Exchange rate pass-through and strategic behavior in Japanese imports of DRAMs

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Abstract

This paper analyzes oligopolistic rivalry among source countries to evaluate the degree of exchange-rate pass-through. Using the recent time-series techniques for the case of imported DRAMs in Japan, the analysis also contributes to the study of the pass-through of relatively homogenous goods produced in emerging countries, which has been analyzed in very few papers. Comparison between traditional OLS estimates, which take competitors' pricing behavior as exogenously given, and GMM estimates, which fully endogenize the rivals' pricing behavior, indicates the misspecification in the OLS estimates and the need to endogenize pricing behavior. The results also show that the degree of pass-through estimated by GMM is lower than that estimated by OLS, and that prices are strategic complements between the following pairs of countries; Korea and Taiwan, Korea and the US, Taiwan and Singapore, and Singapore and the US. In contrast, prices are not complements between Taiwan and the US, perhaps because these two countries do not compete against each other but are complementary through foundry services.

Keywords: Exchange rate pass-through; Oligopoly; International trade
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1 Introduction

The purpose of this paper is to investigate how the strategic behavior of producers affects exchange rate pass-through in the presence of oligopolistic competition. In a seminal paper on the relationship between exchange rate fluctuations and goods

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prices, Dornbusch (1987) presents a model to show that oligopolistic firms set prices that do not fully reflect exchange rate fluctuations, by taking competing firms' behavior into account. There are several empirical papers in the pass-through literature that examine the effect of rivalry on pass-through. However most of these papers use single-equation estimation methods and do not include analysis of pricing interactions among rivals.[1] Other, but related, studies on "pricing-to-market (henceforth, PTM)" are primarily interested in examining how export prices differ across destination markets.[2]

Recently, Gross and Schmitt (2000) have analyzed the relationship between exchange rate pass-through and strategic pricing in an oligopolistic market by using 3SLS to examine the Swiss automobile market. Their results show that the degree of pass-through is relatively low compared to other studies, which do not endogenize rivals' pricing behavior. Our research is based on the results of Gross and Schmitt's findings, but more explicitly compares traditional OLS estimates, which take competitors' pricing behavior as exogenously given, and GMM estimates which fully endogenize the rivals' pricing behavior. Our results indicate the misspecification in the OLS estimates and the need to endogenize pricing behavior.

Another aim of this paper is to investigate exchange rate pass-through of homogenous goods in emerging countries, which has been analyzed in very few papers. Table 1 provides a list of six papers that estimate the effect of exchange rate fluctuations on the price of goods produced in East Asian countries. These studies show that the estimated degree of pass-through is lower (or the PTM ratio is higher) than that of advanced countries. This is because emerging countries have

[1]For example, Feenstra (1989) uses the competing price of imports to control for domestic competition in his study of Japanese automobile exports to the US. Feenstra, Gagnon, and Knetter (1996) construct aggregate prices for competitors to control for substitute products. However, these two studies do not analyze how prices in a market interact following an exchange rate shock. Studies on the pricing of producers from emerging countries, which are shown in Table 1, also take exchange rates or prices of rivals as exogenously given.

[2]Krugman (1987) labeled the phenomenon of exchange rate induced price discrimination in international markets as "pricing-to-market." For empirical research on this issue, see Froot and Klemperer (1989), Hooper and Mann (1989), Knetter (1989), Krugman (1987), and Marston (1989). Goldberg and Knetter (1997) and Knetter (1994) provide a more detailed survey.

very little control over the price at which they sell their commodities and therefore exchange rate changes may be of little relevance in determining the price of these commodities in international markets for the following two reasons.[3] First, emerging countries are relatively small players in international markets, compared to more advanced countries.[4] Second, the industrial goods of producers from emerging countries are more standardized and under more competitive pressure than those of producers from advanced countries.[5]

Unlike Gross and Schmitt, who investigate the automobile industry, in which goods are horizontally-differentiated across producers, we examine dynamic random access memories (DRAMs, thereafter), which are homogenous within a generation but are differentiated between generations. They are classified into generation according to their storage capacity in terms of Binary Information Units (bits). Technical progress in the industry is characterized by increases in a chip's memory capacity. According to Gruber (1992, 1994, 1996), demand for DRAMs is strongly biased towards the latest generation, so that there are only two generations of DRAMs with significant production volumes in the market at the same time.[6] In addition, the statistics of Japanese imports of DRAMs are aggregated across generations. Thus, our approach is to estimate the degree of co-movement of prices among competitive countries, and analyze the difference in their strategies.[7]

[3]For example, in his comments on Hooper and Mann (1989), Tobin observes that a country entering the US market, such as Korea or Taiwan, sells at a price over which it has very little control, and that the effect of exchange rate changes may be on the quantity they choose to sell rather than the price at which they sell.

[4]There are many studies on the relationship between market share and exchange rate pass-through (or PTM). Using the Cournot duopoly model, Ohno (1990), Lee (1995), and Bernhofen and Xu (2000) show that a producer with a small market share exhibits less complete pass-through (greater PTM) than a producer with a larger market share. Feenstra, Gagnon, and Knetter (1996) also provide the same evidence by employing the Bertrand model.

[5]Dornbusch (1987) explores the Dixit-Stiglitz model and proves that markup ratio depends on the pricing of rivals and the degree of the homogeneity of goods. That is, the more differentiated the goods the higher the markup ratio, while the more standardized the goods the lower the markup ratio.

[6]According to Gruber (1992, 1994, 1996), market leaderships for DRAMs are unstable because of intense price competition. The market leaders for the best selling DRAM generations shifted from the US in 1970's to Japan in 1980's, and to South Korea in 1990's.

[7]Previous studies of the industrial organization of DRAM industries have taken the view that producers compete in terms of quantities rather than in terms of prices, and use a Cournot-type

There are two advantages in using highly disaggregated industry data rather than aggregated data. The most important advantage is that the simultaneity between prices and exchange rates can be eliminated. If aggregated data is used, exchange rates are not necessarily exogenous to price determination. However, price data for individual industries can be treated as exogenous to exchange rate movements. This enables us to estimate pass-through coefficients more accurately. Another important advantage is that disaggregated data can reduce measurement error which is caused by the use of unit values,[8] when the products under consideration are not completely homogenous. We have chosen DRAMs, as opposed to other alternative industries for two reasons. First, this industry is highly standardized and is expanding in emerging countries. Second, East Asian countries occupy a large share of the world DRAM market, and DRAMs are one of the most important industries in East Asian countries.[9]

Analysis of Japanese imports of DRAMs shows that two of four OLS estimates, in which rivals' prices are exogenously given, contain misspecifications, while GMM estimates, which endogenize rivals' prices, satisfies the overidentification test. These results indicate the need to endogenize rivals' pricing behavior for more accurate estimates of the degree of pass-through. The degree of pass-through is lower in the GMM estimates than in the OLS estimates. That is, taking price interdependence into account lowers the degree of pass-through in a competitive oligopolistic market.[10] Prices are strategic complements between the

model to analyze Learning-by-Doing throughout the product cycle. As we discussed earlier, however, DRAMs are differentiated between generations, which explains our decision to employ a Bertrand-type model.

[8] Knetter (1989) has discussed this measurement problem.

[9] For example, World Semiconductor Trade Statistics (WSTS) has reported that Asia Pacific share is approximately 25% of semiconductor shipments in the world in 2000. This is next to 31% of North America's share and over 23% of Japan's share. In particular, DRAMs occupy 92% of semiconductor production in South Korea in 2000, according to Korea Semiconductor Industry Association (KSIA).

Table 2 also shows that South Korea and Taiwan together account for about 50% of Japanese imports of DRAMs during 1997 and 2001. Furthermore, overinvestment and excess capacity in the memory chip industry caused a large fall in prices which aggravated current account imbalances prior to the East Asia crisis (World Bank, 1998).

[10] This result can provide microeconomic evidence that is consistent with recent empirical studies on the pass-through in macroeconomic literature. For example, Taylor (2000) conjectures

following pairs of countries: Korea and Taiwan, Korea and the US, Taiwan and Singapore, and Singapore and the US.

The remainder of the paper is organized as follows. Section 2 presents an oligopolistic competition model in which two producers of DRAMs compete against each other in the Japanese market. In Section 3, the dataset is described and empirical implementation is presented. Finally, concluding remarks are provided in Section 4.

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that firms become increasingly difficult to fully pass exchange rate movements on their export prices partly due to intensified worldwide competitive pressure. Campa and Goldberg (2000) report that the average short-run pass-through for 25 OECD countries is lowered during 1975-1990. Otani, et al. (2003) also demonstrate that the exchange rate pass-through to Japan's import prices lowered in the 1990s.

2 The model

The goal of the empirical section of this paper is to investigate pass-through relationships in an oligopoly setting. Its aim is not to test a particular theory but to estimate short-term degrees of exchange rate pass-through as well as price interdependence among sellers. Hence we consider a duopoly situation in which representative producers of DRAMs from different source countries compete against each other in the Japanese market. It is well known that East Asian producers, particularly South Korea, depend on intermediate and capital goods imported from Japan.[11] That is, the fluctuation of the yen affects import prices not only through rivalry but also through changes of production costs. As discussed in the Appendix, however, both of these two factors move the selling price in the same direction, as long as we assume the prices and the weights of intermediate and capital goods denominated by the yen are constant. Thus, for simplicity, we focus on the strategic interaction between two producers.

We assume that Company A produces DRAMs in Country A and Company B in Country B. The profits (π^A) of Company A and the profits (π^B) of Company B, which are calculated in terms of the local currency, can be expressed as follows.

$$\pi^A = \left(\frac{P^A}{e^A} - c^A\right) f\left(p\right); \tag{1}$$

$$\pi^B = \left(\frac{P^B}{e^B} - c^B\right) g\left(\frac{1}{p}\right); \tag{2}$$

where P^A denotes the price of Company A's products in terms of the yen; P^B the price of Company B's products in terms of yen; $p = \frac{P^A}{P^B}$ the relative price of the two companies' products; e^A the yen against Country A's currency; e^B the yen against Country B's currency; $f\left(\cdot\right)$ the demand function for Company A's products ($f'(\cdot) < 0$); $g\left(\cdot\right)$ the demand function for Company B's products ($g'(\cdot) < 0$); c^A the

[11] According to KSIA, Korean semiconductor makers imported 43% of intermediate goods and 86% of capital goods in 2001. Among source countries, Japan supplied 67% of intermediate goods and 33% of capital goods to Korea, while the US supplied 14% and 55%, respectively.

unit cost of Company A in Country A's currency; and c^B the unit cost of Company B in Country B's currency.

Maximizing (1) and (2) with respect to P^A and P^B respectively yields the first order conditions:

$$P^A = \mu^A e^A c^A; \tag{3}$$

$$P^B = \mu^B e^B c^B; \tag{4}$$

where $\mu^A = \frac{\varepsilon^A}{\varepsilon^A - 1}$ denotes the markup of Company A's products; $\varepsilon^A = \frac{-f'(p)p}{f(p)}$ the price elasticity of demand for Company A's products; $\mu^B = \frac{\varepsilon^B}{\varepsilon^B - 1}$ denotes the markup of Company B's products; $\varepsilon^B = \frac{-g'(1/p)}{g(1/p)p}$ the price elasticity of demand for Company B's products. Converting the first order conditions into logarithm form yields:

$$\ln P^A = -\eta^A(\ln P^A - \ln P^B) + \ln e^A c^A; \tag{5}$$

$$\ln P^B = -\eta^B(\ln P^B - \ln P^A) + \ln e^B c^{B\prime}; \tag{6}$$

where $\eta^A = \frac{\mu^{A\prime} p}{\mu^A} > 0$ denotes the price elasticity of the markup of Company A's products, and $\eta^B = \frac{\mu^{B\prime}}{\mu^B p} > 0$ denotes the price elasticity of the markup of Company B's products. We can derive the reaction function of Company A given the prices of Company B's products P^B, and that of Company B given the price of Company A's products P^A.

$$\ln P^A = \frac{\eta^A}{1+\eta^A} \ln P^B + \frac{1}{1+\eta^A}\left(\ln e^A + \ln c^A\right). \tag{7}$$

$$\ln P^B = \frac{\eta^B}{1+\eta^B} \ln P^A + \frac{1}{1+\eta^B}\left(\ln e^B + \ln c^B\right). \tag{8}$$

Equations (7) and (8) are reference equations for the empirical implementation of the model. They show that the price of Company A's products (P^A) depends on Company B's price (P^B), own price elasticity of markup (η^A), own marginal costs (c^A), and the yen against Country A's currency (e^A). Likewise, the price of

Country B's products (P^B) depends on Company A's prices (P^A), own price elasticity of markup (η^B), own marginal costs (c^B), and the yen against Country B's currency (e^B). A stronger yen [decrease of $e^A(e^B)$)] against Country A's currency (Country B's currency) reduces the cost of imports in terms of the yen. Consequently, P^A decreases, and so does P^B, since prices are strategic complements in a static Bertrand game. Likewise, a weaker yen against Country A's currency (Country B's currency) [increase of $e^A(e^B)$], leads to an increase in both P^A and P^B . The degree of exchange rate pass-through is obtained by differentiating (7) and (8) with respect to the yen against the currencies of the two countries (e^A, e^B) respectively.

$$\frac{\partial \ln P^A}{\partial \ln e^A} = \frac{1}{1+\eta^A}; \qquad \frac{\partial \ln P^B}{\partial \ln e^B} = \frac{1}{1+\eta^B};$$

Since $0 < \frac{1}{1+\eta^A} < 1$, $0 < \frac{1}{1+\eta^B} < 1$, Company A and Company B do not fully pass-through the exchange rate fluctuations to selling prices in terms of the yen. Combining (7) and (8), we can derive the equilibrium price of Company A's products and Company B's products:

$$\ln P^A = \frac{1+\eta^B}{1+\eta^A+\eta^B}\left(\ln c^A + \ln e^A\right) + \frac{\eta^A}{1+\eta^A+\eta^B}\left(\ln c^B + \ln e^B\right); \tag{9}$$

$$\ln P^B = \frac{\eta^B}{1+\eta^A+\eta^B}\left(\ln c^A + \ln e^A\right) + \frac{1+\eta^A}{1+\eta^A+\eta^B}\left(\ln c^B + \ln e^B\right). \tag{10}$$

3 Empirical analysis

3.1 Data

Our empirical analysis concentrates on the pricing behavior of DRAM producers from several source countries in Japan from January 1997 to December 2001. The source countries under consideration are South Korea (K), Taiwan (T), Singapore (S), and the United States (A).[12] According to Table 2, these countries captured 76.4% to 94.5% of Japanese imports of DRAMs over the sample period. Other source countries have been excluded from the investigation because they are marginal exporters to the Japanese market, or because they expanded their market share only very recently (e.g. China). Because the present HS Code table relevant to DRAMs was introduced in January 1997 - the beginning of our sample - we use 60 sample data, which is relatively small.

Table 3 summarizes the sources of the data used in the empirical analysis. The variables are observed at monthly frequencies between 1997 and 2001. All the variables are in logarithms and are seasonally unadjusted. The prices (P^K, P^T, P^S, P^A) are measured as unit-values in terms of the yen. They are calculated by the value of imports divided by the quantity of imports. The nominal exchange rates (E^K, E^T, E^S, E^A) are defined as the yen per the currency of the source country.

The remaining variable is the cost of production in the source countries (C^K, C^T, C^S, C^A), which is approximated by the producer price index (PPI) of the related sector, except for Taiwan for which the wholesale price index (WPI) is used.[13] Several previous empirical studies use the unit labor cost and the price of raw materials as proxies for the marginal cost of production. The measure we use is determined partly by data availability and partly by our empirical approach.

[12] According to IC Insights Inc. (USA), top seven DRAM makers (nationality, market share) in 2002 are as follows: Samsung Electronics (Korea, 32%), Micron Technology (USA, 13%), Infineon Technology (Germany, 13%), Hynix Semiconductor (Korea, 13%), Nanya Technology Corporation (Taiwan, 6%), Winbond Electronics (Taiwan, 4%), and Elpida Memory (Japan, 4%).

[13] Among recent empirical studies on pass-through, or PTM, Takagi and Yoshida (2001), Feenstra, Gagnon, and Knetter (1996), and Hung, Kim, and Ohno (1993) also use PPI as a proxy for the marginal cost.

First, because our sample size is small, it is important to avoid reducing the degrees of freedom. Second, it is difficult to obtain unit labor cost based on monthly data in all the source countries examined in the analysis. Third, both PPI and WPI include costs related to intermediate and capital goods imported from Japan, which are not contained in the unit labor cost and the price of raw materials. Thus, in the sense that they capture more comprehensive cost variables, PPI and WPI may be more suitable than the unit labor cost and the prices of raw materials in the case of East Asian producers.

In addition, we include three instrumental variables, which are to be used in the GMM estimation. These variables are (1) currency crisis dummy (DUM), (2) PPI of Japanese integrated circuits (ICs thereafter), and (3) capacity utilization ratio of Japanese electric machineries (CAP). The currency crisis dummy is used to control for drastic exchange rate fluctuations during the East Asian crisis, and takes 1 between July 1997 and December 1998, and 0 in the remaining period. PPI of Japanese ICs and capacity utilization ratio of Japanese electric machineries are chosen to control for prices of ICs produced by Japanese rival companies and demand for DRAMs in Japanese market, respectively.

3.2 Estimation method

The main theoretical implication of the model in Section 2 is that rivalry may lower exchange rate pass-through on price-setting in an oligopolistic market. The goal of this empirical section is to investigate the role of rivalry on the degree of exchange rate pass-through. Based on equations (7) and (8), the model to be estimated is a set of best reply functions for producers from four source countries where price levels are determined simultaneously, with costs and exchange rates exogenously given. .

$$\Delta p_t^j = f\left[\Delta c_t^j, \Delta e_t^j, \Delta p_t^k\right], \tag{11}$$

$$j, k = K, T, S, A, \text{ and } j \neq k$$

Before estimating equation (11), we need to impose model-relevant restrictions. Each source country prices DRAMs according to its own cost, exchange rate and competitors' prices. Thus, we explicitly introduce the constraint that the coefficients on other countries' costs and exchange rates are zero. Note that equations (7) and (8) indicate that exchange rates and costs have the same coefficients. But as discussed earlier, PPI and WPI include the cost of intermediate and capital goods imported from Japan. Equations (12) and (13) in the Appendix, which include intermediate and capital goods, show that we do not need to impose a restriction where exchange rates and costs have the same coefficients.

The following three steps are taken in estimating the equation (11). First, in order to test the non-stationarity of each of our data series, we employ the Augmented Dickey-Fuller (1979) procedure, where the lag length is determined by the Schwartz Criteria, and the Phillips and Perron (1988) procedure. The results of the tests in Table 4 show that for all variables a null hypothesis of integration of order 0 cannot be rejected at 1% significance level, while a hypothesis of integration of order 1 can be rejected at 1% significance level. Although 1% significance level is relatively strict, we decide that a system of simultaneous pricing consistent with equation (11) must be specified in the first difference, considering the possibility of small sample bias.

Second, following Gross and Schmitt, we conduct cointegration tests among the four source-country price levels. If the series are cointegrated a long-term relationship among the levels can still be identified. We use the maximum-likelihood method for the estimation of the cointegration vectors developed by Johansen (1991, 1995), where a critical value is determined by Osterwald and Lenum (1992). The presence of cointegration among the four source-country price levels in each category is tested over the 58 observations of the sample. As the number of degrees of freedom shrinks rapidly, we set the number of lags equal to 1 for level variables. The results of the tests show that a hypothesis of no cointegrating vector cannot be rejected.

Third, we estimate the best response functions. We first conduct OLS estimates, which regard rivals' prices as exogenously given. Then we regress four simultaneous-equations systems for the best reply functions using GMM, and compare the results of the two estimates. We also include the following instrumental variables for each test; exchange rates, costs, prices of rival countries, Japanese PPI and capacity utilization ratio.

3.3 Results

In this section, we compare the estimation results in Table 5, which regard rivals' prices as exogenously given, to those in Table 6, which endogenize rivals' prices. The Ramsey tests in Table 5 reject the null hypothesis of no misspecification at 5% significance level in two of the four estimates. In contrast, for all categories the results in Table 6 satisfy the overidentifying restrictions at 5% significance level. These two results indicate the need to endogenize rivals' prices in the estimation. Furthermore, Durbin-Watson statistics show serial correlation is absent. In addition, R-squared indicates that the model explains 64-99% of the determinants of prices of DRAMs.

Then we look at the short-term effects of exchange rate fluctuations on producers' own prices. The pass-through coefficients are equal to coefficients of the parameter E^j ($j = K, T, S$, and A). If the pass-through coefficient is 0, the change in the price does not reflect the exchange rate changes. That is, producers absorb exchange rate fluctuations by reducing markups. If the coefficient is 1, the change in price fully reflects the exchange rate change. If the coefficient is between 0 and 1, the pass-through is incomplete. A positive sign means that an appreciation (depreciation) of the yen against the currency of the source country leads to a decrease (increase) in the corresponding price of the source country in terms of the yen.

Table 6 shows that the pass-through coefficient is positive at 1% significance level in the case of Korea, which is the top-ranking producer of DRAMs. However, for other countries the pass-through coefficients are negative or insignificant. There are considered to be two reasons why only one country has significantly positive pass-through coefficients. First, since we use monthly data with no lags in estimation, the exchange rate fluctuations may not have been fully reflected in prices in such a short time.[14] Second, because of the severe competition in the DRAM market, each producer has very limited control of its prices.

The estimated pass-through coefficient of Korea in Table 5 is 19.3%, while that in Table 6 is 3.3%. This result is consistent with Gross and Schmitt, and shows that endogenizing price interdependence lowers the pass-through coefficient. Our estimated pass-through coefficient is also smaller than that of other similar empirical studies. For example, Takagi and Yoshida (2001) estimate the pass-through coefficients of Japanese imports of computer parts from January 1989 to June 1999. Their estimated degrees of pass-through are 9.1% for Malaysia, 9.4% for the Philippines, -1.5% for Singapore, 22.7% for Thailand, 5.3% for Germany, and 9.2% for the US. Their estimation does not include lagged variables either, but differs from ours in source countries, industries and sample period. Although we cannot derive a precise comparison of results, Takagi and Yoshida's estimated degree of pass-through for US products is higher than ours. This may be a result of their failure to consider competitors' prices.[15]

We now turn our attention to the effects of the change in cost on selling prices. The coefficients of cost are not the same as those of the exchange rate, as equations (7) and (8) suggest. Table 7 shows the results of a Wald test that investigates a null hypothesis that the coefficients of cost and the exchange rate are identical. The null hypothesis is rejected in the simultaneous test for the four countries under consideration. The coefficients on costs are significantly negative in Korea and Singapore, but insignificant in the remaining countries. There are considered to be two reasons for the negative coefficients. One is the difficulty in passing on

[14]For example, most of contracts to decide prices of DRAMs are extended in two weeks.

[15]Gross and Schmitt's estimated degrees of pass-through are 20-50%, which are much higher than ours. The following two factors may explain this difference. One is that Gross and Schmitt use quarterly data, which may magnify the effects of exchange rate fluctuations on prices due to the longer period of time. The other is that they use automobile exports from industrialized countries, which are highly differentiated. Thus each producer may exert more power to control their prices and pass-through exchange rate fluctuations.

costs to consumers in the face of severe competition. The other is that PPI and WPI, used as proxies of costs, may be affected by exchange rate fluctuations.

Finally, there is the issue of short-term price rivalry among producers. The results show that price-rivalry is source-country specific. Korean and Taiwanese producers, Korean and US producers, Taiwanese and Singaporean producers, and Singaporean and US producers, react positively to each other's price changes. We should note that for these pairs of countries prices are strategic complements. However, there is a nontrivial asymmetry in the size of the response. In all cases, Taiwanese producers react more sensitively to rivals' price changes than producers from other countries. That is, Taiwanese producers tend to follow their rivals' price change.

Note that Taiwanese and US producers react negatively to each other's price changes. This result suggests that DRAMs produced by these two countries may not compete against each other. One possible explanation is the complementarity in production between the two countries. For instance, Taiwanese producers are famous for their success in foundry services after the late 1990's. In addition to the famous US fabless ventures, which are engaged only in designing products, more and more Japanese companies also began foundry-commissioned manufactures with Taiwanese producers.

4 Concluding remarks

This paper analyzes oligopolistic rivalry among source countries to evaluate the degree of exchange-rate pass-through. Using the recent time-series techniques for the case of imported DRAMs in Japan, this exercise also contributes to the study of the pass-through of relatively homogenous goods produced in emerging countries, which has been analyzed in very few papers. Comparison between traditional OLS estimates, which take competitors' pricing behavior as exogenously given, and GMM estimates, which fully endogenize rivals' pricing behavior, indicates a misspecification in the OLS estimates and the need to endogenize pricing behavior. The results also show that the degree of pass-through estimated by GMM is lower than that by OLS, and that prices are strategic complements between the following pairs of countries; Korea and Taiwan, Korea and the US, Taiwan and Singapore, and Singapore and the US. In contrast, prices are not complements between Taiwan and the US, perhaps because these two countries do not compete against each other but are complementary through foundry services.

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Table 1

Previous Empirical Studies on Exchange Rate Pass-Through of Emerging Countries

Focus	Authors	Countries	Data
Rivalry	Hung, Kim, and Ohno (1993)	14 industrialized countries and 2 Asian NIEs (Korea and Taiwan)	Quarterly weighted-average of export price data of wide range of commodities from 1970 to 1989
Rivalry	Ito, Ogawa, and Sasaki (1998)	East Asian countries (Thailand, Indonesia, Korea, Taiwan, Singapore, Philippines) vs. Japan and the USA	Monthly aggeragate export and import price data of East Asian countries from 1986-1996
Not specified	Takagi and Yoshida (2001)	East Asian countries (Indonesia, Malaysia, Philippines, Singapore, Thailand), Germany, and the USA	Monthly Japanese export and import price data of 20 nine-digit industrial commodities from 1988-1999
Market share and rivalry	Lee (1995)	Korea	Quarterly Korean export price data of 16 commodities from 1980 to 1990
Demand pressure and rivalry	Athukorala (1991)	Korea	Quarterly Korean export price data of four four-digit commodities from 1980-1989
Demand pressure and rivalry	Menon and Tongzon (1995)	Singapore	Quarterly Singaporean export price data of four two-digit commodities from 1978 to 1993

Table 2

Structure of Japanese Imports of DRAMs

Country	DRAM 1997	DRAM 2001
Korea (K) (weight、%)	51.7	37.5
Taiwan (T) (weight、%)	16.9	20.5
Singapore (S) (weight、%)	14.1	8.3
USA (A) (weight、%)	11.8	10.1
Sum (=K+T+S+A) (weight、%)	94.5	76.4
World (Yen billion)	256	210

Source: Trade statistics of Ministry of Finance.

Table 3

Data Sources

Data		Sources
Nominal exchange rates (End of period)		
Yen / US$		Bank of Japan
Yen /Won		Bank of Korea
Yen / S$		Statistics Singapore
Yen / NT$		National Statistics of Taiwan
Unit value of imports (Seasonally unadjusted)		
DRAM	HS854213021	Japan Customs
Producer price index (Seasonally unadjusted)		
USA	MOS Memory Devices -DRAM	Bureau of Labor Statistics
Korea	MOS Memory	Bank of Korea
Taiwan (*)	Semi Conductors	National Statistics of Taiwan
Singapore	Machinery and Transport Equipment	Statistics Singapore
Japan	Integrated circuits	Bank of Japan
Capacity utilization ratio (Seasonally unadjusted)		
Japan	Electrical Machinery	Ministry of Economy, Trade and Industry

Note: Wholesale price index.

Table 4

Unit Root Tests 1

	Augmented Dickey-Fuller Tests						
	I(0)			I(1)			
	$a_0=a_3=0$	$a_0\neq0,\ a_3=0$	$a_0,\ a_3\neq0$	$a_0=a_3=0$	$a_0\neq0,\ a_3=0$	$a_0,\ a_3\neq0$	Lag length
Korea (j=K)							
P^j	−0.98	−2.52	−2.94	−3.58 **	−4.29 **	−4.75 **	2
E^j	−0.78	−3.20 *	−2.60	−5.06 **	−5.10 **	−4.56 **	2
C^j	−1.71	−0.96	−1.75	−4.81 **	−5.12 **	−5.07 **	0
Taiwan (j=T)							
P^j	−0.34	−2.33	−2.46	−7.15 **	−7.09 **	−7.07 **	0
E^j	−0.69	−1.90	−2.30	−9.18 **	−9.16 **	−9.29 **	0
C^j	−1.34	−1.13	−2.72	−5.50 **	−5.69 **	−5.64 **	0
Singapore (j=S)							
P^j	−0.49	−1.34	−0.99	−7.79 **	−7.73 **	−7.96 **	0
E^j	−0.72	−1.90	−1.47	−9.51 **	−6.69 **	−9.72 **	0
C^j	−1.91	−1.27	−2.15	−6.37 **	−6.69 **	−6.70 **	0
USA (j=A)							
P^j	−0.46	−2.75	−2.67	−9.28 **	−9.23 **	−9.24 **	0
E^j	0.23	−1.74	−1.58	−8.54 **	−8.48 **	−8.46 **	0
C^j	−0.69	−2.49	−2.95	−2.95 **	−2.92	−2.72	0
Japan							
PPI	−1.65	0.19	−2.37	−3.13 **	−3.89 **	−4.05 *	1
CAP	0.46	−3.04 *	−2.49	−7.43 **	−7.37 **	−7.54 **	0

Notes:

1 The test statistic reported in the t-ratio on a in the following auxiliary regression:

$$\triangle y_t=a_0+a_1y_{t-1}+\Sigma^{p}_{j=1}a_2\triangle y_{t-j}+a_3T+u_t$$

where y is the variable under consideration, T is a time trend, and u is the stochastic error terms.

2 In the estimating the regression, the lag length(p) was determined by the Schwartz Criteria.

3 * indicates that null hypothesis of non-stationarity is not rejected at the 5% level .

** indicates that null hypothesis of non-stationarity is not rejected at the 1% level .

Unit Root Tests 2

	Phillips-Perron Tests					
	I(0)			I(1)		
	$a_0=a_2=0$	$a_0\neq 0$, $a_2=0$	a_0, $a_2\neq 0$	$a_0=a_2=0$	$a_0\neq 0$, $a_2=0$	a_0, $a_2\neq 0$
Korea (j=K)						
P^j	−0.98	−0.74	−1.31	−8.06 **	−8.11 **	−8.22 **
E^j	−0.89	−2.60	−2.53	−7.55 **	−7.60 **	−8.12 **
C^j	−1.98 *	−0.51	−1.34	−4.80 **	−5.11 **	−5.06 **
Taiwan (j=T)						
P^j	−0.38	−2.46	−2.57	−7.50 **	−7.46 **	−7.47 **
E^j	−0.78	−2.30	−2.14	−9.18 **	−9.17 **	−9.37 **
C^j	−1.81	−0.87	−2.38	−5.49 **	−5.68 **	−5.63 **
Singapore (j=S)						
P^j	−0.50	−1.34	−0.83	−7.79 **	−7.74 **	−8.11 **
E^j	−0.82	−1.90	−1.19	−9.44 **	−9.46 **	−9.72 **
C^j	−2.01 *	−1.27	−2.35	−6.38 **	−6.63 **	−6.64 **
USA (j=A)						
P^j	−0.51	−2.63	−2.54	−9.41 **	−9.41 **	−9.63 **
E^j	0.25	−1.71	−1.54	−8.52 **	−8.46 **	−8.44 **
C^j	−1.28	−0.60	−1.38	−2.95 **	−2.92	−2.72
Japan						
PPI	−2.07 *	0.83	−1.07	−3.29 **	−3.54 *	−3.69 *
CAP	0.43	−3.12 *	−2.65	−7.43 **	−7.37 **	−7.54 **

Notes:

1 The test statistic reported in the t-ratio on a in the following auxiliary regression:

$$\triangle y_t=a_0+a_1y_{t-1}+a_2T+u_t$$

where y is the variable under consideration, and u is the stochastic error terms.

2 * indicates that null hypothesis of non-stationarity is not rejected at the 5% level .

** indicates that null hypothesis of non-stationarity is not rejected at the 1% level .

Table 5

OLS estimates

DRAM

	$\triangle P^j$			
	Korea (j=K)	Taiwan (j=T)	Singapore (j=S)	USA (j=A)
Constant	−0.034	0.066	−0.041	0.027
	(0.08)	(0.14)	(0.08)	(0.12)
$\triangle P^K$		1.405	−0.334	−0.165
		(0.17) **	(0.14) *	(0.22)
$\triangle P^T$	0.434		0.293	−0.307
	(0.05) **		(0.08) **	(0.12) *
$\triangle P^S$	−0.169	0.844		1.160
	(0.12)	(0.19) **		(0.12) **
$\triangle P^A$	−0.099	−0.371	0.533	
	(0.09)	(0.15) *	(0.06) **	
$\triangle C^j$	−0.133	0.059	−0.156	0.133
	(0.06) *	(0.08)	(0.06) *	(0.07)
$\triangle E^j$	0.193	−0.136	0.096	−0.068
	(0.06) **	(0.08)	(0.07)	(0.07)
DUM	0.08	−0.19	0.11	−0.12
	(0.14)	(0.25)	(0.15)	(0.22)
Number of observations	58	58	58	58
Standard error of regression	0.47	0.86	0.53	0.78
Adjusted R-squared	0.82	0.76	0.77	0.80
Durbin-Watson	2.19	2.00	2.22	2.49
Ramsey's test	16.06 **	1.18	3.57	7.59 *

Notes: 1 Standard errors in parenthesis.
2 * indicates significance at the 5% level .
** indicates significance at the 1% level .

Table 6

GMM estimates

DRAM

	$\triangle P^j$			
	Korea (j=K)	Taiwan (j=T)	Singapore (j=S)	USA (j=A)
Constant	−0.216	0.239	−0.169	0.153
	(0.05) **	(0.05) **	(0.06) **	(0.08) *
$\triangle P^K$		1.353	−1.045	1.129
		(0.05) **	(0.05) **	(0.11) **
$\triangle P^T$	0.690		0.818	−0.987
	(0.02) **		(0.01) **	(0.05) **
$\triangle P^S$	−0.729	1.154		1.332
	(0.04) **	(0.02) **		(0.03) **
$\triangle P^A$	0.452	−0.771	0.704	
	(0.04) **	(0.03) **	(0.02) **	
$\triangle C^j$	−0.025	0.009	−0.001	0.020
	(0.01) *	(0.00) **	(0.00)	(0.01) **
$\triangle E^j$	0.033	0.002	0.005	−0.011
	(0.01) **	(0.00)	(0.00)	(0.01)
DUM	0.407	−0.414	0.309	−0.312
	(0.13) **	(0.16) *	(0.14) *	(0.19)
Number of observations	58	58	58	58
Standard error of regression	0.64	0.95	0.79	0.99
R-squared	0.68	0.76	0.72	0.68
Durbin-Watson	1.78	1.85	1.87	1.91
L.R. test for overidentifying restrictions	$\chi^2(28)=36.803$ *			

Notes: 1 Standard errors in parenthesis.
2 * indicates significance at the 5% level .
** indicates significance at the 1% level .

Table 7

Wald Tests

	Korea	Taiwan	Singapore	USA	Joint test
DRAM	−0.058 (0.01) **	0.007 (0.01)	−0.006 (0.00)	0.032 (0.01) **	$\chi^2(4)=41.960$ **

Notes: 1 Standard errors in parenthesis.
2 * indicates significance at the 5% level .
** indicates significance at the 1% level .

Appendix

We now incorporate imports of intermediate and capital goods from Japan to East Asia, assuming that the East Asian firm uses them in the production process. Following Ito, Ogawa, and Sasaki (1998), we assume that the shares of parts imported from Japan is constant, ω, with a price of parts imported from Japan in terms of the yen (P^J). Then profits of Company A (π^A) and Company B (π^B) are calculated as follows:

$$\pi^A = \left(\frac{P^A}{e^A} - \frac{P^J}{e^A}\omega - c^A \right) f\left(p\right); \tag{12}$$

$$\pi^B = \left(\frac{P^B}{e^B} - \frac{P^J}{e^B}\omega - c^B \right) g\left(\frac{1}{p}\right). \tag{13}$$

Maximizing (11) and (12) with respect to P^A and P^B respectively gives the first order conditions, and by converting the first order conditions into a logarithm form, we can derive the reaction function of Company A and that of Company B.

$$\ln P^A = \frac{\eta^A}{1+\eta^A} \ln P^B + \frac{1}{1+\eta^A} \ln\left(P^J\omega + e^A c^A\right); \tag{14}$$

$$\ln P^B = \frac{\eta^B}{1+\eta^B} \ln P^A + \frac{1}{1+\eta^B} \ln\left(P^J\omega + e^B c^B\right). \tag{15}$$

When we compare equations (14) and (15) to equations (7) and (8) which exclude intermediate and capital goods, we find that the difference lies only in the $P^J\omega$ term. However, as long as P^J and ω are assumed to be constant, the fluctuation of the exchange rates moves the selling price in the same direction as in the case without intermediate and capital goods.

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