CHAPTER 2

PROFITABILITY, CONCENTRATION, IMPORT AND EXPORT SHARES

2.1 Introduction

During the past two decades, there have been various studies of the relationship between foreign trade and industry performance. Theoretically, import share has been proved to have a negative impact on price-cost margin (*PCM*) (Pugel, 1980; Jacquemin, de Ghellinck and Huveneers, 1980; Jacquemin, 1982). However, Lopez and Lopez (1996) show that imports can have a positive or negative impact on domestic *PCM* depending on the sign and strength of economies of scale, cost effect, domestic price effect and import price effect.

Empirically, through single equation regression, Esposito and Esposito (1971), Khalizadeh-Shirazi (1974) and Pugel (1980) all find that import share affects *PCM* negatively. Jacquemin, de Ghellinck and Huveneers (1980) set up a two equations recursive model and find that import share affects *PCM* negatively. Bennenbroek and Harris (1995) find that concentration affects profitability positively and firm-level import and export intensity variables have negative effects upon profitability. Oustapassidis and Vlachvei (1999) find that concentration and import intensity did not play a significant role in increasing profit margins in Greek food manufacturing over the study period.

Pugel (1978) estimates a simultaneous-equation system including *PCM*, import share, export share, foreign direct investment as well as advertising intensity equations through the use of two-stage least squares (2SLS), and finds that import share affects *PCM* negatively, and export share affects *PCM* positively. Pagoulatos and Sorensen (1981) estimate a simultaneous-equation system including *PCM*, concentration as well as advertising equations through the use of three-stage least squares (3SLS), and find that industry concentration and import share affect *PCM* positively, export share affects *PCM* negatively, and import competition has had little impact on affecting profitabilities of domestic firms especially in some industries which are highly protected via tariffs, quotas and government inspection standards.

Geroski (1982) finds that simultaneous interaction occurs between profit and foreign competition variables, and there is a significantly negative relationship between import share and *PCM*, and a significantly positive relationship between export share and *PCM*. Chou (1986) estimates a simultaneous-equation system of *PCM*, concentration, import share and export share equations through the use of 2SLS. The empirical results show that concentration affects *PCM* positively, import share affects *PCM* negatively, and there is a negative and significant relationship between export share and *PCM*. Stalhammar (1991) shows that concentration affects *PCM* positively, and there also exists a positive relationship between import share and *PCM* because of domestic implicit collusion. McDonald (1999) shows that *PCM* is positively affected by concentration and negatively affected by import share. Thompson (2002) finds that *PCM* is positively affected by concentration, *PCM* is negatively affected by export share and there is no consistent evidence that import share reduced the Canadian firms' *PCM* during 1970s. Delorme, Klein, Kamerschen and Voeks (2002) find that concentration does not depend on firm profitability, though profitability depends on concentration.

Although the empirical studies of the structure-performance relationship in an open-economy have been growing rapidly, there are still some limitations on them. First, the majority of them deal with large and developed countries such as the USA and UK.[3] Only a few of them, such as Jacquemin, de Ghellinck and Huveneers (1980), Chou (1986), Kalirajan (1993) and Go, Kamerschen and Delorme (1999), study small open-economies. Second, most of them make use of aggregate data in their analyses, and the aggregation process might conceal different effects among industries with different characteristics (Pagoulatos and Sorensen, 1976; Pugel, 1980; Nolle, 1991; Go, Kamerschen and Delorme, 1999; Yalcin, 2000). Third, import concentration and country concentration of exports have been neglected, although they could influence the industry performance and market structure significantly.[4] Fourth, although some of the existing studies have adopted four or five equations simultaneous system (Pugel, 1978; Chou, 1986), the theoretical foundations have been neglected. Finally, nonzero conjectural variations among firms have been neglected by most of the existing studies. It might lead to misleading results and the

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[3] See Urata (1979), Khalilzadeh-Shirazi (1974), Pagoulatos and Sorensen (1976, 1981), Pugel (1980), Geroski (1982) and Nolle (1991).

[4] Import concentration represents foreign firms' market power in the domestic country. Country

exact industry situation couldn't be explained effectively. Given the fact that some domestic industries may be characterized by either a monopoly or an oligopoly market structure and collusion behaviors could exist among domestic firms, among foreign firms as well as between domestic and foreign firms (Jacquemin, de Ghellinck and Huveneers, 1980).

In this paper we intend to investigate the determinants of domestic firms' *PCM*, domestic concentration, import share and export share as well as possible relationships among them for the midstream petrochemical industries in Taiwan. [5] To overcome the above limitations, this paper will first set up an open-economy oligopoly model. Then, the possible relationships among domestic firms' *PCM*, domestic concentration, import share and export share will be derived. Thereafter, based on the derived results and the existing literature, a simultaneous-equation system of domestic firms' *PCM*, domestic concentration, import share and export share equations will be established. Finally, the simultaneous-equation system will be estimated by utilizing the disaggregated data of Taiwan's midstream petrochemical industry. [6]

In addition to the introduction, the remainder of this chapter is organized as follows. An oligopoly model in the open-economy will be built in Section 2. The empirical model, data description and the interpretation of empirical results will be presented in Section 3. Section 4 concludes the paper.

2.2 The Model

2.2.1 Theoretical Model

Before setting up the theoretical model, it is worth noting some major characteristics of the midstream petrochemical industries. First, midstream petrochemical products are intermediate goods and homogeneous in each industry (Bernhofen and Xu, 2000). Second, the midstream petrochemical industries have production functions with fixed

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concentration of exports indicates the buyer concentration of the exports.

[5] In this paper, import share is regarded as a proxy for the degree of foreign competition and measured as the ratio of imports to domestic shipments (total sales minus exports plus imports). Export share is measured as the ratio of exports to domestic firms' shipments.

[6] The data set of this paper is based on the Standard Industrial Classification 7-digit products. Therefore, the problem of aggregation bias can be avoided.

proportions, and their marginal costs are constant when the input prices are given. Third, their market structures are either oligopoly or monopoly. Based on these characteristics, a two-nation oligopolistic model is developed to study the determinants of domestic firms' *PCM*, domestic concentration, import share and export share. Following Brander and Krugman (1983), Dei (1990), Wang (1997) and Bernhofen and Xu (2000), we consider two open economies, a home and a foreign country. Assume that there exists an oligopolistic market of a homogeneous product in each country;[7] there are n firms in the home country and n^w firms in the foreign country; the outputs produced by all firms can be sold domestically or exported to the other country. By referring to Sibert (1992), Yang (1997), Wang (1997) and Wang and Wu (1999), we further assume that there may exist non-zero conjectural variations among firms. Define $X^h \equiv \sum_{i=1}^{n} x_i^h$, $X^e \equiv \sum_{i=1}^{n} x_i^e$, $X^m \equiv \sum_{k=1}^{n^w} x_k^m$, $X^f \equiv \sum_{k=1}^{n^w} x_k^f$. x_i^h and x_i^e are the quantities sold domestically and exported to the foreign country by the *i*th domestic firm, respectively; x_k^m and x_k^f are the quantities exported to the home country and sold in the foreign country by the *k*th foreign firm, respectively. Therefore, X^h and X^e represent the total quantities sold domestically and exported to the foreign country by all the domestic firms, respectively; X^m and X^f represent the total quantities exported to the home country and sold domestically by all the foreign firms, respectively. Suppose that fixed costs for domestic firms are F^d in terms of the home country's currency and those for foreign firms are F^w in terms of the foreign country's currency. The marginal cost for the *i*th domestic firm is constant at C_i^h, i=1,2,…,n, in terms of the home country's currency, and that for the *k*th foreign firm is constant at C_k^w, k=1,2,…,n^w, in terms of the foreign country's currency. Let the inverse market demand functions of the homogeneous product in both countries be

$$P^d = P^d(X^h + X^m)$$

and

[7] Although Taiwan's midstream petrochemical industries operate in either oligopolistic or monopolistic markets, we construct a general model for simplicity which is applicable to other kinds of market structure.

$$P^w = P^w(X^e + X^f)$$

where P^d and P^w are the market prices in the home and foreign countries, respectively. The law of demand implies that $P^{d'} < 0$ and $P^{w'} < 0$. For simplicity, the demand functions are assumed to be linear so that $P^{d''} = 0$ and $P^{w''} = 0$. By definition, $X^d = X^h + X^m$ represents the total quantity demanded in the home country, $X^w = X^e + X^f$ represents the total quantity demanded in the foreign country, and $X^T = X^h + X^e$ represents the total quantities sold domestically and abroad by all domestic firms. Therefore, the *i*th domestic firm's profit function in terms of the home country's currency can be expressed as:

$$\pi_i^d = P^d \cdot x_i^h - C_i^h \cdot x_i^h + ex \cdot P^w \cdot x_i^e - (C_i^h + f + t^w) \cdot x_i^e - F^d$$

where π represents profit, *ex* is the exchange rate,[8] t^w is the specific tariff rate imposed by the foreign country, and *f* is the unit transportation cost for domestic firms to export. Similarly, the *k*th foreign firm's profit function in terms of the foreign country's currency can be written as: [9]

$$\pi_k^w = P^w \cdot x_k^f - C_k^w \cdot x_k^f + P^d \cdot x_k^m / ex - \left(C_k^w + f^w + t^h\right) \cdot x_k^m - F^w$$

where t^h stands for the specific tariff rate imposed by the home country and f^w is the unit transportation cost for foreign firms to export.

Assuming there exist non-zero conjectural variations, and manipulating the first-order conditions for profit maximization by the *i*th domestic firm mathematically (see Appendix 2A), we then have

$$PCM^d = \frac{1}{\varepsilon^d} \cdot (1 - ER) \cdot \left\{(1 - MR) \cdot \left[H^d \cdot (1 - \alpha) + \alpha\right] + \beta \cdot MR\right\} \qquad (2\text{-}1)$$

where PCM^d is the weighted average of the domestic firms' *PCM*s in two countries,

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8 *ex* is expressed in terms of domestic currency units per foreign currency unit.

9 Theoretically, the prices of the imported materials by foreign firms and their costs of production may be affected by a change in the exchange rate. However, few foreign petrochemical firms purchase raw materials from Taiwanese firms. Therefore, it is assumed that foreign firms' costs of production are not affected by a change in the exchange rate.

$\varepsilon^d \equiv -P^d / X^d \cdot \partial X^d / \partial P^d$ is the price elasticity of demand in the home country, $ER \equiv X^e / X^T$ is export share, $MR \equiv X^m / X^d$ is import share, $H^d \equiv \sum_{i=1}^{n} (x_i^h / X^h)^2$ is the degree of domestic concentration, $\alpha \equiv \left(\partial \sum_{j \neq i} x_j^h / \partial x_i^h\right) \cdot \left(x_i^h / (X^h - x_i^h)\right)$ is conjectural elasticity among the domestic firms, $\beta \equiv \left(\partial X^m / \partial x_i^h\right) \cdot \left(x_i^h / X^m\right)$ is conjectural elasticity between a domestic firm and the foreign firms selling in the home country.

According to Clark and Davies (1982), Cubbin (1983) and Martin (1993), $\alpha, \beta = 1$ stands for perfect collusion, $\alpha, \beta = -1$ stands for perfect competition, $0 < \alpha, \beta < 1$ stands for imperfect collusion, and $-1 < \alpha, \beta < 0$ stands for imperfect competition. Based on the industry characteristics of Taiwan's midstream petrochemical products (Wang, 1997; Wang and Wu, 1999), we assume that $-1 < \alpha < 1$ and $-1 < \beta < 1$.

Similarly, manipulating the first-order conditions for profit maximization by the *k*th foreign firm mathematically (see Appendix 2B), we can obtain

$$\frac{1}{\varepsilon^d} = \frac{PCM^m}{MR \cdot H^m} \tag{2-2}$$

where PCM^m is the foreign firms' *PCM* in the home country, $H^m \equiv \sum_{i=1}^{n^w} (x_k^m / X^m)^2$ is the degree of import concentration of foreign firms in the home country, substituting Equation (2-2) into Equation (2-1), we obtain

$$PCM^d = \frac{PCM^m}{MR \cdot H^m} \cdot (1 - ER) \cdot \left\{ (1 - MR) \cdot \left[H^d \cdot (1 - \alpha) + \alpha \right] + \beta \cdot MR \right\} \tag{2-3}$$

By transforming, Equation (2-3) can be rewritten in the following forms

$$H^d = \left[\frac{PCM^d \cdot H^m}{PCM^m \cdot (1 - ER)} - \beta \right] \frac{MR}{(1 - MR) \cdot (1 - \alpha)} - \frac{\alpha}{1 - \alpha} \tag{2-4}$$

$$MR = \frac{A \cdot PCM^m \cdot (1\text{-}ER)}{PCM^d \cdot H^m + PCM^m \cdot (1 - ER) \cdot (A\text{-}\beta)} \tag{2-5}$$

and

$$ER = 1 - \frac{MR \cdot H^m \cdot PCM^d}{Z \cdot PCM^m} \tag{2-6}$$

where $A = H^d \cdot (1-\alpha) + \alpha$ and $Z = (1-MR) \cdot A + MR \cdot \beta$. Equations (2-3)-(2-6) indicate that PCM^d, H^d, MR and ER depend on each other. That is, there might exist simultaneous relationships among the dependent variables of these four equations.

2.2.2 Comparative Static Analysis

***PCM^d* Equation**

The impact of each independent variable on PCM^d can be derived by taking partial differentiations of Equation (2-3) with respect to H^d, MR, ER and H^m, respectively, as follows:[10]

The domestic concentration (H^d)[11]

$$\frac{\partial PCM^d}{\partial H^d} = \frac{(1-ER)\cdot(1-MR)\cdot(1-\alpha)\cdot PCM^m}{H^m \cdot MR} > 0$$

The larger the degree of domestic concentration is, the less competitive the domestic market becomes, and domestic firms will have stronger monopoly power to affect the market price of the home country and make more profit. Therefore, the relationship between H^d and PCM^d is expected to be positive.

The import share (MR)

$$\frac{\partial PCM^d}{\partial MR} = -\frac{(1-ER)\cdot PCM^m \cdot A}{H^m \cdot MR^2} < 0, \quad \text{if } \alpha > 0;$$

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

While domestic firms are in a situation of collusion ($\alpha > 0$), the rising MR may make domestic firms feel more competitive pressure. As a result, domestic firms will have

[10] Since PCM^m, α and β will not be incorporated as explanatory variables in the empirical model due to some technical problems in estimating them, their comparative static analyses will be neglected in this paper. However, these comparative static results will be available upon request.

[11] It is assumed that $0 < PCM^m < 1$ when firms are maximizing profit. In addition, 1-*ER*>0, 1-*MR*>0 since $0 \le ER < 1$, $0 \le MR < 1$, $1/(n^w) \le H^m \le 1$ and $1-\alpha > 0$ since $-1 < \alpha < 1$.

weaker incentives to raise price. It will make PCM^d become lower. Therefore, the impact of *MR* on PCM^d is expected to be negative. However, under other conditions, the relationship between *MR* and PCM^d is ambiguous.

The export share (*ER*)

$$\frac{\partial PCM^d}{\partial ER} = -\frac{(1-MR)\cdot PCM^m \cdot Z}{H^m \cdot MR} < 0\,,\ \ if\ \alpha > 0 \quad and \qquad \beta > 0\,;$$

$$?,\quad otherwise$$

When the interactive relationship among domestic firms as well as that between domestic and foreign firms are both collusive ($\alpha > 0$, $\beta > 0$), domestic firms will have stronger monopoly power to affect the market price and make more profit in the home country. The domestic firms' *PCM* in the home country will be higher than that in the foreign country. Then, the rising *ER* may make domestic firms' PCM^d go down. Consequently, the relationship between *ER* and PCM^d is expected to be negative. Similarly, under other conditions, the relationship between *ER* and PCM^d is hard to determine.

The import concentration (H^m)

$$\frac{\partial PCM^d}{\partial H^m} = -\frac{(1-ER)\cdot PCM^m \cdot Z}{(H^m)^2 \cdot MR} < 0\,,\ \ if\ \alpha > 0 \quad and \qquad \beta > 0\,;$$

$$?,\quad otherwise$$

when $\alpha > 0$ and $\beta > 0$, the rising H^m may indicate that foreign firms have more power in negotiating with domestic firms about market share. Consequently, PCM^d will go down while H^m goes up. Therefore, the impact of H^m on PCM^d is expected to be negative. Similarly, the relationship between H^m and PCM^d is hard to determine under other conditions.

In addition, PCM^m can be further decomposed. Then, after mathematical manipulation, the negative impact of *cd* and positive impacts of t^h , f^w and *ex* on PCM^d cab be presented; $cd=(CD/P^d)$, $CD \equiv \left[\overline{C}^h - ex\cdot(\overline{C}^w + f^w + t^h)\right]$ is the cost differential between domestic and foreign firms (see Appendix 2B). The higher the cost differential between domestic and foreign firms, the more competition pressure domestic firms feel from foreign firms, then domestic firms will have weaker monopoly power to affect the market price in the home country and make less profits. The larger the specific tariff rate imposed by the home country, transportation cost per unit of foreign firms or the exchange rate is, the higher barriers for foreign firms to enter domestic market. Therefore, the less competition pressure domestic firms feel from foreign firms, domestic firms will have stronger power to affect the market price in the home country and make more profits. As a result, the relationships between tariff rate, transportation cost as well as exchange rate and PCM^d are all positive.

Based on the above results of comparative static analysis, the relationships between PCM^d and all independent variables can be summarized as:

$$PCM^d = f(\underset{(+)}{H^d}, \underset{(?)}{MR}, \underset{(?)}{ER}, \underset{(?)}{H^m}, \underset{(-)}{cd}, \underset{(+)}{t^h}, \underset{(+)}{f^w}, \underset{(+)}{ex}) \qquad (2\text{-}7)$$

where the notation under each independent variable indicates its expected sign.

H^d Equation

Similarly, by taking partial differentiations of Equation (2-4) with respect to PCM^d, *MR*, *ER* and H^m, respectively, the impact of each independent variable on H^d can be derived as follows:

The domestic firms' *PCM* (PCM^d)

$$\frac{\partial H^d}{\partial PCM^d} = \frac{H^m \cdot MR}{(1-MR)\cdot(1-ER)\cdot(1-\alpha)\cdot PCM^m} > 0$$

When the PCM^d becomes larger, domestic firms will be more capable of raising their market shares and, then, H^d will go up. Consequently, the relationship between PCM^d and H^d is expected to be positive.

The import share (*MR*)

$$\frac{\partial H^d}{\partial MR} = \frac{H^m \cdot PCM^d - \beta\cdot(1-ER)\cdot PCM^m}{(1-MR)^2\cdot(1-ER)\cdot(1-\alpha)\cdot PCM^m} > 0, \quad if \ \ \beta < 0;$$

$$?, \quad otherwise$$

While domestic firms are in a situation of competition ($\beta < 0$), if MR goes up, domestic firms will feel more pressure from foreign firms and have stronger desire to improve their efficiency via merger. Then, H^d will go up. Therefore, the impact of MR on H^d is expected to be positive. However, under other conditions, the relationship between MR and H^d is hard to determine.

The export share (ER)

$$\frac{\partial H^d}{\partial ER} = \frac{H^m \cdot MR \cdot PCM^d}{(1-MR)\cdot(1-ER)^2 \cdot (1-\alpha)\cdot PCM^m} > 0$$

When ER goes up, efficient domestic firms can enjoy economies of scale along with the increasing levels of their outputs. As a result, it will force inefficient domestic firms to exit, decrease the number of domestic firms and, then, raise H^d. Therefore, the impact of ER on H^d is expected to be positive.

The import concentration (H^m)

$$\frac{\partial H^d}{\partial H^m} = \frac{MR \cdot PCM^d}{(1-MR)\cdot(1-ER)\cdot(1-\alpha)\cdot PCM^m} > 0$$

When the degree of H^m goes up, competition pressure on domestic firms by foreign firms will rise. Domestic firms have to improve their efficiency in order to survive. Similarly, it will force inefficient domestic firms to exit, decrease the number of domestic firms and, then, raise H^d. Therefore, the impact of H^m on H^d is expected to be positive.

Dependent upon the above results of comparative static analyses, the relationships between H^d and all independent variables can be summarized as follows:

$$H^d = f(\underset{(+)}{PCM^d}, \underset{(?)}{MR}, \underset{(+)}{ER}, \underset{(+)}{H^m}) \qquad (2\text{-}8)$$

***MR* Equation**

Similarly, by taking partial differentiations of Equation (2-5) with respect to PCM^d, H^d, ER and H^m respectively, the impact of each independent variable on MR can be derived as follows:

The domestic firms' PCM (PCM^d)

$$\frac{\partial MR}{\partial PCM^d} = -\frac{(1-ER)\cdot PCM^m \cdot H^m \cdot A}{\left[H^m \cdot PCM^d + (1-ER)\cdot(A-\beta)\cdot PCM^m\right]^2} < 0, \quad if \ \alpha > 0;$$

$$?, \quad otherwise$$

While domestic firms are in a situation of collusion ($\alpha > 0$), if PCM^d rises, domestic firms will be more capable of prohibiting importing. Then, *MR* will fall. Therefore, the impact of PCM^d on *MR* is expected to be negative. However, under other conditions, the relationship between PCM^d and *MR* is hard to determine.

The domestic concentration (H^d)

$$\frac{\partial MR}{\partial H^d} = \frac{(1-ER)\cdot(1-\alpha)\cdot PCM^m \cdot \left[PCM^d \cdot H^m - \beta \cdot PCM^m \cdot (1-ER)\right]}{\left[H^m \cdot PCM^d + (1-ER)\cdot(A-\beta)\cdot PCM^m\right]^2} > 0, \ if \ \ \beta < 0;$$

$$?, \ otherwise$$

While domestic and foreign firms are in a situation of competition ($\beta < 0$), if H^d goes up, then domestic firms will be more capable of raising price via decreasing their sales in the home country. It will lead to a larger *MR* when the domestic market size remains unchanged. Therefore, the impact of H^d on *MR* is expected to be positive. Under other conditions, the relationship between H^d and *MR* is ambiguous.

The export share (*ER*)

$$\frac{\partial MR}{\partial ER} = -\frac{H^m \cdot PCM^m \cdot PCM^d \cdot A}{\left[H^m \cdot PCM^d + (1-ER)\cdot(A-\beta)\cdot PCM^m\right]^2} < 0, \quad if \ \ \alpha > 0;$$

$$?, \quad otherwise$$

While domestic firms are in a situation of collusion ($\alpha > 0$) and *ER* goes up, it indicates that domestic firms collude to reduce their domestic sales in order to raise the market price in the domestic market, and *ER* will rise. In such condition, domestic firms will have more incentive to construct entry barriers to prohibit foreign firms' entry, then the imports and *MR* will fall. Therefore, the impact of *ER* on *MR* is expected to be negative. Similarly, under other conditions, the relationship between *ER* and *MR* is hard to determine.

The import concentration (H^m)

$$\frac{\partial MR}{\partial H^m} = -\frac{PCM^m \cdot PCM^d \cdot A \cdot (1-ER)}{\left[H^m \cdot PCM^d + (1-ER)\cdot(A-\beta)\cdot PCM^m\right]^2} < 0, \quad if \ \alpha > 0;$$

$$?, \quad otherwise$$

While domestic firms are in a situation of collusion ($\alpha > 0$), the import barrier will be high for foreign firms. If H^m goes up, it indicates that total imports will be dominated by fewer foreign firms. Therefore, less efficient foreign firms may exit the home country. As a consequence, *MR* will go down. Therefore, the impact of H^m on *MR* is expected to be negative. Similarly, under other conditions, the relationship between H^m and *MR* is hard to determine.

In addition, *MR* also can be rewritten. Then, after mathematical manipulation, we can get the positive impact of *cd* on *MR* (see Appendix 2-2). The larger the domestic firms' production cost is over the foreign firms', the more competitive advantage foreign firms will have. Then, the *MR* will go up owing to increasing imports. Therefore, the impact of *cd* on *MR* is expected to be positive.

Similarly, the relationships between *MR* and all independent variables can be summarized from the comparative static analysis as follows:

$$MR = f(\underset{(?)}{PCM^d}, \underset{(?)}{H^d}, \underset{(?)}{ER}, \underset{(?)}{H^m}, \underset{(+)}{cd}) \qquad (2\text{-}9)$$

ER Equation

Similarly, by taking partial differentiations of Equation (2-6) with respect to PCM^d, H^d, MR and H^m, respectively, the impact of each independent variable on *ER* can be derived as follows:

The domestic firms' *PCM* (PCM^d)

$$\frac{\partial ER}{\partial PCM^d} = -\frac{H^m \cdot MR}{PCM^m \cdot Z} < 0, \quad if \ \alpha > 0 \ \ and \ \ \beta > 0;$$

$$?, \quad otherwise$$

While the interactive relationships among domestic firms as well as that between domestic and foreign firms are both collusive, if PCM^d goes up, domestic firms will have weaker desire to export. This, in turn, leads to a smaller *ER*. Therefore, the impact of PCM^d on *ER* is expected to be negative. However, under other conditions, the relationship between PCM^d and *ER* is ambiguous.

The domestic concentration (H^d)

$$\frac{\partial ER}{\partial H^d} = \frac{H^m \cdot MR \cdot PCM^d \cdot (1-MR)\cdot(1-\alpha)}{PCM^m \cdot Z^2} > 0$$

When H^d rises, domestic firms will have stronger power to raise price via decreasing their sales in the home country. This will, in turn, lead to a larger *ER*. Therefore, the impact of H^d on *ER* is expected to be positive.

The import share (*MR*)

$$\frac{\partial ER}{\partial MR} = -\frac{H^m \cdot PCM^d \cdot A}{PCM^m \cdot Z^2} < 0\,,\ if\ \ \alpha > 0\,;$$

$$?,\ otherwise$$

While domestic firms are in a situation of collusion ($\alpha > 0$), if *MR* goes up, it may indicate that foreign firms are more competitive and aggressive than domestic firms, in both home and foreign countries. As a consequence, domestic firms' exports and export share will fall along with the rising import. Therefore, the impact of *MR* on *ER* is expected to be negative. Similarly, under other conditions, the relationship between *MR* and *ER* is ambiguous.

The import concentration (H^m)

$$\frac{\partial ER}{\partial H^m} = -\frac{MR \cdot PCM^d}{PCM^m \cdot Z} < 0\,,\ if\ \ \alpha > 0\ \ and\ \ \beta > 0\,;$$

$$?,\ otherwise$$

While the interactive relationship among domestic firms as well as that between domestic and foreign firms are both collusive, if H^m goes up, the collusive relationship among domestic firms will be easier to remain in business and, then, home market will be more attractive than foreign market because of profit incentive. As a result, domestic firms may decide to lower *ER*. Therefore, the impact of H^m

on ER is expected to be negative. Similarly, under other conditions, the relationship between H^m and ER is ambiguous.

In addition, ER also can be rewritten. Then, after mathematical manipulation, we can get the negative impact of cd on ER (see Appendix 2-2). The larger the domestic firms' production cost is over the foreign firms, the less competitive domestic firms become in the foreign country. Then, domestic firms' exports will decline and their ER will go down. Therefore, the impact of cd on ER is expected to be negative.

Again, the relationships between ER and all independent variables can be summarized as follows:

$$ER = f(\underset{(?)}{PCM^d}, \underset{(+)}{H^d}, \underset{(?)}{MR}, \underset{(?)}{H^m}, \underset{(-)}{cd}) \tag{2-10}$$

2.3 Empirical Specification and Results

2.3.1 Empirical Model

In addition, to make sure that each equation of the simultaneous system of Equations (2-7)-(2-10) be identified, three more independent (exogenous) variables (country concentration of exports (H^{ce}), market size (MS) and capacity utilization (E)) are added to the system by referring to Carlton and Perloff (1994), Chou (1986), Wang (1997) and Bhattacharya (2002).

According to Carlton and Perloff (1994), the buyer concentration can lead to lower price when buyers are larger and more powerful, their concentration can offset the power of sellers. Therefore, taking the importance of buyer concentration on sellers' performance into account, we add country concentration of exports to the PCM^d equation, and its expected sign is negative.

According to Chou(1986) and Wang(1997), when the domestic market size grows, H^d will decline if there is free entry. Bhattacharya (2002) claims that the larger the value is of market size, the lower the level of concentration will be. Therefore, the relationship between market size and H^d is expected to be negative.

According to Wang(1997), capacity utilization represents the economies of scale. The rising ratio of capacity utilization implies that domestic firms are approaching the minimum efficient scale. Therefore, the average cost of domestic firms will be lower, and that will deter foreign firms from entry. Consequently, *MR* will go down. Therefore, the relationship between capacity utilization and *MR* is expected to be negative.

When H^{ce} rises, domestic firms' export negotiation power and export price will decline, export profit and export incentive will decrease. Consequently, exports and *ER* will go down. Therefore, the relationship between country concentration of exports and *ER* is expected to be negative.

Finally, the empirical model in this paper can be established as:

$$PCM^d = f(\underset{(+)}{H^d}, \underset{(?)}{MR}, \underset{(?)}{ER}, \underset{(?)}{H^m}, \underset{(+)}{t^h}, \underset{(+)}{f^w}, \underset{(-)}{H^{ce}}, \underset{(+)}{ex}) \tag{2-11}$$

$$H^d = f(\underset{(+)}{PCM^d}, \underset{(?)}{MR}, \underset{(+)}{ER}, \underset{(+)}{H^m}, \underset{(-)}{MS}) \tag{2-12}$$

$$MR = f(\underset{(?)}{PCM^d}, \underset{(?)}{H^d}, \underset{(?)}{ER}, \underset{(?)}{H^m}, \underset{(-)}{E}, \underset{(+)}{cd}) \tag{2-13}$$

$$ER = f(\underset{(?)}{PCM^d}, \underset{(+)}{H^d}, \underset{(?)}{MR}, \underset{(?)}{H^m}, \underset{(-)}{cd}, \underset{(-)}{H^{ce}}) \tag{2-14}$$

2.3.2 Data Description and Estimation Procedure

The data set used in this paper consists of 21 midstream petrochemical industries. Since the data of H^d on some midstream petrochemical products are unavailable before 1989 and after 1997, the period covered by this paper spans from 1989 to 1997, during which annual data are available for all midstream petrochemical industries under examination. The detailed description of these midstream petrochemical products is presented in Appendix 2C. Although the number of dependent and independent variables in the simultaneous-equation system is only 12, the total number of variables needed for creating these 12 variables is much more than that. Therefore, the data set is a little bit complicated, coming from 6 different sources. Formulas used to calculate the relevant variables and data sources are given in Table 2.1.

Since the relationships among PCM^d, H^d, *MR* and *ER* are simultaneous, there might exist a simultaneous bias should the OLS method be applied to estimate the system of Equations (2-11)-(2-14). To avoid the above problem, a simultaneous regression method will be used to estimate the simultaneous-equation system. Because the rank condition of the simultaneous-equation system is satisfied, and by order condition Equation (2-11) is exactly identified, and Equations (2-12)-(2-14) are over-identified, 3SLS will be chosen to estimate the system.

2.3.3 Empirical Results

The 3SLS estimation results are presented in Table 2.2. The regression result of PCM^d equation shows that there exists a positive relationship between H^d and PCM^d at 5% significant level. That is, domestic firms in the midstream petrochemical industries with higher H^d have stronger market power to affect the market price of the home country and make more profit. Consequently, PCM^d in the midstream petrochemical industry with higher H^d is higher than that with lower H^d. The coefficients of MR and H^m are both negative and significant at 1% level, implying that when the competitive pressure domestic firms feel and/ or foreign firms' negotiation power become stronger domestic firms' profitability will decline. More importantly, based on the comparative static analysis of the PCM^d equation, the former implies that domestic firms in the midstream petrochemical industries might be in a situation of collusion, and the latter implies that the interactive relationship among domestic firms as well as that between domestic and foreign firms might both be collusive. Except for the external market structure factors (H^d, MR and H^m), relevant sale policies also affect firms' profitability. The coefficient of ER is negative and significant at 5% level. It indicates that the weight of PCM^h on PCM^d falls and PCM^d goes down as ER goes up. This result implies that the interactive relationship among domestic firms as well as that between domestic and foreign firms might both be collusive. In such situation, domestic firms should exert the monopoly advantage and decrease the ER as much as they can to raise PCM. In addition, the coefficient of H^{ce} is negative and significant at 10% level, implying that diversifying international markets can improve domestic firms' PCM. Finally, the coefficients of t^h, f^w and ex are statistically insignificant, probably owing to the inaccurate calculation method.

Except for *ER*, each of the estimated coefficients of H^d equation is statistically significant. The regression result of H^d equation shows that there exists a positive relationship between PCM^d and H^d at 1% significant level. It indicates that along with the rising PCM^d, domestic firms will have stronger power to expand market share and, then, H^d will go up. The coefficients of *MR* and H^m are both positive and significant at 1% level, implying that when *MR* and/ or H^m go up, domestic firms will have stronger desire to improve their efficiency via merger, or the stronger monopoly power by foreign firms in the import market of the home country will force inefficient domestic firms out of business. Then, H^d will go up. The coefficient of *MS* is significantly negative at 1% level with an expected sign,[12] indicating that H^d will fall along with the rising number of domestic firms due to the rising domestic market size.

Each of the estimated coefficients of *MR* equation is statistically significant. The regression result of *MR* equation shows that, there exists a negative relationship between PCM^d and *MR* at 1% significant level. When PCM^d rises, domestic firms will have stronger power to prohibit importing and it will lead to a smaller *MR*. It implies that domestic firms in the midstream petrochemical industries might be in a situation of collusion based on the comparative static analysis of the *MR* equation. There exists a positive relationship between H^d and *MR* at 1% significant level. As H^d increases, domestic firms have stronger power to raise price via decreasing their sales in the home country. This will lead to a larger *MR*. It implies that domestic and foreign firms might be in a situation of collusion. The coefficients of *ER* and H^m are both significantly negative at 1% level, implying that domestic firms in the midstream petrochemical industries might be in a situation of collusion. As expected, there exists a negative relationship between *E* and *MR* at 5% significant level. It indicates that the rising capacity utilization will deter foreign firms from entering into domestic market and force the *MR* to go down. The coefficient of *cd* is positive at 1% significant level.

The regression result of *ER* equation shows that the coefficient of PCM^d is significantly negative at 5% level, implying that the interactive relationship among domestic firms as well as that between domestic and foreign firms might be collusive

[12] This result is consistent with Bhattacharya's (2002) finding.

based on the comparative static analysis of the *ER* equation. There exists a positive relationship between H^d and *ER* but insignificant. The coefficients of *MR* and H^m are both significantly negative. The former implies that domestic firms might be in a situation of collusion; the latter implies that the interactive relationship among domestic firms as well as that between domestic and foreign firms might be collusive. Finally, H^d, H^{ce} and *cd* do not influence *ER* significantly.

Finally, it is noteworthy that the regression results of Equations (2-11)-(2-14) consistently indicate that domestic firms in the Taiwan's midstream petrochemical industries seem to be in a situation of collusion during the period of 1989-1997. We can reasonably doubt that the collusive behavior between domestic firms originates from the business relationship between them. For example, A firm could be B firm's subsidiary company or A firm's owner used to be B firm's employee. Then, it will be easier for the two firms to collude in order to increase their profits. This kind of collusion does take place in Taiwan. In addition, some importers are also domestic manufacturers or are invested by domestic manufacturers, partly explaining the collusive behavior between domestic and foreign firms.

2.4 Conclusions

Since the liberalization policy was adopted by the government in 1986, the tariffs and import restrictions of petrochemical products in Taiwan have been continuously reduced. As a result, the changes in domestic firms' *PCM*, domestic concentration, import and export shares show that there might exist simultaneous relationships among them. Therefore, dependent upon industry characteristics of Taiwan's midstream petrochemical products, an open-economy oligopoly model is established and used to derive causalities among domestic firms' *PCM*, domestic concentration, import and export shares. Then, based on the derived results and by referring to the existing literature, a simultaneous-equation system consisting of domestic firms' *PCM*, domestic concentration, import and export shares is built. Thereafter, by utilizing the 1989-1997 disaggregated data of Taiwan's midstream petrochemical industries, the simultaneous-equation system is estimated through 3SLS.

The regression results confirm the causalities derived from the theoretical model, and demonstrate that there do exist simultaneous relationships among domestic firms'

PCM, domestic concentration, import and export shares in Taiwan's midstream petrochemical industries. Specifically, domestic concentration affects domestic firms' *PCM* positively while import share, export share, import concentration and country concentration of exports affect domestic firms' *PCM* negatively. Domestic firms' *PCM*, import share and import concentration affect domestic concentration positively while market size affects domestic concentration negatively. Domestic concentration and cost differential affect import share positively while domestic firms' *PCM*, export share, import concentration and capacity utilization affect import share negatively. Domestic firms' *PCM*, import share and import concentration affect export share negatively. Based on the derived causalities, the above empirical results imply domestic firms seem to be in a situation of collusion during the period of 1989-1997, and the collusive behavior probably has originated from their subsidiary or old employer-employee relationship.

Three possible policy implications emerge directly from our empirical results. First, as the empirical results demonstrated above, import concentration not only reduces domestic firms' profitability but also increases domestic concentration. Its impacts should be carefully taken into account while the government formulates industrial and competitive policies since liberalization policy is inevitable. Second, appropriate policy tools might be adopted by the government to encourage domestic firms to diversify foreign markets since such tools can improve domestic firms' profitability. Third, collusion among domestic firms as well as that between domestic firms and foreign firms should be considered as an important factor in formulating industrial and trade policies because it is highly suspected that collusion does take place. Nevertheless, the conjectural elasticity among domestic firms or that between domestic and foreign firms has not been incorporated as one of the explanatory variables in the empirical studies because of the technical problems in estimating it. These problems have to be overcome if we want to understand the determinants of domestic firms' *PCM*, domestic concentration, and import and export shares more thoroughly. Only in this way can more meaningful policy implications be obtained.

Appendix 2A

The first-order conditions for profit maximization by the *i*th domestic firm are

$$\frac{\partial \pi_i^d}{\partial x_i^h} = P^d + x_i^h \cdot P^{d\prime}\left[1 + \frac{\partial \sum_{j\neq i} x_j^h}{\partial x_i^h} + \frac{\partial X^m}{\partial x_i^h}\right] - C_i^h = 0 \qquad \text{(2A-1)}$$

$$\frac{\partial \pi_i^d}{\partial x_i^e} = ex \cdot P^w + x_i^e \cdot \frac{\partial (ex \cdot P^w)}{\partial X^w}\left[1 + \frac{\partial \sum_{j\neq i} x_j^e}{\partial x_i^e} + \frac{\partial X^f}{\partial x_i^e}\right] - (C_i^h + f + t^w) = 0 \quad \text{(2A-2)}$$

Equation (2A-1) can be rewritten as

$$P^d - C_i^h = -x_i^h \cdot \frac{\partial P^d}{\partial X^d}\left(1 + \frac{\partial \sum_{i\neq j} x_j^h}{\partial x_i^h} \cdot \frac{x_i^h}{X^h - x_i^h} \cdot \frac{X^h - x_i^h}{x_i^h} + \frac{\partial X^m}{\partial x_i^h} \cdot \frac{x_i^h}{X^m} \cdot \frac{X^m}{x_i^h}\right) \qquad \text{(2A-3)}$$

Dividing through by P^d, we then have

$$\frac{P^d - C_i^h}{P^d} = -\frac{x_i^h}{X^d} \cdot \frac{X^d}{P^d} \cdot \frac{\partial P^d}{\partial X^d}\left(1 + \frac{\partial \sum_{i\neq j} x_i^h}{\partial x_i^h} \cdot \frac{x_i^h}{X^h - x_i^h} \cdot \frac{X^h - x_i^h}{x_i^h} + \frac{\partial X^m}{\partial x_i^h} \cdot \frac{x_i^h}{X^m} \cdot \frac{X^m}{x_i^h}\right) \text{(2A-4)}$$

Equation (2A-4) can be rewritten in the form

$$PCM_i^h = \frac{x_i^h}{X^d} \cdot \frac{1}{\varepsilon^d}\left[1 + \alpha \cdot \left(\frac{X^h}{x_i^h} - 1\right) + \beta \cdot \frac{X^m}{x_i^h}\right]$$

$$= \frac{x_i^h}{X^d} \cdot \frac{1-\alpha}{\varepsilon^d} + \frac{\alpha}{\varepsilon^d} \cdot \frac{X^h}{X^d} + \frac{\beta}{\varepsilon^d} \cdot \frac{X^m}{X^d} \qquad \text{(2A-5)}$$

where $PCM_i^h \equiv P^d - C_i^h / P^d$ is the *i*th domestic firm' *PCM* in the home country, $\varepsilon^d \equiv -P^d / X^d \cdot \partial X^d / \partial P^d$ is absolute value of price elasticity of demand in the home country, $\alpha \equiv \left(\partial \sum_{j\neq i} x_j^h / \partial x_i^h\right) \cdot \left(x_i^h / (X^h - x_i^h)\right)$ is conjectural elasticity among domestic firms in the home country, $\beta \equiv \left(\partial X^m / \partial x_i^h\right) \cdot \left(x_i^h / X^m\right)$ is conjectural elasticity between a domestic firm and foreign firms selling in the home country.

Multiplying both sides of Equation (2A-5) by x_i^h / X^h and summing up by individual firm, we obtain

$$PCM^h = \sum_{i=1}^{n}\left(\frac{x_i^h}{X^h}\right)^2 \cdot \frac{X^h}{X^d}\cdot\frac{1-\alpha}{\varepsilon^d} + \frac{\alpha}{\varepsilon^d}\cdot\frac{X^h}{X^d} + \frac{\beta}{\varepsilon^d}\cdot\frac{X^m}{X^d} \qquad \text{(2A-6)}$$

Equation (2A-6) can be presented as

$$PCM^h = \frac{1}{\varepsilon^d}\cdot\left\{(1-MR))\cdot\left[H^d\cdot(1-\alpha)+\alpha\right]+\beta\cdot MR\right\} \qquad \text{(2A-7)}$$

where $MR \equiv X^m/X^d$ is import share, $H^d \equiv \sum_{i=1}^{n}(x_i^h/X^h)^2$ is domestic concentration.

Similarly, Equation (2A-2) can be rewritten as

$$ex\cdot P^w - (C_i^h + f + t^w) = -x_i^e\cdot\left(\frac{\partial ex}{\partial X^w}\cdot P^w + \frac{\partial P^w}{\partial X^w}\cdot ex\right)$$

$$\cdot\left(1+\frac{\partial\sum_{i\neq j}x_j^e}{\partial x_i^e}\cdot\frac{x_i^e}{X^e-x_i^e}\cdot\frac{X^e-x_i^e}{x_i^e}+\frac{\partial X^f}{\partial x_i^e}\cdot\frac{x_i^e}{X^f}\cdot\frac{X^f}{x_i^e}\right) \qquad \text{(2A-8)}$$

Dividing through by $ex\cdot P^w$, we then have

$$\frac{ex\cdot P^w-(C_i^h+f+t^w)}{ex\cdot P^w} = -\frac{x_i^e}{X^w}\cdot\left(\frac{\partial ex}{\partial X^w}\cdot\frac{X^w}{ex}+\frac{\partial P^w}{\partial X^w}\cdot\frac{X^w}{P^w}\right)$$

$$\cdot\left(1+\frac{\partial\sum_{i\neq j}x_j^e}{\partial x_i^e}\cdot\frac{x_i^e}{X^e-x_i^e}\cdot\frac{X^e-x_i^e}{x_i^e}+\frac{\partial X^f}{\partial x_i^e}\cdot\frac{x_i^e}{X^f}\cdot\frac{X^f}{x_i^e}\right) \qquad \text{(2A-9)}$$

Equation (2A-9) can be rewritten in the form

$$PCM_i^w = \frac{x_i^e}{X^w}\cdot\left(\frac{1}{\varepsilon^{ex}}+\frac{1}{\varepsilon^w}\right)\cdot\left[1+\gamma\cdot\left(\frac{X^e}{x_i^e}-1\right)+\delta\cdot\frac{X^f}{x_i^e}\right]$$

$$=\left(\frac{1}{\varepsilon^{ex}}+\frac{1}{\varepsilon^w}\right)\cdot\left[\frac{x_i^e}{X^w}\cdot(1-\gamma)+\frac{X^e}{X^w}\cdot\gamma+\frac{X^f}{X^w}\delta\right] \qquad \text{(2A-10)}$$

where $PCM_i^w \equiv \left[ex \cdot P^w - (C_i^h + f + t^w)\right] / ex \cdot P^w$ is the *i*th domestic firm' *PCM* in the foreign country, $\varepsilon^w \equiv -P^w / X^w \cdot \partial X^w / \partial P^w$ is absolute value of price elasticity of demand in the foreign country, $\varepsilon^{ex} \equiv -ex / X^w \cdot \partial X^w / \partial ex$ is absolute value of exchange rate elasticity of demand in the foreign country, $\gamma \equiv \left(\partial \sum_{j \neq i}^n x_j^e / \partial x_i^e\right) \cdot \left(x_i^e / (X^e - x_i^e)\right)$ is conjectural elasticity among domestic firms in the foreign country, $\delta \equiv \left(\partial X^w / \partial x_i^e\right) \cdot \left(x_i^e / X^w\right)$ is conjectural elasticity between a domestic firm and foreign firms selling in the foreign country.

Multiplying both sides of Equation (2A-10) by x_i^e / X^e and summing up by individual firm, we obtain

$$PCM^w = \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^w}\right) \cdot \left[\sum_{i=1}^n \left(\frac{x_i^e}{X^e}\right)^2 \cdot \frac{X^e}{X^w} \cdot (1-\gamma) + \frac{X^e}{X^w} \cdot \gamma + \frac{X^f}{X^w} \cdot \delta\right]$$

$$= \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^w}\right) \cdot \left\{\left[\sum_{i=1}^n \left(\frac{x_i^e}{X^e}\right)^2 \cdot (1-\gamma) + \gamma\right] \cdot \frac{X^e}{X^w} \cdot \frac{X^w}{X^T} \cdot \frac{X^T}{X^w} + \left(1 - \frac{X^e}{X^w}\right) \cdot \delta\right\}$$

$$= \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^w}\right) \cdot \left\{\left[\sum_{i=1}^n \left(\frac{x_i^e}{X^e}\right)^2 \cdot (1-\gamma) + \gamma\right] \cdot \frac{X^e}{X^T} \cdot \frac{X^T}{X^w} + \left(1 - \frac{X^e}{X^w}\right) \cdot \delta\right\} \quad \text{(2A-11)}$$

Equation (2A-11) can be presented as

$$PCM^w = \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^w}\right) \cdot \left[\sum_{i=1}^n \left(\frac{x_i^e}{X^e}\right)^2 \cdot \frac{X^e}{X^w} \cdot (1-\gamma) + \frac{X^e}{X^w} \cdot \gamma + \frac{X^f}{X^w} \cdot \delta\right]$$

$$= \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^w}\right) \cdot \left\{\left[H^e \cdot (1-\gamma) + \gamma\right] \cdot ER \cdot \frac{X^T}{X^w} + \left(1 - \frac{X^e}{X^w}\right) \cdot \delta\right\}$$

(2A-12)

where $ER \equiv X^e / X^T$ is export share, $H^e \equiv \sum_{i=1}^n (x_i^e / X^e)^2$ is domestic firms' concentration in the foreign country.

Since PCM^d is the weighted average of domestic firms' *PCM*s in two countries, then

$$PCM^{d} = \frac{X^{h}}{X^{T}} \cdot PCM^{h} + \frac{X^{e}}{X^{T}} \cdot PCM^{w} \tag{2A-13}$$

Substituting Equation (2A-7) and Equation (2A-12) into Equation (2A-13), we obtain

$$PCM^{d} = \frac{1}{\varepsilon^{d}} \cdot (1-ER) \cdot \left\{(1-MR) \cdot \left[H^{d} \cdot (1-\alpha) + \alpha\right] + \beta \cdot MR\right\}$$

$$+ \left(\frac{1}{\varepsilon^{ex}} + \frac{1}{\varepsilon^{w}}\right) \cdot ER \cdot \left\{\left[H^{e} \cdot (1-\gamma) + \gamma - \delta\right] \cdot \frac{X^{e}}{X^{w}} + \delta\right\} \tag{2 A-14}$$

For the purpose of simplicity, according to Gollop and Roberts (1979), Spiller and Favaro (1984), Gelfand and Spiller (1987), McGee (1988) as well as Hay and Morris (1991), different firms' conjectural elasticities may be different while the market information acquired by them are asymmetric. Due to the fact that domestic firms usually have better information in the home country than foreign firms do. In addition, most of Taiwan's midstream petrochemical products needs are met by imports, fraction of domestic production export to foreign country. Consequently, the amount of export is very small relative to the whole world's demand. For example, in 1998, the whole world's demand for PVC was around 2.4 million tons, Taiwan's export was around 0.36 million tons; the whole world's demand for LDPE was around 2.6 million tons, Taiwan's export was around 0.26 million tons; the whole world's demand for HDPE was around 2 million tons, Taiwan's export was around 0.04 million tons; the whole world's demand for PA was around 3 million tons, Taiwan's export was around 0.01 million tons. So we can see the ratio between Taiwan's export and the whole world's demand is approximating to zero. Therefore, we assume that $\gamma = 0$, $\delta = 0$ and $X^{e} / X^{w} = 0$, then Equation (2A-14) becomes

$$PCM^{d} = \frac{1}{\varepsilon^{d}} \cdot (1-ER) \cdot \left\{(1-MR) \cdot \left[H^{d} \cdot (1-\alpha) + \alpha\right] + \beta \cdot MR\right\}$$

Appendix 2B

The first-order conditions for profit maximization by the kth foreign firm are

$$\frac{\partial \pi_k^w}{\partial x_k^f} = P^w + x_k^f \cdot \frac{\partial P^w}{\partial X^w}\left(1 + \frac{\partial \sum_{k \neq s} x_s^f}{\partial x_k^f} + \frac{\partial X^e}{\partial x_k^f}\right) - C_k^f = 0 \qquad \text{(2B-1)}$$

and

$$\frac{\partial \pi_k^w}{\partial x_k^m} = \frac{1}{ex}\left\{P^d + x_k^m \cdot \frac{\partial P^d}{\partial X^d}\left[1 + \frac{\partial \sum_{k \neq s} x_s^m}{\partial x_k^m} + \frac{\partial X^h}{\partial x_k^m}\right] - (C_k^w + f^w + t^h) \cdot ex\right\} = 0 \qquad \text{(2B-2)}$$

Equation (2B-2) can be rewritten as:

$$P^d - (C_k^w + f^w + t^h) \cdot ex = -x_k^w \cdot \frac{\partial P^d}{\partial X^d} \cdot \left(1 + \frac{\partial \sum_{k \neq s} x_s^m}{\partial x_k^m} \cdot \frac{x_k^m}{X^m - x_k^m} \cdot \frac{X^m - x_k^m}{x_k^m} + \frac{\partial X^h}{\partial x_k^m} \cdot \frac{x_k^m}{X^h} \cdot \frac{X^h}{x_k^m}\right)$$

Dividing through by P^d, we then have

$$\frac{P^d - (C_k^w + f^w + t^h) \cdot ex}{P^d} = -\frac{x_k^w}{X^d} \cdot \frac{X^d}{P^d} \cdot \frac{\partial P^d}{\partial X^d} \cdot \left(1 + \frac{\partial \sum_{k \neq s} x_s^m}{\partial x_k^m} \cdot \frac{x_k^m}{X^m - x_k^m} \cdot \frac{X^m - x_k^m}{x_k^m} + \frac{\partial X^h}{\partial x_k^m} \cdot \frac{x_k^m}{X^h} \cdot \frac{X^h}{x_k^m}\right) \qquad \text{(2B-3)}$$

(2B-3) can be rewritten in the form

$$PCM_k^m = \frac{1}{\varepsilon^d} \cdot \left[\frac{x_k^m}{X^d} \cdot (1 - \gamma^w) + \gamma^w \cdot \frac{X^m}{X^d} + \delta^w \cdot \frac{X^h}{X^d}\right] \qquad \text{(2B-4)}$$

where $PCM_k^m \equiv \left[(P^d - (C_k^w + f^w + t^h) \cdot ex\right]/P^d$ is the kth foreign firm' PCM in the home country, $\gamma^w \equiv \left(\partial \sum_{k \neq s} x_s^m / \partial x_s^m\right) \cdot \left(x_s^m / (X^m - x_s^m)\right)$ is conjectural elasticity among foreign firms in the home country, $\delta^w \equiv \left(\partial X^h / \partial x_k^m\right) \cdot \left(x_k^m / X^h\right)$ is conjectural elasticity between a foreign firm and domestic firms selling in the home country.

Multiplying both sides of Equation (2B-4) by x_k^m / X^m and summing up by individual firm, we obtain

$$PCM^m = \frac{1}{\varepsilon^d} \cdot \left[\sum_{k=1}^{n^w} \left(\frac{x_k^m}{X^m} \right)^2 \cdot \frac{X^m}{X^d} \cdot (1-\gamma^w) + \frac{X^m}{X^d} \cdot \gamma^w + \frac{X^h}{X^d} \cdot \delta^w \right] \quad \text{(2B-5)}$$

Equation (2B-5) can be presented as

$$PCM^m = \frac{1}{\varepsilon^d} \cdot \left\{ MR \cdot \left[H^m \cdot (1-\gamma^w) + \gamma^w \right] + (1-MR) \cdot \delta^w \right\} \quad \text{(2B-6)}$$

where PCM^m is the foreign firms' *PCM* in the home country, $H^m \equiv \sum_{i=1}^{n^w} (x_k^m / X^m)^2$ is the degree of import concentration of foreign firms in the home country, $\gamma^w \equiv \left(\partial \sum_{k \neq s} x_k^m / \partial x_s^m \right) \cdot \left(x_s^m / (X^m - x_s^m) \right)$ is conjectural elasticity among the foreign firms in the home country, and $\delta^w \equiv \left(\partial X^h / \partial x_k^m \right) \cdot \left(x_k^m / X^h \right)$ is conjectural elasticity between a foreign firm and the domestic firms selling in the home country.

Assuming that $\gamma^w = 0$ and $\delta^w = 0$ (see Appendix 1), it enables us to express Equation (2B-6) as:

$$\frac{1}{\varepsilon^d} = \frac{PCM^m}{MR \cdot H^m} \quad \text{(2B-7)}$$

PCM^d Equation

PCM^m can be further decomposed as:

$$PCM^m = PCM^h + \frac{CD}{P^d} \quad \text{(2B-8)}$$

where $PCM^h \equiv \left[(P^d - \overline{C}^h) / P^d \right]$ stands for the domestic firms' *PCM* in the home country, $\overline{C}^h \equiv \left(\sum_{i=1}^{n} C_i^h \, x_i^h / X^h \right)$ represent the weighted average of the domestic firms' marginal costs, and $CD \equiv \left[\overline{C}^h - ex \cdot (\overline{C}^w + f^w + t^h) \right]$ is the cost differential between domestic and foreign firms, $\overline{C}^w \equiv \left(\sum_{k=1}^{n^w} C_k^w \cdot x_k^m / X^m \right)$ represent the weighted average of the foreign firms' marginal costs. Substituting Equation (2B-8) into Equation (2B-7) and (2A-13) yields

$$PCM^d = (1-ER) \cdot \left(\frac{1}{\varepsilon^d} \cdot MR \cdot H^m - cd \right) \quad \text{(2B-9)}$$

where cd=(CD/P^d). Taking partial differentiation of Equation (2B-9) with respect to cd gives us the impact of cd on PCM^d as:

$$\frac{\partial PCM^d}{\partial cd} = -(1-ER) < 0$$

Substituting $cd = \left[\overline{C}^h - ex\cdot(\overline{C}^w + f^w + t^h)\right] / P^d$ into Equation (2B-9) yields

$$PCM^d = (1-ER)\cdot\left(\frac{1}{\varepsilon^d}\cdot MR\cdot H^m - \frac{\overline{C}^h - ex\cdot(\overline{C}^w + f^w + t^h)}{P^d}\right)$$

Taking partial differentiations of the above equation with respect to t^h , f^w and ex, respectively, gives us the impacts of t^h , f^w and ex on PCM^d as:

$$\frac{\partial PCM^d}{\partial t^h} = \frac{(1-ER)\cdot ex}{P^d} > 0$$

$$\frac{\partial PCM^d}{\partial f^w} = \frac{(1-ER)\cdot ex}{P^d} > 0$$

and

$$\frac{\partial PCM^d}{\partial ex} = \frac{(1-ER)\cdot(\overline{C}^w + f^w + t^h)}{P^d} > 0$$

***MR* Equation**

Referring to Equation (2B-9), MR also can be rewritten as:

$$MR = \frac{\varepsilon^d}{H^m}\cdot\left(\frac{PCM^d}{1-ER} + cd\right)$$

By taking differentiation of the above equation with respect to cd, the impact of cd on MR can be derived as:

$$\frac{\partial MR}{\partial cd} = \frac{\varepsilon^d}{H^m} > 0$$

***ER* Equation**

By reformulating Equation (2B-9), ER can be rewritten as:

$$ER = 1 - \frac{PCM^{d} \cdot \varepsilon^{d}}{MR \cdot H^{m} - cd \cdot \varepsilon^{d}}$$

Then, by taking partial differentiation of the above equation with respect to *cd*, the impact of *cd* on *ER* can be derived as:

$$\frac{\partial ER}{\partial cd} = -\frac{(\varepsilon^{d})^{2} \cdot PCM^{d}}{(H^{m} \cdot MR - \varepsilon^{d} \cdot cd)^{2}} < 0$$

Appendix 2C

Description of the 21 midstream petrochemical products chosen in this paper

Name of product	Abbreviation
ABS resin	ABS
Acrylontrile	AN
Butadiene rubber	BR
Carbon black	CB
Caprolactam	CPL
Dioctyl phthalate	DOP
Ethylene glycol	EG
High-density polyethylene	HDPE
Low-density polyethylene	LDPE
Melamine	ME
Methanol	ML
Phthalic anlydride	PA
Polypropylene	PP
Polystyrene	PS
Terephthalic acid	PTA
Polyvinyl alcohol	PVA
Polyvinyl chloride	PVC
Styrene-butadiene rubber	SBR
Styrene	SM
Vinyl acetate	VAM
Vinyl chloride	VCM