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8 Exchange Rate Pass-through and Industry Characteristics: The Case of Taiwan's Exports of Midstream Petrochemical Products

Kuo-Liang Wang and Chung-Shu Wu

8.1 Introduction

In the 1980s there were many significant structural changes in Taiwan's economy. One of them was the drastic appreciation of the New Taiwan (NT) dollar. It can be seen from table 8.1 that though the export price index had been decreasing along with the appreciation of NT dollars during this period, the magnitude of the export price index's decline did not match that of the NT dollar appreciation.[1] Furthermore, the trade imbalance kept growing. Does this imply that there exists incomplete exchange rate "pass-through" in Taiwan's export price index, or do Taiwan's domestic firms display "pricing-to-market" behavior?[2]

Most recent empirical studies show that firms in newly industrializing countries tend to have pricing-to-market behavior in response to changes in real exchange rates (Hooper and Mann 1989; Athukorala 1991; Liu 1994).[3] However, Marston (1990), Knetter (1993), and Athukorala and Menon (1994) find

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1. It can be seen from table 8.1 that the average NT dollar–U.S. dollar exchange rate had been decreasing from 36.84 in 1981 to 26.41 in 1989, which is over a 38.31 percent appreciation. However, during the same period the export price index dropped from 111.68 to 97.40, only 12.79 percent.

2. Incomplete exchange rate pass-through is often mentioned as one of the main reasons for sluggish adjustment in trade imbalances among countries.

3. For the case of Japan and other countries, see Athukorala and Menon (1994), Froot and Klemperer (1989), Knetter (1993), Marston (1990), Menon (1995), and Ohno (1989).

Table 8.1 **Main Economic Indicators for Taiwan External Sectors**

Indicator	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Export price index	103.93	111.68	113.01	112.85	113.15	112.43	108.44	102.06	100.29	97.40	99.64	100.00	96.39	100.94	103.60	110.07
Import price index	116.03	126.00	124.20	122.72	122.02	120.07	109.46	101.93	101.03	98.09	100.39	100.00	95.27	99.33	103.85	113.23
Exchange rate (NT/U.S.$)	36.00	36.84	39.12	40.07	39.60	39.83	37.84	31.74	28.59	26.41	26.89	26.81	25.16	26.39	26.46	26.48
Exports of goods and services (million U.S.$)	21,758	24,998	24,347	27,809	33,270	33,674	43,836	58,456	66,694	73,959	74,896	85,062	92,038	98,477	106,305	127,437
Imports of goods and services (million U.S.$)	22,251	24,015	21,847	23,281	26,643	25,101	28,900	40,768	53,743	62,777	66,914	76,929	87,592	94,274	101,730	121,441
Trade surplus (million U.S.$)	−493	983	2,500	4,528	6,628	8,574	14,937	17,689	13,221	11,183	7,981	8,132	4,445	4,204	4,576	5,996
GDP growth rate	7.30	6.16	3.55	8.45	10.60	4.95	11.64	12.74	7.84	8.23	5.39	7.55	6.76	6.32	6.54	6.06

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, *National Income, Taiwan Area, R.O.C.* (Taipei, 1996).

that different industries even in the same country may not have identical behavior toward pricing to market. Therefore, if we want to investigate the exchange rate pass-through pattern, it is more appropriate to explain pricing to market on the basis of observable industry characteristics. Similarly, Krugman (1987), Dornbusch (1987), Feenstra (1987), Fisher (1989), Knetter (1989), and Shinjo (1993) also show that the elements of market structure are very important in determining the degree of exchange rate pass-through.

There do exist a few studies that investigate exchange rate pass-through effects in Taiwan (Hooper and Mann 1989; Liu 1994; Wu 1995). However, most of them are based on aggregate data. As mentioned before, if we study the pass-through effect by examining general aggregate price indexes, we might obtain misleading results because market structure elements are neglected. In order to avoid the aggregation problem, in this paper we use survey data on the exports of 22 Taiwanese petrochemical industries during 1986–92 to investigate the exchange rate pass-through effect. Moreover, in addition to production cost and capacity utilization, special attention has been paid to the Herfindahl index and price elasticities of demand in order to emphasize the importance of market structure and industry characteristics to the study of exchange rate pass-through effects.[4]

A number of important features should be noted when discussing exchange rate pass-through effects for Taiwan's petrochemical industry. First, though it is a large-scale industry in Taiwan, it only exports a relatively small portion of its total output.[5] Second, it is a highly concentrated industry; that is, it has relatively strong monopoly power. Therefore, we expect this kind of industry to have a lower incentive to adjust its markup ratio in response to exchange rate changes except for the purpose of holding foreign market share (Froot and Klemperer 1989). By studying these particular industries' exchange rate pass-through effects, we can not only examine whether all industries in Taiwan have manipulated the exchange rate for the purpose of gaining an unfair competitive advantage in the international market but also obtain more information about industry-specific pricing behavior.

The rest of the paper is organized as follows. Section 8.2 sets up the analytical framework for our empirical analysis of exchange rate pass-through and builds the empirical equations used in this study. Section 8.3 illustrates the characteristics of Taiwan's petrochemical industries and gives a data description. Section 8.4 presents and analyzes econometric estimates of exchange rate pass-through effects. Section 8.5 summarizes some of the main findings of this paper.

4. The Herfindahl index is a measure of market concentration or fewness and is equal to the sum of squares of the market shares of the firms in the market.

5. It can be seen in table 8.2 that 12 out of 22 industries had average shares of exports in domestic production of less than 10 percent during the period 1986–92.

8.2 Analytical Framework

As mentioned by Hooper and Mann (1989), exchange rate pass-through can be broadly defined as the extent to which a change in the nominal exchange rate induces a change in the import price. Since our analysis is focused on the export price index, it is natural to define the exchange rate pass-through effect as the partial derivative of the export price index with respect to the exchange rate minus one. In addition, following previous empirical research (e.g., Hooper and Mann 1989; Marston 1990; Kim 1990; Athukorala 1991; Athukorala and Menon 1994), we adopt a variant of markup models of price determination. In this kind of framework, we can discuss the strategic interaction between domestic and foreign firms operating through variations in the markup.

Under the assumption of imperfect competition, domestic firms more or less have the capability to control their prices of output and set home currency export prices (PEX) at a markup (MK) over the level of normal unit production cost (MC):

$$\text{PEX} = (1 + \text{MK})\text{MC}. \tag{1}$$

According to the existing literature, many factors may have an impact on the markup ratio, for example, demand pressures in all markets combined, competitive pressures in foreign markets, desire to maintain foreign market share, and market structure. In this study, the demand pressures in all markets are proxied by the capacity utilization rate (CU). As the capacity utilization rate goes up, it implies that total demand in all markets is increasing. It is then easier for domestic firms to raise domestic and export prices above marginal and average costs. Competitive pressures in foreign markets are represented by price elasticities of demand with respect to domestic firms in foreign markets (EL) and the weighted exchange rate (RX). Pricing theory tells us that, other things being equal, markup ratios are inversely related to elasticities of demand. Therefore, the higher the price elasticities of demand with respect to domestic firms in foreign markets, the less possible it is for domestic firms to raise export prices above marginal costs. As for the exchange rate, it partly reflects the pressure of the foreign competitive price and partly reflects domestic firms' pricing strategy toward foreign market share (Mann 1986; Froot and Klemperer (1989). On the other hand, market structure is captured by domestic market concentration (H). It has been shown in oligopoly theory that the higher the level of domestic market concentration, the more likely it is that domestic firms will be able to raise domestic prices and then export prices above marginal and average cost (Khalizadeh-Shirazi 1974). As a result the markup ratio function can be expressed as follows:

$$\text{MK} = \text{MK}(\overset{(+)}{\text{CU}}, \overset{(-)}{\text{EL}}, \overset{(+)}{\text{RX}}, \overset{(+)}{\text{H}}). \tag{2}$$

Substituting equation (2) into equation (1), the export price equation can be written as

$$\text{pex}_t^i = \alpha_0 + \alpha_1 \text{rx}_t^i + \alpha_2 \text{mc}_t^i + \alpha_3 \text{CU}_t^i + \alpha_4 \text{H}_t^i + \alpha_5 \text{EL}_t^i + \varepsilon_{1t}; \quad (3)$$
$$0 \le \alpha_1 \le 1; \quad \alpha_2, \alpha_3, \alpha_4 \ge 0; \quad \alpha_5 \le 0; \quad i = 1, \ldots, 22;$$

where lowercase letters represent logarithmic values of variables, superscript i denotes the ith petrochemical product, and subscript t denotes the time period.

Not all of the export prices of petrochemical products are based on f.o.b. terms, some of them are based on c&f or c.i.f. terms. When the distance between the home and destination countries increases, the transportation cost and the probability of an accident occurring during shipping will go up, and domestic firms will tend to raise export prices. Therefore, we add a transportation cost variable (TC) to equation (3) to yield

$$\text{pex}_t^i = \alpha_0 + \alpha_1 \text{rx}_t^i + \alpha_2 \text{mc}_t^i + \alpha_3 \text{CU}_t^i + \alpha_4 \text{H}_t^i + \alpha_5 \text{EL}_t^i + \alpha_6 \text{tc}_t^i + \varepsilon_{2t}; \quad (4)$$
$$0 \le \alpha_1 \le 1; \quad \alpha_2, \alpha_3, \alpha_4, \alpha_6 \ge 0; \quad \alpha_5 \le 0.$$

The partial derivative of pex with respect to rx, α_1, measures the responsiveness of the domestic currency export price to a change in the weighted exchange rate. The pass-through coefficient or pricing-to-market coefficient (PTM) is then $\alpha_1 - 1$, which measures the effect of a changing exchange rate on the foreign currency price. At one extreme, if domestic firms are price takers, then $\alpha_1 = 1$, and exchange rate changes are reflected entirely in domestic currency prices through a markup adjustment leaving foreign currency prices unchanged while PTM will be zero. At the opposite extreme, where domestic firms have market or monopoly power in foreign markets, changes in the exchange rate are passed through completely and the markup is left unchanged; that is, $\alpha_1 = 0$ and PTM $= -1$. Between these two extremes, we have the case of incomplete pass-through or pricing to market, where $-1 \le \alpha_1 - 1 \le 0$.

Rewriting equation (1) and substituting the related explanatory variables into the equation, we can get a variant of the empirical model of the markup ratio equation as follows:

$$\text{MK}_t^i = \beta_0 + \beta_1 \text{rx}_t^i + \beta_2 \text{CU}_t^i + \beta_3 \text{H}_t^i + \beta_4 \text{tc}_t^i + \beta_5 \text{EL}_t^i + \varepsilon_{3t}; \quad (5)$$
$$0 \le \beta_1 \le 1; \quad \beta_2, \beta_3, \beta_4 \ge 0; \quad \beta_5 \le 0;$$

where MK = (PEX − MC)/MC.

Equation (5) can directly measure the effects of factors influencing a change in the markup ratio, and its estimation results are supposed to be consistent with those in equation (4).

Furthermore, we can discuss the pricing behavior of the exporting firms through price-cost margin (PCM). Assuming that the PCM function has the same explanatory variables as MK or pex, the PCM equation can be expressed as

$$\text{PCM}_t^i = \gamma_0 + \gamma_1 \text{rx}_t^i + \gamma_2 \text{CU}_t^i + \gamma_3 \text{H}_t^i + \gamma_4 \text{tc}_t^i + \gamma_5 \text{EL}_t^i + \varepsilon_{4t}; \quad (6)$$
$$0 \le \gamma_1 \le 1; \quad \gamma_2, \ \gamma_3, \ \gamma_4 \ge 0; \quad \gamma_5 \le 0;$$

where PCM = (PEX − MC)/PEX.

However, the effect of exchange rate fluctuations on PCM is not as clear as the above equations. Nevertheless, appendix A shows that under some reasonable assumptions, the exchange rate still has a positive effect on PCM.

8.3 Data Descriptions and Features of Taiwanese Petrochemical Industries

The data used in this study are based on annual survey data of 22 midstream petrochemical industries in Taiwan for the period 1986–92. Though there are more than 30 different products in the midstream petrochemical industries, data on some of these products are not complete. Therefore, we take samples from only 22 products. Moreover, because data for some related explanatory variables are missing before 1986, we have to limit our sampling period to start from 1986. Detailed information about the 22 petrochemical products, computations of the Herfindahl index, price elasticities, weighted exchange rate, and weighted transportation cost, and related data sources are given in appendix B.

Before we begin our empirical analysis, it is worth describing the features of Taiwanese petrochemical industries. Table 8.2 reports some characteristics of those 22 petrochemical industries. First, in column (7) we see that 10 out of 22 industries had Herfindahl indexes equal to one during the period; that is, they had strong monopoly power in the domestic market. Second, from columns (3), (4), and (5) we find that only 5 of 22 industries had average ratios of exports to domestic production higher than 30 percent during the period. However, most industries' ratios of exports to domestic production were increasing during the period. This implies that foreign countries' market shares became more and more important for Taiwan's petrochemical industries. Third, in the early stages of the petrochemical industries' development, their focus was on the domestic market; not until the mid-1980s did they start to export their products. Moreover, most of the export destination countries were small countries in which domestic firms usually produced a small amount of those outputs. It can be seen from table 8.3 that only a few products' export destination countries are developed countries.

8.4 Estimation Results

Since each of equations (4), (5), and (6) in section 8.2 has different economic implications, in this section we will estimate the above-mentioned equations and examine whether the empirical results are consistent or not. Table 8.4 reports empirical results of the export price (pex), markup ratio (MK),

Table 8.2 **Important Characteristics for 22 Midstream Petrochemical Industries (average for 1987–92)**

Industry[a]	PRO (1)	EX (2)	EX/PRO (%) 1987–89 (3)	EX/PRO (%) 1990–92 (4)	EX/PRO (%) 1987–92 (5)	CU (%) (6)	H (7)
ABS	373,437.50	229,783.70	53.28	65.44	59.36	66.08	0.60
AN	134,428.50	2,876.50	3.57	6.62	2.10	97.55	1.00
BR	41,687.17	21,742.67	59.80	45.35	52.58	104.05	1.00
CPL	104,830.17	896.67	0.36	1.34	0.85	103.13	1.00
DOP	191,212.33	7,144.33	3.86	3.71	3.78	61.88	0.55
EG	189,398.00	9,407.67	6.66	2.84	4.75	73.97	0.52
HDPE	162,913.17	50,362.00	26.18	36.67	31.42	79.28	0.54
LDPE	197,460.50	38,800.67	10.90	28.40	19.65	81.73	0.50
ME	11,338.50	2,537.00	25.19	19.62	22.40	97.32	1.00
ML	26,331.83	3,620.50	9.13	54.66	27.34	23.98	1.00
MMA	27,465.83	2,575.50	0.82	18.22	9.52	69.95	1.00
PA	66,728.17	1,575.33	63.16	1.58	2.37	91.92	1.00
PP	224,162.33	13,228.33	2.57	9.01	5.79	80.00	0.51
PPG	20,938.33	3,138.17	8.45	21.56	15.01	81.98	1.00
PS	336,417.00	119,572.50	22.88	40.98	31.93	70.52	0.34
PTA	780,547.17	13,199.67	0.00	2.10	1.05	87.17	0.90
PVA	40,798.67	30,578.83	79.13	71.69	75.41	82.25	1.00
PVC	888,982.67	29,244.83	1.21	5.01	3.11	80.23	0.78
SBR	140,195.50	21,627.83	10.94	28.57	19.76	56.97	0.88
SM	333,008.83	15,600.33	8.32	1.37	4.85	85.52	0.51
VAM	78,779.00	4,953.67	7.15	5.48	6.32	78.93	1.00
VCM	661,603.67	0.00	0.00	0.00	0.00	75.47	0.91

Note: PRO, domestic production; EX, exports; CU, capacity utilization rate; H, Herfindahl index.
[a]For a key to industry abbreviations, see appendix table 8B.1.

and price-cost margin (PCM) equations for Taiwan's petrochemical industries. Since all we have is seven years of annual survey data for 22 petrochemical industries, we adopt the pooling regression procedure to estimate the three equations. The explanatory variables consist of unit production cost (mc), weighted exchange rate (rx), capacity utilization rate (CU), Herfindahl index (H), demand elasticity (EL), and transportation cost (tc). The production cost, weighted exchange rate, and transportation cost are in logarithmic form. Because not all variables have significant estimates, we report several variants of estimates. In addition to the coefficient for each variable, the table also reports the adjusted R^2 and root mean square error.

The estimation results for the export price equations show that, except for demand elasticity, all the explanatory variables have the expected signs. Among them, most coefficients of unit production cost, weighted exchange rate, capacity utilization rate, and transportation cost are significantly different from zero. Though the effect of the exchange rate on export prices is signifi-

Table 8.3 **Major Export Destination Countries for Taiwanese Petrochemical Products in 1992 (percent of product exports)**

ABS		HDPE		PA	
Hong Kong	78.01	Hong Kong	87.18	Hong Kong	27.51
Malaysia	3.52	Malaysia	4.35	Korea	27.51
United States	3.22	Thailand	3.09	Indonesia	23.21
Japan	1.58	Japan	2.81	Japan	9.08
Thailand	1.25	Philippines	0.94	Singapore	7.95
Netherlands	1.16	Jordan	0.91	Philippines	1.93
Belgium	1.14	Indonesia	0.73	Australia	1.83
United Kingdom	1.03	LDPE		South Africa	0.97
Philippines	0.86	Hong Kong	69.36	PP	
Singapore	0.86	Thailand	6.72	Hong Kong	59.04
AN		Japan	5.85	Indonesia	25.40
Indonesia	98.82	Australia	5.11	Thailand	6.75
Hong Kong	0.94	Malaysia	3.12	Malaysia	5.07
Bahrain	0.24	Philippines	2.49	Italy	1.20
BR		Singapore	2.41	South Africa	0.31
Hong Kong	22.38	India	1.82	Philippines	0.30
Japan	13.62	Indonesia	1.33	Vietnam	0.28
Malaysia	10.03	Vietnam	0.80	Venezuela	0.28
Thailand	7.89	ME		United States	0.26
Philippines	7.82	Japan	69.52	PPG	
Germany	7.76	Indonesia	18.75	Hong Kong	86.68
United Kingdom	6.33	Malaysia	8.84	Singapore	7.63
Korea	3.90	Thailand	1.54	Thailand	2.90
Australia	3.13	United States	0.35	Australia	1.18
United States	2.86	Israel	0.35	Indonesia	0.69
CPL		Iran	0.31	Pakistan	0.42
Hong Kong	83.88	Singapore	0.28	Malaysia	0.40
Thailand	16.12	Belgium	0.06	India	0.10
DOP		ML		PS	
Hong Kong	58.80	Hong Kong	96.14	Hong Kong	85.02
Vietnam	12.28	Pakistan	3.69	Japan	3.30
Australia	9.84	Malaysia	0.06	Thailand	2.59
Korea	8.55	Macao	0.06	Malaysia	2.06
Philippines	3.66	Korea	0.03	Korea	1.48
Thailand	1.93	Vietnam	0.03	Singapore	0.99
Libya	1.60	MMA		South Africa	0.77
Indonesia	1.57	Thailand	25.50	Philippines	0.66
Japan	0.52	Philippines	14.83	India	0.61
United States	0.52	Hong Kong	13.44	Vietnam	0.54
EG		South Africa	9.02	PTA	
Hong Kong	56.51	Korea	7.78	Thailand	78.02
Singapore	18.71	Australia	7.66	Indonesia	9.07
Philippines	8.67	Japan	6.27	Hong Kong	8.12
Malaysia	6.67	New Zealand	5.19	Singapore	1.62
South Africa	2.89	Indonesia	4.97	Philippines	1.35
Indonesia	2.65	Malaysia	3.04	Iceland	0.68
Australia	1.97			Pakistan	0.68
New Zealand	1.16			Japan	0.32
Japan	0.72			Australia	0.11
Sri Lanka	0.04			Spain	0.03

Table 8.3 (continued)

PVA		SBR		VAM	
United States	55.84	Hong Kong	46.86	Hong Kong	49.28
Germany	12.61	Korea	21.15	Nigeria	18.97
Indonesia	7.05	Indonesia	14.43	Indonesia	13.09
Thailand	3.86	Philippines	10.58	Sri Lanka	11.76
Malaysia	3.82	Thailand	2.82	Thailand	5.31
Mexico	2.45	Pakistan	2.82	New Zealand	0.76
Singapore	1.99	Mexico	0.80	India	0.38
Korea	1.86	Singapore	0.53	Malaysia	0.38
Pakistan	1.85	India	0.00	Japan	0.08
Hong Kong	1.19	SM		VCM	
PVC		Hong Kong	59.62	Hong Kong	100.00
Hong Kong	32.50	Indonesia	11.89		
Thailand	30.81	Malaysia	11.31		
Philippines	22.34	Australia	4.99		
Japan	4.80	United Arab Emirates	4.11		
Singapore	3.30	Egypt	4.11		
Malaysia	3.06	Pakistan	2.06		
Indonesia	1.90	Thailand	0.73		
Vietnam	0.68	Nigeria	0.44		
South Africa	0.19	Saudi Arabia	0.44		
United States	0.15				

Table 8.4 **Estimates of Export Price, Markup Ratio, and Price-Cost Margin, 1986–92**

Dependent Variable	Independent Variables							Adjusted R^2	Root Mean Square Error
	Constant	mc	rx	CU	tc	H	EL		
pex	4.293	0.341	0.073	0.835	0.196	0.0006	0.0002	.094	.297
	(−1.470)	(1.357)	(2.008)**	(1.997)*	(1.632)	(1.411)	(0.155)		
pex	3.008	0.481	0.077	1.118	0.156	0.0006		.279	.287
	(1.261)	(2.379)**	(2.357)**	(3.563)***	(1.454)	(1.503)			
pex	2.972	0.512	0.054	0.897	0.170			.280	.284
	(1.672)*	(3.336)***	(2.070)**	(3.167)***	(1.819)*				
MK	−4.260		0.156	2.183	0.373	0.001	−0.0004	.425	.431
	(−3.447)***		(3.072)***	(3.854)***	(2.188)**	(1.706)*	(−0.272)		
MK	−4.217		0.138	2.137	0.334	0.001		.448	.417
	(−3.402)***		(2.913)***	(4.731)***	(2.224)**	(1.779)*			
PCM	−2.270		0.067	0.751	0.219	0.0005	−0.0004	.196	.281
	(−2.594)***		(2.027)**	(2.031)**	(1.972)*	(1.131)	(−0.428)		
PCM	−2.064		0.063	0.796	0.190	0.0005		.233	.265
	(−2.619)		(2.095)**	(2.771)***	(1.993)**	(1.239)			

Note: Numbers in parentheses are *t*-statistics.

*Significant at the 10 percent level.

**Significant at the 5 percent level.

***Significant at the 1 percent level.

cantly different from zero, the magnitude is rather small, around 0.07. This implies that, on average, Taiwanese petrochemical firms absorb only about 7 percent of a given exchange rate change in their export prices; that is, the exchange rate pass-through effect is as high as 93 percent. This is contrary to the general perception that most exporters in developing countries have pricing-to-market behaviors.

The results for the markup ratio function are very similar to those for the export price equations. Weighted exchange rate, capacity utilization rate, transportation cost, and market concentration rate all have significant positive effects on the markup ratio. Though demand price elasticity has the right sign, it is insignificantly different from zero. Since the markup ratio is not expressed in logarithmic form, we cannot interpret the coefficient of the weighted exchange rate as an elasticity. However, we can approximate it through dividing the coefficient by the sample mean of MK. In this way, we get an elasticity of the markup ratio with respect to the weighted exchange rate of around 0.19.[6] The results for the price-cost margin equations are also very similar to those for the export price and markup ratio equations. The computed elasticity of PCM with respect to the weighted exchange rate is also around 0.19, which is very close to the findings for the markup equations.[7] Moreover, by reference to equation (A12) in appendix A, the positive sign of the coefficient of the exchange rate in the PCM equation implies that firms in Taiwanese petrochemical industries and export destination countries are in a competitive situation.

The empirical results for the export price, markup, and price-cost margin equations all show that the impact of the exchange rate on the export price is relatively small, in the range of 7 to 19 percent. These results are quite different from economists' general impression. Actually, in some existing empirical studies, exporters in developing countries such as Korea and Taiwan have been found to show pricing-to-market behavior (Athukorala 1991; Liu 1994). However, why do the exporting firms of petrochemical products in Taiwan enjoy more than an 80 percent pass-through effect? The possible reasons are as follows. First, it is a general feature of the petrochemical industry that the volatility of profitability is very large. Therefore, firms are unwilling to change their markups when the exchange rate fluctuates. Second, table 8.2 showed that the petrochemical industries in Taiwan are highly concentrated. They have strong monopoly power and a large domestic market share. Moreover, as we showed in section 8.3, the share of exports in domestic production is relatively small. Petrochemical industries do not rely on foreign markets to maintain production efficiency. Third, most of the markets to which Taiwan's petrochemical products are being exported are small-scale markets in which the domestic firms usually do not produce or only produce a small amount of related products. Therefore, Taiwanese petrochemical firms can take a strong position toward

6. The sample mean of the markup ratio during the period 1987–92 is 0.737.
7. The sample mean of the price-cost margin for the sampling period is 0.333.

those countries. This can also be justified by all the estimated coefficients of demand elasticity in the variant equations being insignificantly different from zero.

It can be noted from table 8.1 that the NT dollar–U.S. dollar exchange rate has been stabilizing since 1989. It is interesting to ask whether the exchange rate pass-through effect for Taiwan's petrochemical industries has undergone structural changes or not (Kim 1990). However, our data period is too short to analyze the time-varying properties of exchange rate pass-through parameters. Nevertheless, we can discuss the issue by dividing our sample period into two separate periods. Our estimation results are presented in tables 8.5 and 8.6.

Comparing the exchange rate parameters between these two tables, we find that when the coefficients are significant, the exchange rate parameters in the second period are all almost twice as large as those in the first period. The exchange rate elasticity of MK or PCM in the first period was around 13 percent; in the second period it was about 30 percent.[8] In table 8.7 we also present a rolling estimation for every four years of each equation. It can be seen from the table that exchange rate elasticities of the estimated parameters do have the tendency to increase through time. By reference to equation (A12) in appendix A, this implies that when the elasticity of collusion (β) is negative and the absolute value of β is increasing, the impact of exchange rate change on price-cost margin will be positive and increasing. That is, Taiwan's petrochemical export firms have been pricing to market more and more in recent years. This implication may be justified by the fact that while petrochemical firms in most countries have continued expanding their capacities since 1986, the degree of competition in world petrochemical markets has increased. In addition, Taiwanese petrochemical firms have not been so well protected as before in holding their market shares in domestic markets since the government lifted all restrictions on the import of petrochemical products and lowered related import tariffs in 1986. They have gradually realized that proper pricing behavior in response to exchange rate changes is very important if they are to penetrate the world market, to reach minimum efficient scale, and to attain production efficiency. On the other hand, the increasing degree of pricing to market may also be explained by the acquisition of modern management and marketing knowledge among entrepreneurs in Taiwan's petrochemical industries. Therefore, they are increasingly aware of the importance of holding world market share in order to maintain a long-run business (Froot and Klemperer 1989).[9]

8. The sample means of the markup ratio and price-cost margin are respectively 0.769 and 0.359 for the first period and 0.706 and 0.307 for the second period.

9. Since 1985, accompanied by the recovery of the world economy, petrochemical industries worldwide have vigorously expanded their production capacities, which increases competitiveness among world petrochemical exporters.

Table 8.5 **Estimates of Export Price, Markup Ratio, and Price-Cost Margin, 1986–89**

Dependent Variable	Independent Variables							Adjusted R^2	Root Mean Square Error
	Constant	mc	rx	CU	tc	H	EL		
pex	−3.004	1.183	0.071	2.120	−0.038	0.0005	−0.0008	.576	.178
	(−0.715)	(3.283)***	(2.321)**	(3.368)***	(−0.270)	(1.799)*	(−0.565)		
pex	−2.021	1.082	0.065	1.496	0.033	0.0005		.639	.178
	(−0.598)	(3.784)***	(2.318)**	(4.040)***	(0.309)	(1.730)			
pex	3.756	0.639	0.033	1.247	−0.108			.553	.192
	(1.986)*	(4.097)***	(1.326)	(3.939)***	(−1.145)				
MK	−1.895		0.108	3.502	−0.094	0.0009	−0.0009	.605	.251
	(−1.665)		(2.642)**	(3.959)***	(−0.551)	(2.105)*	(−0.520)		
MK	−2.706		0.102	2.742	0.016	0.0009		.659	.248
	(−1.923)*		(2.668)**	(5.503)***	(0.125)	(2.136)**			
PCM	−0.454		0.044	1.331	−0.058	0.0003	−0.0003	.387	.133
	(−0.752)		(2.024)*	(2.833)**	(−0.634)	(1.439)	(−0.287)		
PCM	−0.594		0.043	0.838	0.015	0.0003		.382	.132
	(−1.031)		(2.085)*	(3.152)***	(0.228)	(1.385)			

Note: Numbers in parentheses are *t*-statistics.

*Significant at the 10 percent level.

**Significant at the 5 percent level.

***Significant at the 1 percent level.

Table 8.6 **Estimates of Export Price, Markup Ratio, and Price-Cost Margin, 1990–92**

Dependent Variable	Independent Variables							Adjusted R^2	Root Mean Square Error
	Constant	mc	rx	CU	tc	H	EL		
pex	7.903	−0.170	0.054	0.251	0.406	0.0032	0.0005	.121	.294
	(2.218)**	(−0.556)	(0.848)	(0.500)	(2.307)**	(0.675)	(0.421)		
pex	5.149	0.164	0.106	0.588	0.344	−0.0021		.257	.298
	(1.764)*	(0.672)	(1.943)*	(1.306)	(2.174)**	(−0.751)			
pex	4.314	0.205	0.116	0.726	0.355			.349	.280
	(1.839)*	(0.961)	(2.517)**	(1.971)*	(2.783)***				
MK	−7.149		0.211	1.872	0.712	0.0012	0.0007	.375	.539
	(−2.461)**		(1.901)*	(2.193)**	(2.219)**	(0.139)	(0.284)		
MK	−6.074		0.167	1.551	0.644	−0.0004		.385	.510
	(−2.805)***		(1.793)*	(2.038)*	(2.417)**	(−0.081)			
PCM	−3.200		0.095	0.543	0.375	−0.0019	−0.0003	.131	.362
	(−1.638)		(1.269)	(0.946)	(1.738)*	(−0.340)	(−0.215)		
PCM	−3.023		0.089	0.470	0.365	−0.0021		.211	.332
	(−2.149)**		(1.472)	(0.950)	(2.108)**	(−0.672)			

Note: Numbers in parentheses are *t*-statistics.

*Significant at the 10 percent level.

**Significant at the 5 percent level.

***Significant at the 1 percent level.

Table 8.7 **Estimated Exchange Rate Elasticities for Different Periods**

Dependent Variable	1987–89	1988–90	1989–91	1990–92
pex	0.065	0.066	0.074	0.106
MK	0.102	0.114	0.122	0.167
	(0.133)	(0.152)	(0.179)	(0.237)
PCM	0.043	0.048	0.054	0.089
	(0.120)	(0.137)	(0.172)	(0.290)

Note: Since the estimates of demand elasticity in all equations are insignificantly different from zero, in this table we present regression results that contain mc, rx, CU, tc, and H as explanatory variables. The numbers in parentheses are elasticities.

8.5 Conclusion

In the existing literature, there is a general perception that newly industrializing countries like Korea and Taiwan have little control over the prices at which they sell and that therefore exchange rate changes may not have a significant impact on their foreign-currency-denominated export prices in international markets. In this paper we investigate a special industry, petrochemicals, which has a high degree of monopoly power and faces weak competition in export destination countries, in order to demonstrate that not all industries in Taiwan's export sectors display a strong pricing-to-market pattern. The empirical results show that Taiwanese petrochemical export firms absorb only about 7 percent of a given weighted exchange rate change in their export prices, and we find a 19 percent impact of a 1 percent exchange rate change on the markup ratio or price-cost margin. This implies that Taiwan's petrochemical industries have had a weak pricing-to-market pattern during the period 1987–92. The empirical results may be explained by the great volatility of profitability, high market concentration, and small share of exports in domestic production. These empirical results further support the argument, pointed out by Knetter (1993), that the range of parameter estimates across industries within each source country is very wide and there exist few differences in behavior within common industries of different source countries. We also show that though the influence of the exchange rate on export prices, markup ratios, and price-cost margins is relatively weak in Taiwan's petrochemical industries, the impact has tended to increase over time. This might be attributed to increasing competition in the world market or the realization of the importance of world market shares for Taiwanese petrochemical export firms. Finally, our results are very preliminary due to the short sampling period and insufficient data for foreign countries. If we could obtain the prices of petrochemical products in every Taiwan export destination country, we would have more reasonable proxies for demand pressures. In addition, more rigorous analyses of the causes of structural change in pricing-to-market behavior and the cyclical nature of pass-through effects are worthy of future research.

Appendix A
Derivation of the Impact of the Exchange Rate on PCM

Following Cowling and Waterson (1976), Brander and Krugman (1983), and Dei (1990), we envisage two open economies, a home and a foreign country. Assume that there is a monopolist producing a homogeneous product with the same cost condition in each country. Suppose that marginal costs are constant at c for both monopolists, and the inverse market demand functions in both countries are as follows:[10]

$$P^{d} = P^{d}(X^{h} + X^{m}), \quad P^{d\prime} < 0, \tag{A1}$$

$$P^{w} = P^{w}(X^{e} + X^{f}), \quad X^{w} = X^{e} + X^{f}, \quad P^{w\prime} < 0; \tag{A2}$$

where P^{d} and P^{w} represent prices at home and in the foreign country, respectively; X^{h} and X^{e} quantities produced by the domestic firm and sold at home and in the foreign country, respectively; X^{m} and X^{f} quantities produced by the foreign firm and sold at home and in the foreign country, respectively; and X^{w} total quantity demanded in the foreign country. Let $P^{e} = r \cdot P^{w}$, where P^{e} represents the home currency export price and r is the exchange rate. Then the domestic firm's and the foreign firm's profits can be formulated as follows:

$$\pi^{d} = (P^{d} - C)X^{h} + (P^{e} - C)X^{e} - F^{d}, \tag{A3}$$

$$\pi^{w} = (rP^{w} - C)X^{f} + (P^{d} - C)X^{m} - F^{w}, \tag{A4}$$

where π^{d} and π^{w} represent the domestic firm's and the foreign firm's profits, respectively; and F^{d} and F^{w} the domestic firm's and the foreign firm's fixed costs, respectively.

Assuming profit-maximizing behavior and Cournot zero conjectural variation, the first-order conditions for a maximum can be derived as follows:

$$\frac{\partial \pi^{d}}{\partial X^{e}} = P^{e} + rX^{e}P^{w\prime} - C = 0, \tag{A5}$$

$$\frac{\partial \pi^{w}}{\partial X^{f}} = rP^{w} + rX^{f}P^{w\prime} - C = 0. \tag{A6}$$

By total differentiation of equations (A5) and (A6), and rearrangement and manipulation, we obtain

$$\begin{bmatrix} 2rP^{w\prime} & rP^{w\prime} \\ rP^{w\prime} & 2rP^{w\prime} \end{bmatrix} \begin{bmatrix} dX^{e} \\ dX^{f} \end{bmatrix} = \begin{bmatrix} -(P^{w} + P^{w\prime}X^{e})dr + dC \\ -(P^{w} + P^{w\prime}X^{f})dr + dC \end{bmatrix}. \tag{A7}$$

10. For computational convenience, the notation in this appendix differs from that in the text.

Assuming that the costs of production remain constant (i.e., $dC = 0$), we can obtain by Cramer's rule

$$\text{(A8)} \qquad \frac{\partial X^e}{\partial r} = \frac{rP^{w\prime}[(P^{w\prime}X^f - 2X^e) - P^w]}{3(rP^{w\prime})^2},$$

$$> 0 \quad \text{if} \quad X^f > 2X^e,$$

$$? \qquad \text{otherwise}.$$

$$\text{(A9)} \qquad \frac{\partial X^f}{\partial r} = \frac{rP^{w\prime}[P^{w\prime}(X^e - 2X^f) - P^w]}{3(rP^{w\prime})^2},$$

$$> 0 \quad \text{if} \; X^e > 2X^f,$$

$$< 0 \quad \text{if} \; X^f > 2X^e,$$

$$? \qquad \text{otherwise},$$

where the absolute value of $-3X^eP^{w\prime}$ is assumed to be greater than that of P^w.

In order to allow possible collusion between the domestic and foreign firms, we relax the assumption that the domestic firm expects no response from the foreign firm to its output change. Therefore, equation (A5) becomes

$$\text{(A10)} \qquad rX^eP^{w\prime}\left(1 + \frac{\partial X^f}{\partial X^e}\right) + rP^w - C = 0.$$

By rearranging and manipulating equation (A10), we can obtain

$$\text{(A11)} \qquad \text{PCM} \equiv \frac{P^e - C}{P^e} = \left(1 + \frac{X^f}{X^e}\beta\right)\frac{1}{\varepsilon^p_{w,h}},$$

where PCM represents the exporting price-cost margin of the domestic firm, β the elasticity of collusion between the domestic and foreign firms, and $\varepsilon^p_{w,h}$ the domestic firm's price elasticity of demand in the foreign country. Finally, by partial differentiation of equation (A11) with respect to r and referring to equations (A8) and (A9), we can obtain

$$\text{(A12)} \qquad \frac{\partial \text{PCM}}{\partial r} = \frac{\beta}{\varepsilon^p_{w,h}} \cdot \frac{X^e(\partial X^f/\partial r) - X^f(\partial X^e/\partial r)}{(X^e)^2},$$

$$> 0 \quad \text{if} \quad \beta < 0 \quad \text{and} \quad X^f > 2X^e,$$

$$< 0 \quad \text{if} \quad \beta > 0 \quad \text{and} \quad X^f > 2X^e,$$

where $\beta = 1$ stands for perfect collusion, $\beta = -1$ is perfect competition, $0 < \beta < 1$ is imperfect collusion, and $-1 < \beta < 0$ is imperfect competition (Clarke and Davies 1982; Cubbin 1983).

Appendix B
Computation of Related Variables and Data Sources

Computation of Related Variables

MK *markup ratio* = (PEX − MC)/MC

PCM *price-cost margin* = (PEX − MC)/PEX

H *Herfindahl index* = $\sum_{i=1}^{22}[(PRO_t - EX_i)/\sum_{j=1}^{22}(PRO_j - EX_j)]^2$

EL *export demand price elasticity* = $(EX_t - EX_{t-1}/EX_{t-1})/(PEX_t - PEX_{t-1}/PEX_{t-1})$

RX *weighted exchange rate* = $\sum_{i=1}^{n}(EX_i/\sum_{j=1}^{n}EX_j)RX_i$

TC *weighted transportation cost* = $\sum_{i=1}^{n}(EX_i/\sum_{j=1}^{n}EX_j)VD_i$

Data Sources, Indicated by (A)–(E)

CU	capacity utilization rate	(A)
EX	export quantity	(B)
MC	unit production cost	(C)
PEX	export price	(A)
PRO	domestic production quantity	(A)

Table 8B.1 **Description of 22 Midstream Petrochemical Industries**

Abbreviation	Industry
ABS	ABS resin
AN	Acrylonitrile
BR	Butadiene rubber
CPL	Caprolactam
DOP	Dioctyl phthalate
EG	Ethylene glycol
HDPE	High-density polyethylene
LDPE	Low-density polyethylene
ME	Melamine
ML	Methanol
MMA	Methyl methacrylate acid
PA	Phthalic anlydride
PP	Polypropylene
PPG	Polypropylene glycol
PS	Polystyrene
PTA	Terephthalic acid
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
SBR	Styrene-butadiene rubber
SM	Styrene
VAM	Vinyl acetate
VCM	Vinyl chloride

RX	exchange rate	(D)
VD	voyage distance	(E)

(A) Petrochemical Industry Association of Taiwan, *Petrochemical Industries in Taiwan, Republic of China* (Taipei, 1986–92).

(B) Ministry of Finance, Department of Statistics, *Monthly Statistics of Exports and Imports, Taiwan Area, R.O.C.* (Taipei, 1986–92).

(C) Directorate-General of Budget, Accounting and Statistics, Executive Yuan, *Commodity-Price Statistics Monthly in Taiwan Area, R.O.C.* (Taipei, 1986–92).

(D) Central Bank of China, Economic Research Department, *Financial Statistics Monthly, Taiwan District, R.O.C.* (Taipei, 1986–92).

(E) Ministry of Communication, Executive Yuan, Taiwan, R.O.C.

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Comment Kenichi Ohno

Wang and Wu's paper investigates the export-pricing behavior of Taiwan's 22 midstream petrochemical firms. The study is interesting because of its focus on Taiwan as a newly industrialized economy whose role has expanded rapidly in the Asia Pacific region and its use of microeconomic firm-level data. The main finding is that these Taiwanese firms do not exhibit the typical "small country" property of taking international prices as given. Instead, they largely maintain their export prices in NT dollars even when the exchange rate changes. In other words, their exchange rate pass-through is high.

Midstream petrochemical firms are not meant to be representative of Taiwanese exporting firms. Their relatively large size and small number in the home market make them an exception in the Taiwanese industrial landscape, where a large number of small and medium-sized enterprises are the common feature. The lack of export price sensitivity may well be due to this peculiar characteristic of the industry chosen for the study—as Wang and Wu suggest. However, before evaluating the validity of this interpretation—or any other interpretations offered in this paper—several technical issues must be clarified.

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First, the authors adopt three specifications of pricing behavior for estimation, namely, the export price equation, the markup equation, and the price-cost equation. These are not independent but simply different arrangements of the same variables. While running all equations that have been tried previously is one possible strategy, clearly, a more satisfactory procedure is to begin with a theoretical model that leads to an empirical equation, allowing economic interpretation of the estimated parameters. The present paper does not permit such an interpretation. Nor is there a criterion for choosing among the three specifications when they produce somewhat different results.

Second, the use of the Herfindahl index to measure the degree of domestic monopoly has its limitations, because the number of firms in an industry—or the distribution of their market shares—is not necessarily correlated with the competitive environment of that industry. In the Taiwanese context, the status of contestability (free entry) as well as foreign competition must also be taken into account. Of course, to be fair, this is a broader problem of how to measure the state of competition and is not unique to this paper.

Third, we need more information to interpret the estimated pass-through coefficients. As the authors explain, most petrochemical firms in Taiwan do not export much; they are home market oriented and export only a tiny fraction of their output to a large number of small countries. But what is the market structure like in those foreign countries? If prices there do not follow global trends, due to either import protection or the monopolistic power of Taiwanese exporters, it is easy to understand why the pricing of the Taiwanese firms is not sensitive to the exchange rate. In addition, the possibility of intrafirm trade may be an important factor. If Taiwanese petrochemical products are inputs to Taiwanese subsidiaries abroad, the transfer price may be insensitive to the exchange rate as it does not affect the consolidated profits of the entire industrial group.

Finally, there is an inescapable problem arising from running regressions on only seven annual observations. True, these time series are pooled across 22 firms so there is no apparent lack of degrees of freedom. Even so, what the paper essentially does is find a correlation between the exchange rate and export price movements during seven recent years (1986–92). For such a short period, which can include only a few major turns of the exchange rate, it is very difficult to tell whether the correlation is real or accidental. One suspects that the estimation may not be very robust against alternative sample periods, and this suspicion is vindicated when tables 8.5 and 8.6 are compared. These tables report the estimation results when the sample period is subdivided further into 1986–89 and 1990–92. Many key parameters—including those on marginal cost, exchange rate, and capacity utilization—lose significance from the first period to the second, while others—like transportation cost—become highly significant only in the second period. One would like to have a longer time series, or explore the possibility of using quarterly data, to overcome these weaknesses.

Comment Y. C. Jao

The Wang-Wu paper is a highly specialized and technical study of the export-pricing behavior of one particular industry, the petrochemical industry, in Taiwan. According to the received theory, developing countries, including newly industrializing countries, are price takers in world markets. Specifically, this behavior implies that exchange rate changes do not affect foreign currency export prices and there should be little or no exchange rate pass-through. With a few notable exceptions, such as OPEC in its heyday, this proposition is generally well founded empirically.

Wang and Wu, however, find that the impact of the exchange rate on the domestic currency export prices, or markup ratio, or price-cost margin, of Taiwan's petrochemical products was very small, ranging from 7 to 19 percent, or in other words, the pass-through effect was remarkably high, ranging from 81 to 97 percent during their sample period. Their results seem to contradict the conventional wisdom.

The authors use a well-specified model to test the pricing behavior of the petrochemical industry, with unit production cost, weighted exchange rate, capacity utilization rate, Herfindahl index, demand elasticity, and transportation cost as the explanatory variables. In general, the estimated coefficients seem to be satisfactory.

The authors explain their results by the following factors: profit volatility, high industrial concentration, small share of exports in total domestic output, and weakness of domestic firms in export markets. Except perhaps for profit volatility, the other factors are reasonable enough. The "market power" factor, in particular, reminds one of the behavior of OPEC, which at the height of its power could exact huge increases in crude oil prices to compensate for the decline of the U.S. dollar.

The obvious question to ask is: how typical is the behavior of Taiwan's petrochemical industry? This issue is not addressed in the paper. An outsider's impression is that the petrochemical industry is most probably a special case, with a pricing strategy unlikely to be typical, even for Taiwan, let alone the whole developing world. Wang and Wu themselves note that the impact of the exchange rate on domestic currency export prices may be expected to increase over time, due to increasing liberalization of trade, foreign competition, and the realization by the export firms concerned of the importance of maintaining export market shares.

Another limitation is the shortness of the sampling period, 1986–92. Some economic variables may change unpredictably. Take the NT dollar–U.S. dollar exchange rate for instance. Between 1983 and 1989, the NT dollar appreciated strongly, with the exchange rate falling from 40.07 to 26.41. Between 1989

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and 1995, the rate was generally stable, fluctuating within a narrow range. Since the Taiwan Strait crisis erupted in July 1995, the NT dollar has shown a mild tendency to depreciate. It is to be hoped that the authors can extend their empirical study as more data become available, in order to take into account the rapidly changing economic environment.

The most significant contribution of Wang and Wu's paper is the demonstration that disaggregative studies of industrial structure can yield richer insights into pricing behavior not otherwise obtainable from highly aggregative studies. However, for reasons already stated, the case of Taiwan's petrochemical industry per se is not enough to upset the general proposition that developing countries, on the whole, are price takers in world markets.

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