 11 exporters from 10 commodity markets show significant pass-through for rival exchange rates. Meanwhile, reduced form estimation indicates that 17 exporters from 16 commodity markets show significant pass-through for own exchange rate while 13 exporters from 12 commodity markets show significant pass-through for rival exchange rates.

From the 3SLS estimation, 8 exporters from 7 markets did not show pass-through behaviors for own exchange rate but showed significant pass-through behaviors for rival exchange rate. Reduced form estimation also indicates 11 exporters from 11 markets are effected by rival exchange rate but not by own exchange rate. With the 3SLS estimation, 10 product markets' prices are affected by only the exchange rate of the biggest market shared country while trade weighted exchange rates seem to work well in 6 markets. Reduced form estimations also indicate that 13 product markets' prices are affected by only the exchange rate of the biggest market shared country while trade weighted exchange rates seem to work well in 2 markets.

VI. CONCLUSION

This study which tests a simultaneous system with aggregated data at the finest level incorporated the strategic behaviors among firms in a market. Also, two different models about exchange rate expectation were considered (polynomial distributed lag and rational expectation). The evidences across four estimations (3SLS with polynomial distributed lag, reduce form with polynomial distributed lag, 3SLS with rationally expected exchange rate, and reduced form with rationally expected exchange rate) indicate that price adjustment tends to pass through to the local currency price in the destination market, and that the pass-through rate are significantly different across countries and products. The study results confirm quite well to other research on traded good prices and exchange rates. However, this study manifests the importance of rival exchange rate. While the own exchange rate pass-through tends to be related inversely with market share, firms that have small market shares often pass through for the fluctuation of rival exchange rate. Particularly, some exporters who have small market shares pass through the change of rival exchange rate but not the change of own exchange rate. This study also gives some implications at the macro-level. First, in the export price pass-through studies, an export price is affected by not only own trade weighted exchange rate across destination countries but also rival exchange rate in each destination market. This study also shows that, in many markets, prices are affected by only the exchange rate of the country that has the largest market share, rather than the trade weighted exchange rate. It tells that import pass-through studies using trade weight exchange rate may have a specification problem.

The value added of this research is the approach to manifest strategic interaction and the level of industry detail. The next step of this study is to link with other destination markets to incorporate exporter's price discrimination behaviors across destination markets. For example, in the beer market, Netherlands exports not only to U.S. but also to Japan, Korea etc. Then the cost function will be inter-linked across destination markets. Knetter (1989) studied the price discrimination behaviors across destination markets for U.S and Canada firms. If the broad firm level data are available, the study of this line can be developed tremendously. Of course, it will be restricted to micro level study rather than macro level study. Another interesting extension is to incorporate the exchange rate uncertainty issue. The variability of exchange rate may also affect on exchange rate pass-through. In incorporating the exchange rate uncertainty into empirical studies, the calculation of expected exchange rates and exchange rate variabilities may be a major step and obstacle.

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