E C O N O M I C S B U L L E T I N

Exchange rate pass−through and strategic pricing: Evidence from 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. The analysis of Japanese imports of DRAMs 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, Taiwan and Singapore, and Singapore and the US.

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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 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]

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.[2] These studies show that the estimated degree of pass-through is lower than that of advanced countries. This is because emerging countries have very little control over the price at which they sell their commodities and therefore exchange

[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]See Table 1 for example.

rate changes may be of little relevance in determining the price of these commodities.[3] 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.[4]

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. Prices are strategic complements between the following pairs of countries: Korea and Taiwan, Taiwan and Singapore, and Singapore and the US.

The rest 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. Section 3 describes the dataset and presents empirical implementation. Finally, concluding remarks are provided in Section 4.

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

[3]For example, in his comments on Hooper and Mann (1989), Tobin observes that a country such as Korea and Taiwan sells at a price over which it has very little control.

[4]DRAMs 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.

each other in the Japanese market.

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.

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

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; $f(\cdot)$ the demand function for Company A's products ($f'(\cdot) < 0$); $g(\cdot)$ the demand function for Company B's products ($g'(\cdot) < 0$); c^A the 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) with respect to P^A and P^B and rearranging, 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.

$$\ln P^A = \frac{\eta^A}{1+\eta^A} \ln P^B + \frac{1}{1+\eta^A} \left(\ln e^A + \ln c^A\right). \tag{2}$$

$$\ln P^B = \frac{\eta^B}{1+\eta^B} \ln P^A + \frac{1}{1+\eta^B} \left(\ln e^B + \ln c^B\right). \tag{3}$$

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.

Equations (2) and (3) are reference equations for the empirical implementation of the model. They show that the price of each company's products depends on its rival's price, own marginal costs, and the exchange rate. 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. Since $0 < \frac{1}{1+\eta^A} < 1$, $0 < \frac{1}{1+\eta^B} < 1$, the exchange rate pass-through is incomplete for both countries.

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.[5] The source countries under consideration are South Korea (K), Taiwan (T), Singapore (S), and the United States (A). 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).

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^j) 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^j) 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^j), 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.[6]

[5]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.

[6]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.

In our data sets, neither unit-values of imports nor PPI reflect quality improvement. Using these variables are consistent with the assumption that goods are vertically differentiated across generations.

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.

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 (2) and (3), 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..

$$\Delta p_t^j = f\left[\Delta c_t^j, \Delta e_t^j, \Delta p_t^k\right], \tag{4}$$

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

Before estimating equation (4), 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.[7]

[7]We test the non-stationarity of each of our data series using the Augmented Dickey-Fuller (1979) procedure and the Phillips and Perron (1988) procedure. Based on the results of the tests we decide that a system of simultaneous pricing consistent with equation (5) must be specified in the first difference, considering the possibility of small sample bias.

We then conduct cointegration tests among the four source-country price levels. The results of the tests show that a hypothesis of no cointegrating vector cannot be rejected.

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 4, which regard rivals' prices as exogenously given, to those in Table 5, which endogenize rivals' prices. The Ramsey tests in Table 4 reject the null hypothesis of no misspecification at 5% significance level in two of the four estimates. In contrast, the results in Table 5 satisfy the overidentifying restrictions at 5% significance level. These two results indicate the need to endogenize rivals' prices in the estimation.

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. Table 5 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. 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, as discussed in Section 1, because of the severe competition in the DRAM market, each producer has very limited control of their prices. Second, 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[8]. The estimated pass-through coefficient of Korea in Table 4 is 19.5%, while that in Table 5 is 6.4%. This result is consistent with Gross and Schmitt, and shows that endogenizing price interdependence lowers the

[8]For comaprison, 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.

pass-through coefficient.

The coefficients on costs are significantly positive in Taiwan and the USA, but is significantly negative in Korea in Table 5. The negative coefficient for Korea may result from the government subsidization to a DRAM producer (Hynix), which has been strongly accused of the US Trade Representatives[9].

There is the issue of short-term price rivalry among producers. The results show that price-rivalry is source-country specific. Korea and Taiwan, Taiwan and Singapore, and Singapore and the US, react positively to each other's price changes. In contrast, Taiwan and the US 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. The US fabless ventures, which are engaged only in designing products, foundry-commissioned manufactures with Taiwanese producers.

Finally, we provide the estimation results of 3SLS in Table 6 in order to show the robustness of our results. The results in Table 6 satisfy the overidentifying restrictions at 5% significance level. The pass-through coefficient of Korea is 5%, almost the same as that estimated by GMM. There are also the same pattern of price rivalry as in Table 5.

4 Concluding remarks

This paper analyzes the pass-through of Japanese imports of DRAMs from East Asian countries. Comparing OLS estimates to GMM estimates, we show a mis-specification 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 among rival countries.

[9]Hynix is Korea's second largest semiconductor manufacturer and in trouble during 2001-2002. The USTR reports that aid to Hynix was provided in complex refinancing agreements involving debt rollovers, partial debt agreements, interest rate reductions, new lending and other forms of assistance.

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Table 1

Previous Empirical Studies on the Exchange Rate Pass-Through of Eat Asian 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: OLS Estimates

DRAM

	$\triangle P^j$			
	Korea (j=K)	Taiwan (j=T)	Singapore (j=S)	USA (j=A)
$\triangle P^K$		1.402	−0.330	−0.168
		(0.17) **	(0.14) *	(0.22)
$\triangle P^T$	0.434		0.292	−0.306
	(0.05) **		(0.08) **	(0.12) *
$\triangle P^S$	−0.167	0.841		1.158
	(0.12)	(0.19) **		(0.12) **
$\triangle P^A$	−0.101	−0.372	0.534	
	(0.09)	(0.15) *	(0.06) **	
$\triangle C^j$	−0.134	0.059	−0.156	0.132
	(0.06) *	(0.08)	(0.06) *	(0.07)
$\triangle E^j$	0.195	−0.137	0.096	−0.068
	(0.06) **	(0.08)	(0.07)	(0.07)
DUM	0.05	−0.12	0.07	−0.09
	(0.11)	(0.20)	(0.12)	(0.18)
Number of observations	58	58	58	58
Standard error of regression	0.47	0.86	0.53	0.77
Adjusted R-squared	0.82	0.76	0.77	0.81
Durbin-Watson	2.18	1.99	2.22	2.49
Ramsey's test	12.40 **	1.29	3.52	5.42 *

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

Table 5: GMM Estimates

DRAM

	$\triangle P^j$			
	Korea (j=K)	Taiwan (j=T)	Singapore (j=S)	USA (j=A)
$\triangle P^K$		1.304	−1.004	1.171
		(0.05) **	(0.07) **	(0.14) **
$\triangle P^T$	0.699		0.843	−1.095
	(0.03) **		(0.02) **	(0.06) **
$\triangle P^S$	−0.661	1.087		1.400
	(0.04) **	(0.03) **		(0.04) **
$\triangle P^A$	0.390	−0.704	0.679	
	(0.04) **	(0.03) **	(0.02) **	
$\triangle C^j$	−0.051	0.024	−0.004	0.034
	(0.01) **	(0.01) **	(0.00)	(0.01) **
$\triangle E^j$	0.064	0.000	0.012	−0.016
	(0.01) **	(0.00)	(0.01)	(0.01)
DUM	0.178	−0.307	0.260	−0.336
	(0.08) *	(0.12) *	(0.11) *	(0.15)
Number of observations	58	58	58	58
Standard error of regression	0.60	0.90	0.77	1.03
Adjusted R-squared	0.73	0.77	0.71	0.69
Durbin-Watson	1.88	1.88	1.88	1.89
L.R. test for overidentifying restrictions	$\chi^2(28)=39.8481$ *			

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

Table 6: 3SLS Estimates

DRAM

	$\triangle P^j$			
	Korea (j=K)	Taiwan (j=T)	Singapore (j=S)	USA (j=A)
$\triangle P^K$		1.382	−1.026	1.027
		(0.08) **	(0.10) **	(0.21) **
$\triangle P^T$	0.653		0.833	−1.027
	(0.04) **		(0.05) **	(0.12) **
$\triangle P^S$	−0.612	1.100		1.415
	(0.07) **	(0.06) **		(0.09) **
$\triangle P^A$	0.297	−0.631	0.637	
	(0.07) **	(0.07) **	(0.04) **	
$\triangle C^j$	−0.037	0.018	−0.009	0.041
	(0.02)	(0.01) *	(0.01)	(0.02)
$\triangle E^j$	0.050	−0.006	0.007	−0.014
	(0.02) *	(0.02)	(0.01)	(0.03)
DUM	0.095	−0.155	0.131	−0.168
	(0.10)	(0.16)	(0.15)	(0.21)
Number of observations	58	58	58	58
Standard error of regression	0.56	0.88	0.75	0.97
Adjusted R-squared	0.76	0.77	0.70	0.72
Durbin-Watson	1.88	1.87	1.87	1.91

Notes: 1 Standard errors in parenthesis.

2 * indicates significance at the 5% level .

** indicates significance at the 1% level .