

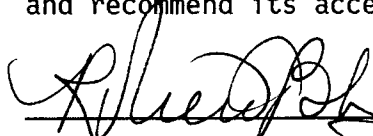
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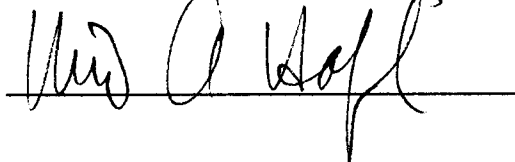
I am submitting herewith a dissertation written by Sung Bok Kim entitled "Simultaneous Export Supply-Export Price Equations under Uncertainty: The Case of the United States." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

Don P. Clark

Don P. Clark, Major Professor

We have read this dissertation
and recommend its acceptance:





Accepted for the Council:

Cowminkel

Vice Provost
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SIMULTANEOUS EXPORT SUPPLY-EXPORT PRICE EQUATIONS
UNDER UNCERTAINTY: THE CASE OF THE UNITED STATES

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Sung Bok Kim

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ABSTRACT

Traditionally the estimation of the import and export functions has been done by specifying either linear or log linear functions of some income and relative price variables then using, usually, ordinary least squares technique. Furthermore, most of earlier studies have concentrated on the demand relationships for imports and exports in one market with one price. This procedure, however, may be a subject to a wide range of criticisms due to its unrealistic assumptions and its restrictive relationships between the export supply and the export price. In this thesis the simultaneous relationships between the export supply behavior and the export price behavior is investigated empirically within a more general theoretical framework introduced by Haynes and Stone. For the study of simultaneous relationships this thesis deals with two markets and two prices in the open economy.

A framework similar to that of Haynes and Stone is used to estimate the structure of U.S. export supply. We depart, however, from Haynes and Stone by adding several exogenous variables and the export price as an endogeneous variable to the model.

The scope of this thesis is to use a simultaneous-equation system to estimate the elasticities of export supply, export price, and domestic price as well as the strategies of the United States economy in the open market.

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CHAPTER I

INTRODUCTION

According to the well-known result of general equilibrium theory, once many goods are produced, it is theoretically ambiguous to show the cross-price elasticities of supply. That is to say, an increase in the price of one good may cause the output of any other good to rise or fall. Generally speaking if all prices change at once, no definite statement can be made about even the direction of output change for any particular good. In fact, no statement of any kind can be made about the output response to price changes. However, it has been said that the correlation between price changes and output changes should be positive.¹ Thus, while the output of any particular good may rise or fall when the prices change, it is true that on average price changes are associated with output changes in the same direction. This result is valid for competitively organized production in any context, but it is ambiguous for the world market where the firms should consider two prices (the export price and the domestic price) and two markets (the world market and the domestic market).

In recent years, trade theorists have worked increasingly to extend the standard theorems of international trade beyond the two-good models in which they have most often been formulated and expositied. These efforts have sometimes been frustrated by the

¹Alan V. Deardorff (August 1980, p. 441).

sorts of ambiguity and indeterminacy to which general equilibrium models are prone, for example, factor abundance and autarky price.

According to the H-O theorem, trading nations export services of abundant factors through exports of goods using relatively more of those abundant factors. In this statement it is very difficult to define "abundant" exactly, since it can refer to either relative endowment level or factor payment levels. In a simple form of the H-O model, the model concerns itself with a world which consists of a group of countries which use identical factors to produce identical goods by the use of identical production functions, these production functions having the property of constant returns to scale. These assumptions of identical production functions and constant returns to scale have been attacked as unrealistic.

The law of comparative advantage states that a comparison of home and foreign relative autarky prices predicts the patterns of trade and gives bounds for the terms of trade. In two dimensions, this law of comparative advantage is rather robust across models. However, it is widely appreciated that the proposition can be vitiated by certain phenomena, such as multiple autarky equilibria or scale economies. In particular, it is almost impossible to get the relative autarky prices.

Another question for the world market is how we can perform the export prices and predict the direction of trade flows with changes in the domestic prices. The result of this paper suggests,

however, that some progress can be made toward generalizing our understanding of the international economy if we look for relationships between the prices (the export price and the domestic price) and the export supply.

Recently Goldstein and Khan (1978), Dunlevy (1980), Haynes and Stone (1983) have reported estimates of supply behavior in international trade. For the estimates Goldstein-Khan assumed that the export price elasticity facing any individual country was infinite. The assumption of infinite price elasticity seems reasonable a priori in the case of the world supply of imports to a single country, but this assumption may be not reasonable when applied to the supply of exports of an individual country. Dunlevy assumed that the world market would be cleared, i.e., market-clearing, by setting the export supply equal to the export demand. This assumption of market-clearing has been attacked as unrealistic. Thus, one of purposes of the present study is to drop those assumptions and show the simultaneous relationships between the prices and the export supply. Without the fixed export price and the market-clearing assumptions, the present study will investigate the export supply equation and the export price equation in a simultaneous system.

Thus, this study will introduce a structural model of an export-supply equation and export-price equation with the quantity of exports supplied, and export price as endogeneous variables. Most studies treat the export price as the exogenous variable where

this variable is assumed to be independent of the dependent variable. Goldstein-Khan (1978) and Haynes-Stone (1983) estimated log-linear supply-quantity equations for exports where the export price was an exogenous variable. When the export price is considered as an exogenous variable for the export supply function, it is assumed that the country pursues quantity strategies, not pricing strategies. In this case, the Goldstein-Khan's model (1978) may be a more appropriate specification. Their supply-quantity specification, however, cannot capture the dynamic supply behavior. Thus, if we assume that supplying firms in an uncertain world pursue quantity strategies as well as pricing strategies based on market performance, then the quantity of exports supplied and the export price should be considered as endogeneous variables.

This study is expected to find that export supply is positively related to both the export price and the real incomes of the country's trading partners. These positive relationships were shown by Goldstein-Khan (1978) and Haynes and Stone (1983). Another expectation in this study is that the domestic price level will have a significant effect on export supply and export price. It is expected that, while the domestic price is positively related to the export price, the domestic price is negatively related to the export supply. This is true when we assume that the country is a big country and that the country forms its own export price at the beginning of the period based

on rational expectation. This implies that the export supply in a big country is elastic to the export price as well as to the domestic price. This study will show how the export price and the domestic price are related to the export supply simultaneously.

In the second chapter, the related literatures will be introduced regarding estimation of export supply functions, and price estimation. The theoretical background of the structural model and the econometric method will be outlined in the next chapter.

In Chapter IV, the Autocorrelation and Identification problems are considered. For the simultaneous-equation model with time series data, these two problems are commonly encountered. To correct for these econometric problems, several estimating methods are introduced in Chapter V, and the results are reported in the following chapter. In Chapter VII, the conclusion and summary are presented.

CHAPTER II

LITERATURE REVIEW

Since Leontief's pioneering work testing the Heckscher-Ohlin strong factor intensity hypothesis, theoretical and empirical studies of trade structure have taken two directions. On the one hand, there have been substantial theoretical efforts to understand the critical assumptions of the basic two-factor static model. They may be characterized as factor proportion models, since they all stress in one way or another factor endowment as fundamental to an explanation of the structure of foreign trade. On the other hand, there is a second direction in which inquiries into trade structure have gone. Studies in this group commonly emphasize technological and other forms of innovation, and have been described as neo-technological explanations. In any direction, however, most empirical studies of international trade flows have concentrated on the formulation and estimation of demand relationships for imports and exports.² The representative studies are those by Houthakker and Magee (1969), Taplin (1973), and Hickman and Lau (1973). Thus, in this

²Stern, Francis, and Schumacher's (1976) bibliographical survey of price elasticities in international trade devotes over 350 pages to demand estimates but 10 pages to supply estimates.

section some studies about the export supply function will be discussed.

II-1. The Single Export Supply Equation

Sung Y. Kwack (1972) assumed that there are two markets for a group of commodities (the domestic market and the world market), and developed a model of U.S. exports to provide a basis for extensive policy studies.³ The model consisted of single export supply equation as

$$EX_j/PX_j = G^j[FY_j, (PXRW_j/PX_j), (GRL_j/PX_j), DMYILST]$$

where

j = 1 (SITC 0-4), 2 (SITC 5-9)

EX_j = value of U.S. exports

FY_j = foreign real income

PX_j = unit value index of U.S. exports

$PXRW_j$ = unit value index of foreign exports

GRL_j = U.S. governments grants and loans to foreign countries

$DMYILST$ = the dummy variable for the longshoremen's strikes.

In this paper the author developed a quarterly model of U.S. exports disaggregated by types of commodity according to the Standard International Trade Classification (SITC). Exports were grouped into nonmanufactured goods (SITC 0-4) and manufactured goods (SITC 5-9). S. Y. Kwack estimated the equation by means of

³Sung Y. Kwack (1972, pp. 302-303).

ordinary least squares with quarterly data from the third quarter of 1960 through the fourth quarter of 1967 for each category of U.S. exports. He found that there existed price competition among the different exporters to a country. However, for his estimates he assumed that U.S. domestic and export prices were predetermined.

For this simple equation with assumption of constant prices, the problem is the serial correlation in the residuals. Furthermore, the equation shows only the quantitative changes at constant prices. If a country adjusts its supply behavior to the price changes, then this single equation may mislead the direction of trade flows.

For the neo-technological explanations of trade structure, Bernard Goodman and Fikret Ceyhun (1976) investigated the determinants of U.S. export performance in manufacturing industries.⁴

This full model may be written as

$$Y = F(X_1, \dots, X_8)$$

where Y = export performance

X_1 = technological innovations

X_2 = industry concentration

X_3 = industry growth

X_4 = scale economies

X_5 = sales promotion

X_6 = labor skills ratio

⁴Bernard Goodman and Fikret Ceyhun (1976, pp. 527-528).

X_7 = unit labor costs

X_8 = capital-labor ratio.

To estimate this equation they used principal components analysis as applied to both cross section and time series (covering the period 1956-1968) of U.S. two-digit and three-digit SIC data on U.S. exports of manufactures. In their studies, however, the problem is multicollinearity. The explanatory variables appear to be highly collinear because the phenomena they attempt to explain require that their occurrence be jointly dependent. Even though the principal components regression method can reduce the degree of multicollinearity, the estimates still have large standard errors for the estimators. As a result, the goodness of fit., i.e., $\bar{R}^2$, had a very small value (.35). This means that much is left unexplained by the regression.

Another single-equation export function was studied by Juergen B. Donges and James Riedel in 1977.⁵ They employed the small country assumptions of a perfectly elastic demand for a country's exports in the world markets. Rather than estimate a simultaneous model of export supply, they chose the approach of including a domestic demand variable in the single-equation export function. This variable was included in order to pick-up recession-boom effects. Accordingly, the model was

$$\ln E_t = a + b \ln R_t + c \ln I_t + d \ln U_t$$

⁵Donges, Juergen B. and James Ridel (1977, pp. 64-65).

where E_t = value of manufactured exports in year
 R_t = exchange rate
 I_t = index of industrial production
 U_t = capacity utilization.

Aside from the problems of simultaneity, inclusion of the variable U (recession-boom) violates the necessary assumption of independence between explanatory variables. Since U , in this case, is defined in terms of I , it becomes difficult to accurately interpret the value or significance of the regression coefficients.

Right after this quantitative single-equation export function, Goldstein and Khan (1978) built a simultaneous export functions under equilibrium and disequilibrium conditions. They showed the relationships between demand for and supply of exports assuming the constant domestic and export prices.

Several attempts have been made to estimate both demand and supply relations simultaneously. In 1951, D. J. Morgan and W. J. Corlett studied the influence in international trade by applying the least squares method. First, they used a simple regression equation to associate the logarithm of the relative quantities of imports of a commodity from two sources with the logarithm of the corresponding relative prices including import duties. Of 47 cases, 36 of the regression coefficients were negative and 11 positive. The correlation coefficients are significant at the 5 percent level for 28 cases only.

Second, they tried to make use of the multiple regression by introducing successively a number of other variables purported to eliminate some systematic influences on relative quantities not explained by relative prices. They first added a logarithm of the income of the importing country to each regression. Next, they introduced a linear trend. Finally, they included both the logarithm of income and the trend factor.

Later, A. R. Bergstorm (1955) attempted to estimate the parameters of the supply and demand equations for New Zealand's exports of dairy products, lamb, and mutton to the United Kingdom. The results showed negative price elasticities of supply for dairy products and mutton in New Zealand, presumably because of the dominant income effects in the supply of these products.

Professor Lawrence R. Klein, one of the supporters of simultaneous methods, suggests that "International trading relationships pitting a small country's demand or supply against an overwhelming world market may also properly be estimated by the ordinary method of least squares."⁶ In such cases, the position of the country is similar to that of the individual producer in the perfect competitive market and thus the classical regression model holds.

On the other hand, when the country supplies a significant percentage of the total world market, any decisions the country makes to increase or reduce its supply will have a noticeable

⁶Lawrence R. Klein (1957).

effect on the total world supply and consequently on world price. It is, however, unfortunately true that none of the work published since the late fifties contributed new developments to the methods available to estimate the supply function, but were only repetitive attempts to estimate demand elasticities. References to recent works were Goldstein-Khan (1978), Dunlevy (1980), and Haynes-Stone (1983). Their models consisted of simultaneous supply, demand, and export price under the condition of market clearing. Other references will be included in the text of this research when and where they are appropriate and the above three models will be introduced in detail.

II-2. Estimation of Export Supply Functions

(A) The Supply and Demand for Exports

Goldstein and Khan (1978) developed and investigated export demand and export supply of a number of nations, using quarterly data on aggregate exports for the period 1955-1970. In this study, two relatively simple models of export demand and supply-equilibrium and disequilibrium-are introduced and estimated simultaneously so as to eliminate any bias arising from the two-way relationship between export quantities and export prices.⁷

⁷Goldstein and Khan's study may differ from other studies in a number of other respects including, inter alia, the degree of country aggregation, the use of annual versus quarterly data, the time periods under study, and the proxy used for export capacity in the export supply equation.

In the equilibrium model, it is assumed that there are no lags in the system. This would mean that the adjustment of export quantities and prices to their respective equilibrium values takes place within a one-quarter period. In the disequilibrium model, the above assumption is relaxed to permit some delay in the adjustment of actual to equilibrium values. Therefore, in the disequilibrium model, excess demand and supply are allowed and this may affect the prices and quantities of exports.

World demand for an individual country's exports and the supply of exports in the equilibrium model are specified as the follows:

$$(2-1) \quad \log X_t^d = a_0 + a_1 \log(PX/PXW)_t + a_2 \log YW_t$$

$$(2-2) \quad \log X_t^s = \beta_0 + \beta_1 \log(PX/P)_t + \beta_2 Y_t^*$$

where

X^d = quantity of exports demanded,

PX = price of exports,

PXW = weighted average of the export prices of the country's trading partners,

YW = weighted average of the real incomes of the country's trading partners,

X^s = quantity of exports supplied,

PX = price of exports,

P = domestic price index,

Y^* = logarithm of an index of domestic capacity

In equation (2-1) where all variables are specified in logarithms, the coefficients, a_1 and a_2 are the relative price and real income elasticities of export demand, respectively. It is usually expected that a_1 will be negative and a_2 positive.⁸ For the equation (2-2), it is expected that both β_1 and β_2 will be positive. This is because equation (2-2) hypothesizes that as the price of exports rise relative to domestic prices, production for export becomes more profitable, hence exporters will supply more. In addition, exports are assumed to be positively related to the size of the country's capacity to produce.

Goldstein and Khan (1978) normalize equation (2-2) for the price of exports, PX_t . This normalized equation with equation (2-1) constitute the equilibrium model, and structural parameters were estimated using a simultaneous estimation procedure.⁹

For the disequilibrium model, the adjustment mechanism outlined by Houthakker and Taylor (1970) is introduced into the export model. Here, exports are assumed to adjust to the difference between demand for exports in period t and the actual flow in the previous period:¹⁰

⁸If the exports of a country were simply the difference between world production and consumption of importables, then a_2 would be negative if increases in world income were associated with faster growth in production than in consumption of importables. See also Magee (1975) and Khan and Ross (1975).

⁹It is assumed that $X_t^d = X_t^s = X_t$. Goldstein and Khan found the reduced forms of the equations in order to obtain the effect of solely exogenous variables on the quantity and price of exports. See Appendix.

¹⁰A dynamic model expressed in continuous time is:

$$\frac{d}{dt} \log X(t) = \gamma [\log X^d(t) - \log X(t)], \gamma > 0$$

$$(2-3) \Delta \log X_t = \gamma [\log X_t^d - \log X_{t-1}]$$

where γ is the coefficient of adjustment, and Δ is a first-difference operator,

$$\Delta \log X_t = \log X_t - \log X_{t-1}$$

This adjustment function assumes the price of exports is determined in the exporting country. An alternative function could be specified where the change in export quantity is related to excess supply, so that excess demand would determine the change in price of exports.¹¹

Also, since the quantity of exports is specified as adjusting to excess demand, the price of exports adjusts to conditions of excess supply. That is:

$$(2-4) \Delta \log PX_t = \lambda [\log X_t - \log X_t^s], \lambda > 0$$

where λ is the coefficient of adjustment. In this framework, there is a negative relationship between excess supply and the price of exports.

Goldstein and Khan (1978) substituted equation (2-1) into (2-3), obtaining an estimated equation for exports, and equation (2-2) into (2-4), solving for $\log PX_t$. Then they found reduced-form equations to show the signs of reduced-form coefficients. Their findings are:

¹¹According to Goldstein and Khan (1978), experimentation with this alternative model yielded markedly inferior results. This suggests that the supply side of the export market may have a more monopolistic market structure than the demand side.

	$\log PXW_t$	$\log YW_t$	Y_t^*	$\log P_t$	$\log PX_{t-1}$	$\log X_{t-1}$
$\log X_t$	+	+	+	-	-	+
$\log PX_t$	+	+	-	+	+	+

Note: Reduced-form coefficients of the disequilibrium model taken from Goldstein and Khan (1978).

A linear Full Information Maximum Likelihood estimation technique was used to estimate the equilibrium model. This estimator requires a particular attention to specification of the model.¹² For the disequilibrium model, however, due to the nonlinear restrictions on parameters, a nonlinear Full Information Maximum Likelihood estimator was used. In the equilibrium model, the expected positive sign of price elasticity in export demand equation was found, and it was significantly different from zero at the usual 5 percent level in the eight countries -- Belgium, France, Germany, Italy, Japan, Netherland, United Kingdom, and the United States. In these countries, except Germany and Japan, the estimated price elasticity was greater than unity. This indicates that exports largely responded to changes in relative prices. However, these price elasticity results differ from results

¹²It should be pointed out that this estimator can be highly sensitive to small changes in specification and/or data, and utilizes all restrictions on the system to estimate the structural coefficients simultaneously by maximizing the likelihood function of the model.

obtained by Houthakker and Magee (1969) for the same group of countries.¹³

Also Hickman and Lau (1973) computed the export price elasticities for these countries and found these price elasticities to be considerably smaller than elasticities estimated by Goldstein and Khan (1978).¹⁴ This implies the results of Goldstein and Khan (1978) indicate an important role for relative prices in determining world demand for these countries' exports.

Estimated income elasticities have the positive signs, as expected, and are significantly different from zero at the 1 percent level in the equations for all eight countries. In contrast to the price elasticities of demand, estimated income elasticities is very similar to the results obtained by Houthakker and Magee (1969) for this group of countries.¹⁵

In the disequilibrium model, as expected, the short-run price elasticities are smaller than the equilibrium price elasticities. The same result is true of the short-run versus the equilibrium income elasticities. The coefficient on lagged exports is significantly different from zero, which implies a degree of dynamic

¹³Houthakker and Magee (1969) found a significantly negative relationship between exports and relative export prices only in the cases of France and the United States.

¹⁴See Goldstein and Khan (1978, p. 282) Table 5.

¹⁵The inter-country pattern of income elasticities observed by Houthakker and Magee, where exports of the United States and the United Kingdom have a relatively low, and the exports of Japan a relatively high, income elasticity is also evident in the results of Goldstein and Khan (1978).

adjustment. As expected, the coefficient of exports has a positive sign in all eight countries and is significantly different from zero. Domestic prices are positively and significantly related to export prices in all countries, except Germany and Japan, while productive capacity has a significantly negative relationship in all countries. The coefficient of lagged export prices is quite large and highly significant in all equations. This indicates that changes in export prices are largely dependent on this variable.

As a matter of fact, it is not clear which version of the model, equilibrium or disequilibrium, is superior in this study. However, the disequilibrium model has the distinct advantage that it permits time lags to occur in the adjustment of actual to equilibrium values. On the other hand, the supply price elasticities obtained from the equilibrium model seem more credible than those from the disequilibrium model. In short, the question of whether an equilibrium or disequilibrium version of the export model is more appropriate must be remained agnostic. For either of those two models, the export price was considered as an exogenous variable and the country was assumed to pursue quantity strategies only. Furthermore, the autocorrelation test is not available for the nonlinear model.

(B) A Simultaneous Model of Export Performance

For an export supply phenomenon, Dunlevy (1980) employed a simultaneous equations approach, showing the role of capacity pressure on exports, and the price and income demand elasticities.

In his study, the model consisted of simultaneous supply, demand, and market clearing relationships.

The model is:

$$(2-5) \quad QD = f (PX, PW, XW, \text{dummy variable, random variables, random errors}),$$

$$(2-6) \quad QS = g (PX, PH, CAPUTIL, CAPACITY, \text{dummy variables, random errors}),$$

$$(2-7) \quad QD = QS = QX,$$

where

QD = the demand for exports represented by the physical volume of exports,

PX = the relevant export unit value,

PW = the alternative price faced by a prospective buyer of exports and measured by a unit value of world trade,

XW = a measure of effective world purchasing power,

QS = the quantity supplied,

PH = the domestic wholesale price of goods; it is the alternative price at which the exporter may sell his product,

$CAPUTIL$ = measures of domestic capacity pressure,

$CAPACITY$ = the level of domestic industrial pressure.

In this model, since domestic conditions affect the seller's abilities and desires to export, the impact of capacity pressure

is viewed as a supply phenomenon.¹⁶ Export quantity and export unit value are considered endogenous and equation (2-7) is the equilibrium values for the model. This model is estimated in log-linear form both for total exports from the United States and for total exports from the United Kingdom, using quarterly data over the 1957 through 1975 period. The estimator used is the Sargan two-stage procedure (S2SLS) described by Fair (1970). Dunlevy found that for both countries, demand relationships are estimated to be inelastic but statistically significant, in both price and income. These results counter those of Goldstein and Khan (1978).¹⁷ Houthakker and Magee (1969) report export demand elasticities for the United Kingdom similar to the estimates found by Dunlevy. The differences in the United States may be attributable to the use of world trade as the measure of income for Dunlevy, whereas Houthakker and Magee (1969) and Goldstein and Khan (1978) use weighted averages of the incomes of the nation's trading partners as their measures.

According to the results of Dunlevy (1980), supply-price elasticities are estimated as 1.09 for the United States and 1.45 for the United Kingdom. The British estimate is similar to the 1.4 reported by Goldstein and Khan (1978). The United States

¹⁶Therefore, this intent is similar to that of Ball, Eaton, and Steuer (1966).

¹⁷See Goldstein and Khan (1978, p. 282).

supply-price elasticity estimate, however, is considerably below their 6.6.¹⁸ Also, it is found that the level of capacity utilization appears to have been positively related to exports for both countries, and its coefficient is statistically significant for the United States. These results contrast dramatically with those of the earlier capacity pressure studies and the differences are not the result of using simultaneous equations techniques. Rather, these differences are due to the use of domestic capacity rather than domestic price as an explanatory variable.

Finally, Dunlevy (1980) was unable to find a lagged response for either U.K. or U.S. exports, and he indicated that two-stage and single equation methods could be misleading because of their use of capacity rather than the trend value of production as an explanatory variable.

(C) Supply-Quantity Estimates

Haynes and Stone introduce the following static versions of traditional log-linear supply-quantity equations for exports and imports:

$$(2-8) \quad QX_t = \alpha_0 + \alpha_1 PX_t + \alpha_2 WP_t + \alpha_3 TY_t + \alpha_4 CY_t + U_t$$

$$(2-9) \quad QM_t = \beta_0 + \beta_1 PM_t + \beta_2 WP_t + \beta_3 TY_t + \beta_4 CY_t + E_t$$

¹⁸Dunlevy (1980) normalized the supply regressions on export quantity since he viewed the capacity pressure effect as directly affecting quantity. Goldstein and Khan (1978) normalized their supply equation on export price and then estimate the supply-demand system using the full information maximum likelihood approach.

where

QX_t = the quantity of exports,

QM_t = the quantity of imports,

PX_t = the unit-value indices of exports,

PM_t = the unit-value indices of imports,

WP_t = the wholesale price index of the supply country,

TY_t = capacity (trend income) for the supply country,

CY_t = capacity utilization (deviation from trend income) for the supply country,

α_0 and β_0 are intercepts, and U_t and E_t are error terms.

In these equations, all variables are in logarithmic form and it is expected that the coefficients α_1 , α_3 , β_1 , and β_3 are positive, and α_2 , α_4 , β_2 , and β_4 are negative. In this specification, it is assumed that firms are price-takers.

Haynes and Stone (1983) applied these equations in order to estimate the static versions for the United Kingdom and the United States based on quarterly data from 1947 to 1979. An arbitrary lag length of four quarters was initially chosen for own-prices, and shorter lags for the control variables.¹⁹ Results indicate coefficients on TY are positive and generally significant, as expected. Coefficients on CY are positive and generally significant. This contradicts the traditional supply pressure hypothesis, yet is consistent with Dunlevy (1980). Dunlevy found the level of capacity utilization to be positively related to exports

¹⁹This permitted test of the significance of the lagged price variables, reducing the potential problems of multicollinearity.

for both countries, and its coefficient is statistically significant for the United States.²⁰

Haynes and Stone (1983) also found that, although coefficients on the contemporaneous WP are significant with the negative sign for exports, none of the remaining WP coefficients are significant with the negative sign. The coefficient on contemporaneous own-prices are positive and significant in the U.S. import equation and in both export equations, but insignificant in the U.S. import equation. Most of the coefficients on lagged own-prices are negative rather than positive for both exports and imports, and none are significant with the correct sign. In other words, although coefficients on the contemporaneous own-price variables in three of the equations support a supply response, the absence of significantly lagged supply responses for own-prices or WPs seems implausible with quarterly data. Here, the problem is that if a dynamic supply-quantity equation is more appropriate, theory suggests that coefficients on present and past prices should be positive for the typical case of increasing- or constant-cost industries and that coefficients on present and past WP should be negative.

II-3. Estimation of Export Price Equation

Most economists would probably agree that uncertainty of some kind should be taken into account in analyzing price and export

²⁰This suggests, contrary to the customary version of the capacity pressure hypothesis, that a high level of capacity utilization does not, of itself, choke off exports.

policies. Under the condition of uncertainty, firms will adjust prices to the market conditions for profit maximization. In this case firms are price-setters at least in short run. It, then, can be said that firms may be price-takers to maintain their market shares in a market-sharing framework, but firms are not price-takers in the short run due to the uncertainty regarding market-clearing prices. The firms will consider the internal structure of their price formation to maximize their profits.

This section will show how firms ignore the pressure of price uncertainty in setting output and will introduce several price formations.

In the riskless theory²¹ it is assumed that the demand for the product is a function of the price set by the export country and that the export country knows the function relating the two variables. The export country knows its demand function, the difference being that the function now contains a random term over which the export country has no control. This can be written

$$M = M(p, u)^{22}$$

²¹In this section the terms "risk" and "uncertainty" are used interchangeably.

²²In addition to this, the further specialization can be made that u affects additively, i.e.,

$$M = M(p) + u.$$

This assumption means that u shifts the demand function parallel to itself in the quantity direction, and that the probability of M differing from $M(p)$ by any amount is independent of p . This is strong assumption but it simplifies the result.

where M is the quantity demanded, p is the price set and u is the random term. Thus, for each pair of values of p and u the export country knows the resulting M , but it is unable to predict M in advance because it does not know which of its possible values u will take. However, it knows the distribution function $f(u)$ which gives it the probability that u will take any value. Hence the export country knows, for each p , the probability that M will take any value. Knowing $f(u)$ the export country can also calculate the frequency function

$$F(a) = \int_{-\infty}^a f(u) du$$

giving the probability that u will not exceed any number a . To say that the export country has no control over u means that u is distributed independently of p . With this restriction it can be assumed that the mean value of u is zero, i.e.,

$$E(u) = \int_{-\infty}^{\infty} u f(u) du = 0$$

since if $E(u) = k \neq 0$, then the constant k can be induced in the function $M(p)$.

$M(p)$ is now referred to as the riskless demand function. It is the function which the export country would be concerned with if there were no uncertainty, i.e., if u were identically zero.

However, if the export country could postpone its decisions until it observed the value of u in each period, then the export country could, on the average, do better. For an example, suppose the export country must commit itself only to production at the

beginning of the period, and can wait till it observes the actual demand of the period before setting price. Further suppose that the random terms shift the demand curve parallel to itself in the price direction. Then, it can be written

$$p = p(M) + \varepsilon$$

where ε is the random term, independent of M . Again assume that the random term has a zero mean. In this formulation, the export country can ignore the pressure of uncertainty in setting output since expected profit depends only on the expected price of each M . The equilibrium conditions for the export country are now the usual ones where the riskless marginal cost of production is equal to the marginal revenue. This gives the export country an optimal output and an expected price and revenue. Thus, in this case uncertainty does not affect the export country's decisions. However, the export country under the uncertainty often adjusts itself to both price changes and changes in quantity. In other words, it is not true that the price is the only one which maximizes expected profit. The export country has its own price formation which is related to quantity changes and changes in internal supply structure. Thus, the following sections will analyze how the price can be formulated.

(A) Supply-Price Estimates

As a traditional view of dynamic supply behavior, it can be assumed that firms are price-setters, at least in the short run.

Especially under the uncertainty of the real world, even a competitive firm may not be a price-taker in the short run.²³ It may wait to observe the buyers' reactions to that price. The empirical study of Haynes and Stone (1983) supports a supply-price specification for exports based on quarterly data.

The static versions of supply-price equations for exports and imports are:

$$(2-10) \quad PX_t = \gamma_0 + \gamma_1 QX_t + \gamma_2 WP_t + \gamma_3 TY_t + \gamma_4 CY_t + \zeta_t$$

$$(2-11) \quad PM_t = \delta_0 + \delta_1 QM_t + \delta_2 WP_t + \delta_3 TY_t + \delta_4 CY_t + \theta_t$$

where the definitions of the variations of the variables are the same in the supply-quantity equations (2-8) and (2-9). Here, it is expected that all coefficients except γ_3 and δ_3 are positive.

It should be noted that, if a supply-price equation is more appropriate, two complementary possibilities exist. First, it may be difficult for the firms to adjust prices to market conditions in a single period. In this case coefficients on both present and past quantities should be positive. Second, in the long run, the pressure of demand on price may diminish, since initial increases in price, due to increases in demand, may be gradually offset by supply adjustments with decreases in price. This implies that coefficients on quantities should first be positive, and then

²³Early theoretical support for a price-adjustment formulation in world of imperfect information is developed for non-competitive firms by Clower (1959).

negative, i.e., reverse sign.²⁴ Haynes and Stone (1983) provided Fair Instrumental-variable estimates of these two equations for the United Kingdom and the United States. They found that coefficients on TY were negative as expected, but three of the coefficients on CY were negative, which contradicted the supply-pressure hypothesis. It was found that coefficients on WP were generally positive and highly significant, and indicated a distributed-lag response. This result was generally consistent with that based on the quantity estimates. In other words, according to the results of Haynes and Stone (1983), it can be said that for the empirical estimates of the supply of exports and imports for both the United Kingdom and the United States, the more appropriate specification of aggregate supply behavior is a supply-price not a supply-quantity formulation. Theoretically speaking, a supply-price specification is plausible when the assumption of perfect certainty for firms is relaxed to incorporate learning processes, delayed adjustment, and price-quoting behavior.²⁵

²⁴In the equilibrium model of Goldstein and Khan (1978), it is indicated that the choice between quantity and price as the dependent variable is arbitrary because they use full-information maximum-likelihood estimation methods. However, in their disequilibrium model, a supply-price equation based on a Koyck lag is used because inferior results were obtained from a supply-quantity equation.

²⁵See Haynes and Stone (1983, p. 631).

(B) Error-Learning Hypothesis

One of the theories about expectations was the error-learning hypothesis.²⁶ According to the error-learning hypothesis, expectations about an economic variable are revised in light of the most recently observed error. Thus, if X_t is the actual value of some economic variable (the general price level, for an example) in time-period t , and X^e is the value of X in period t which was expected in the previous period, $t-1$, then the error-learning hypothesis says that the change in expected value from $t-1$ to t , $(X_t^e - X_{t-1}^e)$, depends on the error made in previous period, $(X_{t-1} - X_{t-1}^e)$. In linear form, the hypothesis states:

$$(2-12) \quad X_t^e - X_{t-1}^e = a (X_{t-1} - X_{t-1}^e), \quad 0 \leq a \leq 1 \text{ or}$$

$$(2-13) \quad X_t^e = aX_{t-1} + (1-a)X_{t-1}^e$$

As the second equation makes clear, the hypothesis implies that the current expected level of a variable is related positively to both the previous level and to the previous expected level, and that the sum of the response to these two explanatory variables is equal to 1.0.

The error-learning hypothesis has been found to have failed to explain many major movements in expectations series, especially

²⁶The original statement of this hypothesis appears in Philip Cagan (1956, p. 37).

price expectations.²⁷ As a result, other variables have been added to the explanation of expectations, on the hypothesis that one or more variables serve as indicators of the future trend of inflation or of some "normal" rate of inflation to which the actual rate is expected to return. For an example, those variables are the recent change in actual inflation, the capacity utilization in primary producing industries, and the recent rate of change of the money supply.

(C) Rational Expectations Hypothesis

A somewhat different hypothesis about expectations which has attracted widespread attention in recent years is the so called "rational expectations" hypothesis. Advocates of this hypothesis do not necessarily deny that mechanisms such as error-learning and attention to various indicators of inflation helps business reach a view about future inflation. They maintain these indicators are used in a flexible way so that the expected value of a variable is an unbiased and efficient forecast of the actual value. The error-learning hypothesis described above, at least with a constant coefficient of adaptation (a in equation (1)), would give rise to persistent errors in expectations in one direction during periods in which the actual inflation rate was accelerating, or was

²⁷See E. J. Kane and B. G. Malkiel (Jan. 1976, p. 1-15). Using cross-section data from a panel of institutional investors, Kane and Malkiel found that, while the error-learning mechanism explained a proportion of the variance in expected price changes, there was evidence that other variables were also important.

decelerating. The rational expectations hypothesis denies that such systematic errors take place.

The rational expectations hypothesis has important implications for the behavior of aggregate economic variables. Many theories and models of short-run aggregate economic developments rely on hypotheses about price expectations which imply that inflation will tend to be underestimated following a major expansionary policy change, and overestimated following a major restrictive policy change. By denying the presence of such systematic error, the rational expectations hypothesis implies that widely held views greatly exaggerate the magnitude and duration of the effect of monetary and fiscal policies on output and employment.²⁸ A widely used test of the rational expectations hypothesis makes use of the following simple relationship between actual (p_t) and expected (p^e) price changes:

$$(2-14) \quad \dot{p}_t = a + b\dot{p}_t^e + U_t,$$

where U_t is a random error with zero mean, etc. According to the rational expectations hypothesis, the coefficient of expected price change, b , will not differ significantly from 1.0, and the constant term, a , will not differ significantly from zero. This is a test for the unbiasedness of price expectations.

A further implication of the rational expectations hypothesis is that after taking account of the influence of expected price

²⁸A recent summary of the macroeconomic significance of the rational expectations model is Bennett McCallum (1980).

change, actual price change should not be systematically related to any variable widely known to those forming expectations. The reason for this implication is that if there is a systematic relationship to some other variable over and above the relationship to some expected price change, then expected price change is not as efficient a predictor of actual price change as it could be. Persistent high or low levels of the additional variable will lead to systematic errors in expectations.

In the following chapter, the export-price equation will be formulated with the implication of the rational expectation, based on Haynes and Stone's supply-price equation.

CHAPTER III

MODEL

The objective of this chapter is to build a model of the behavior of an export-supply country in an open market in which trader's plans may not be realized. The emphasis of this section is motivated by desire to introduce explicit price-makers into the analysis of open markets.

The study by Bradfield and Zabel (1979) considers price formation on an organized security exchange using the "Specialist System" to facilitate trading. The essential rule is that the specialist is free to call prices subject to an obligation of absorbing excess demand (or excess supply) by trading for his own account. In that study it is assumed that buy and sell orders are generated by stationary random process and that the specialist chooses prices sequentially to maximize expected profit. In this framework, the specialist will derive a price with his "own rule."

As in the securities exchange, the price-maker chooses prices but is only obligated to satisfy market demand to the degree permitted by his production of the market commodity. In the experiment, one objective is to examine sensitivity of a country's behavior to different sets of market information. However, the information may vary across countries, and each country's behavior may become irregular if the qualitative form of

each country's behavior is sensitive to information. Consequently, each country has its own production plan.

Thus, it is now assumed that the competitive exporting country operates under conditions of uncertainty, and its export decision is made based on price formation which can be derived from the total output function. In this assumption price and export are all endogenous. With these endogeneous variables Haynes and Stone (1983) showed simultaneous effects between the export supply and the export demand in the market clearing model and then between the export price and the import price in the same market clearing model. Any earlier study did not test two-way relationships between the export supply and the export price. To test this two-way relationship, in this section, a simultaneous-equation system will be built.

The static version of Haynes and Stone's equation is ²⁹

$$(3-1) \log X_t = a_0 + a_1 \log PX_t + a_2 \log P_t + a_3 \log TY_t + a_4 \log CY_t$$

where X_t = the quantity of exports

PX_t = the quantity of imports

P_t = the wholesale price of the supply country

TY_t = the capacity (trend income) for the supply country

CY_t = the capacity utilization (deviation from trend income) for the supply country.

In the above equation (3-1), the assumption of market-clearing where the quantity of exports is equal to the quantity of imports

²⁹See Haynes and Stone (1983), p. 626.

does not cause any econometric problem. However, without the market-clearing assumption, if the equation (3-1) is used with the export-price equation which includes all the same exogenous variables, then the econometric problem will be encountered. In other words, endogenous variables cannot be identified by the exogenous variables and thus the equations will be unidentified. Therefore, one of exogenous variables needs to be dropped and then another exogenous variable needs to be added. For equation (3-1), dropping one of TY or CY will reduce the multicollinearity problem between those two variables. That is, if the movement of the changes in capacity utilization is parallel to the movement of the capacity changes, then it will become very difficult to precisely identify the separate effects of the variables involved. In fact, since the regression coefficients are interpreted as reflecting the effects of changes in their corresponding variables, all other things held constant, our ability to interpret the coefficients declines the more persistent and severe the collinearity. Thus, to avoid this multicollinearity problem without changing the characteristics of the model, we should find a variable which is independent of capacity utilization, but related to the export supply. For this variable the foreign private consumption may be a good alternative.³⁰

³⁰Goldstein and Khan (1978) used weighted average of the real incomes of the country's trading partners. In the market clearing model it can be possible for the amount of income to be equal to the amount of consumption. However, without the market clearing assumption it is not always true that the amount of income is equal to the amount of consumption. Also for the model of this study the use of trend income will cause an unidentified problem.

In order to explain changes in output, our task is to identify the factors for production. These factors include both tangible and intangible inputs. For the tangible inputs, three types of inputs--labor, physical capital, and intermediate inputs--are usually examined. For the intangible inputs, such factors as technology and economies of scale are discussed. Assuming the Hicks neutrality of technology, i.e., a proportional rate of inputs and the constant economies scale, it can be said that a change in output is positively related to the change in amount of tangible inputs used. Further, if it is assumed that the supply of tangible inputs in a country is constant, then the amount of imported tangible inputs will have a direct relationship with the output level. Thus, assuming that there is no labor movement between two countries, the imported resources of physical capital and intermediate goods for the manufactures will explain the change in output as well as the other exogenous variables. The econometric problems were eliminated by dropping one variable TY and by adding two variables C^* and M . Then, with the assumption of Hicks neutrality the export supply equation can be stated as

$$(3-2) \log X_t = a_0 + a_1 \log PX_t + a_2 \log P_t + a_3 \log M_t + a_4 \log CY_t + a_5 \log C_t^*$$

where M_t = the quantity of imported resources

C_t^* = the private consumption in the country's trading partners.

Assuming that the export supply is related to total output, and the export price is obligated to the export supply, the export price can be induced from the total output function.

Then, under the condition of uncertainty, the price could be subject to the total output at the beginning of period.

For a function of total output, consider an open economy that produces its output, Y , and one variable factor, L (labor), and one fixed factor, K (capital), according to

$$(1) \quad Y = f(L, K), \quad f_1 > 0,$$

where the subscript indicates the first-order differential. The output, Y , is both consumed domestically and exported. Producers determine their demand for labor according to the marginal productivity condition which is

$$(2) \quad W = PF_L,$$

where P denotes the price of domestic output, and W is the nominal wage. This equation implies a demand for labor. Assume that the producers maximize profits, which is an increasing function of sales of the domestic goods (denoted by S), and of exports of goods (denoted by S^*), and a decreasing function of the amount of labor employed, L_e . Their profits, expressed in terms of the domestic good, are

$$(3) \quad \Pi = \pi(S, S^*, L_e).$$

The equation (3) can be written in money value as, where PX is the price of exports in domestic currency terms,

$$(3') \quad S + \frac{PX}{P} S^* - \frac{WL_e}{P}$$

In other words the equation (3') implies the domestic price level and the export price level.

$$(4) \quad L_s = h\left(\frac{W}{P}, \frac{PX}{P}\right).$$

On the presumption that the labor supply is a function of $\frac{W}{P}$, and PX/P , it is postulated that labor supply is an increasing function of $\frac{W}{P}$. Moreover, labor supply is specified as an increasing function of the export/domestic price ratio. Notice that an increase in PX/P , holding the other terms constant, implies an increase in L employed. Assuming equilibrium in the labor market, and substituting the resulting equilibrium labor employment into equation (1) yields

$$(5) \quad Y = f\left(\frac{W}{P}, \bar{K}\right).$$

This is the economy's output supply with respect to the labor supply and has the property that output supply is an increasing function of the labor supply.

Assume that the producers maximize total output, which is an increasing function of domestic consumption, denoted by C , and of the amount of exports, denoted by X . Including the imported resources, denoted by M , the production function will be

$$(6) \quad Y = g(C, X, M), \quad g_1 > 0.$$

In other words equation (6) is a quantitative equation but indirectly affected by price level.

The price level for all final goods is given by

$$(7) \quad P = P_d^{1-\theta} (PM \cdot E)^\theta, \quad 0 < \theta < 1,$$

where

P_d = the price of other goods

E = the exchange rate

θ = the direct import content of final goods

PM = the price of imported resources.

Taking logarithms of (7) and differentiating, we obtain

$$(8) \quad \dot{P} = (1-\theta) \dot{P}_d + \theta (\dot{p}_m + \dot{e})$$

where $\dot{x} = (d/dt)(\ln X) = (1/X)(dX/dt)$. Equation (8) expresses the overall rate of inflation in terms of its domestic and imported components. We obtain PX from the following wage-price system;

$$(9) \quad \dot{w} = f(x) + \dot{p}^e, \quad f' > 0$$

$$(10) \quad \dot{p}_x = g(Y) + b_1 (\dot{p}_m + \dot{e})^e + (1-b_1)(c_1 \dot{w} + (1-c_1)(\dot{p}_m + \dot{e})^e),$$

$$g' > 0, \quad 0 < b_1 < 1, \quad 0 < c_1 < 1$$

where W is the wage rate, $w = \ln W$ and the superscript e denotes expectations. Equation (9) is an expectations augmented Phillips Curve with the level of export supply as a proxy for the demand for labor (as implied by Okun's Law). In equation (10), Y is the production function in the market, b_1 reflects the competitive effects of the prices of imported resources on domestic price decisions, and $(1 - b_1)$ reflects the cost element in which c_1 is the rate of wages and $(1 - c_1)$ is the weight of imported resources.

Taking expectations of (8) and combining with (9) and (10) we obtain

$$\dot{p}_x = h(x) + \beta_2 (\dot{p}_m + \dot{e})^e + (1-\beta_2) \dot{P}_d^e, \quad h' > 0,$$

where $h(x) = Y + (1-b_1)c_1 f(y)$ and $\beta_2 = 1 - (1-b_1)(1-\theta)c_1$.

Thus, assuming constant exchange rate it can be said that the export price function is

$$PX = G (X, P_d, PM, C)$$

Therefore the export equation and the export price equation can be written as

$$X = H (PX, P_d, M, CY, C^*),$$

$$PX = G (X, P_d, PM, C).$$

X = the quantity of exports

where PX = the export price

P_d = the domestic price of the supply country

M = the quantity of imported resources

CY = the capacity utilization of the supply country

PM = the price of imported resources

C = the domestic consumption of the supply country

C^* = the consumption of the country's trading partners

Taking logarithms of these two equations we obtain

$$(3-2) \log X_t = a_0 + a_1 \log PX_t + a_2 \log P_{dt} + a_3 \log M_t + a_4 \log CY_t + a_5 \log C_t^*$$

$$(3-3) \log PX_t = b_0 + b_1 \log X_t + b_2 \log p_{dt} + b_3 \log PM_t + b_4 \log C_t.$$

In this model the variables, X , and PX , are endogeneous variables and the coefficients a_1 , a_3 , a_4 , a_5 , b_1 , b_2 , b_3 , and b_4 are expected to be positive and a_2 is expected to be negative.

The above model includes a supply-quantity export equation and a price equation. In this system of equations, each endogenous variable absorbs simultaneous changes of other variables.

Here, simultaneous adjustments of price and quantity can be shown. Haynes and Stone (1983) noted that for both the United Kingdom and the United States, the supply-price formulation was more plausible. However, they treated the export supply as an exogenous variable in the price equation. In this case, it must be assumed that the supplying firms in an uncertain world pursue pricing strategies based on past market performance (as in Zabel (1981)). This is not, however, a necessary assumption if a simultaneous model is used to treat the export quantity and the export price as endogeneous variables. Even the supply-quantity estimates of Haynes and Stone (1983) were not so different from the supply-price estimates. The only difference was the estimates of coefficients on CY.

Furthermore, the above model indicates that the export price is partly dependent on the change in total production. This may show the directions of international trade flows being due to change in domestic price which can be absorbed into the export price. Also, since the price is rationally expected on the basis of total output, the change in export supply can be indirectly shown in terms of change in total output.

Furthermore, the behavior of export supply can be exercised showing the simultaneous relationships between the endogenous and the exogenous variables. Comparing the sizes and signs of all the coefficients, the effectiveness of each variable on the other variable can be discussed.

CHAPTER IV

ECONOMETRIC PROBLEMS

IV-1. Introduction

Dunlevy used 2SLS for structural estimation. A problem sometimes arises in the application of 2SLS to equations in medium-size or large-size econometric models. The difficulty is that the number of predetermined variables in such a model may become large in relation to the number of observation points.³¹

The 2SLS estimator is essentially a limited-information estimator where in the estimation of any structural equation complete information on all other structural equations in the model is not taken into account. In principle, information on the complete structure, if correct, will yield estimators with greater asymptotic efficiency than that attainable by limited-information methods. There are two main full-information methods, namely, three-stage least squares (3SLS) and full-information maximum likelihood (FIML).

For structural estimation, Goldstein and Khan (1978) used a linear Full Information Maximum Likelihood (FIML) estimator for equilibrium model and a nonlinear FIML for disequilibrium model in which there were nonlinear restrictions on parameters. FIML involves the usual application of the maximum likelihood principle

³¹Johnston, J., (1984, pp. 477-80).

to all stochastic equations of the system simultaneously. The maximum likelihood estimates are consistent, asymptotically efficient, and their asymptotic distribution is normal. However, maximum likelihood estimation frequently requires the use of non-linear optimization techniques and is very sensitive to the specification of model.³² It becomes computationally more expensive than 3SLS. FIML estimators are equivalent to the so-called "least generalized residual variance estimators," which are obtained by minimizing the determinant of the variance-covariance matrix of the reduced form residuals. The asymptotic variance matrix of the FIML estimator, however, turns out to be identical with that for 3SLS, thus indicating the asymptotic efficiency of the later method.³³ This feature, combined with its less severe computational problems, leads some authors to recommend 3SLS over FIML.

As it was described above, 3SLS is preferred in this study to FIML. The initial development of 3SLS is due to Zellner and Theil (1962).

It should be, however, noted that there may be an identification problem in the present model. It is concerned with the question of whether any specific equation in a model can be estimated. It is not a question of the method of estimation nor of sample size, but of whether meaningful estimates of structural coefficients can be obtained. Simultaneity bias in the price

³²Goldstein and Khan (1978, pp. 278).

³³Theil, H., (1971, pp. 524-27).

coefficients and autocorrelation problems also should be considered. To correct these problems, if any, an instrumental-variable procedure will be used. The instruments will include the contemporaneous and lagged values of all exogenous variables as well as lagged values of endogeneous variables.

For economic time-series data, the autocorrelation problem is frequently encountered. Thus Durbin-Watson's test builds on an earlier development by von Newmann and Hart. The improvement in the von Newmann test is that it is specifically adopted for use in regression analysis by Durbin-Watson, thus taking direct account of the fact that the calculated residuals are dependent on both the number of observations and the number of independent variables in a regression model. As a result, the power of the Durbin-Watson test is quite good.³⁴

However, the Durbin-Watson test possesses the inconclusive region. This is because the distribution of "d" value is not known exactly³⁵ (since the exact distribution of "d" depends on the matrix of regressors), but is bounded by two other known distributions. The inconclusive region is large, particularly when the number of observations is small and when the number of estimated parameters is not small. To use the Durbin-Watson table, $T \geq 15$ and $K \leq 5$ where T = number of observations and K = number of

³⁴Tillman (1975, pp. 959-74).

³⁵These days appropriate computer software (SHAZAM) is available for the inconclusive region. Durbin and Watson (1971) also introduced an approximation for this region. See Judge, Griffiths, Hill, Lütkepohl, and Lee (1985, pp. 323).

estimated parameters. For a smaller T and larger K , Savin and White have extended the Durbin-Watson statistics to $6 \leq T \leq 200$ and $K \leq 20$.³⁶

It is important to emphasize that the Durbin-Watson test was derived for nonstochastic explanatory variables and thus is not applicable when lagged dependent variable appears among the explanatory variables. With a lagged dependent variable the Durbin-Watson statistic is biased toward 2, i.e., biased against finding autocorrelation.³⁷

IV-2. Autocorrelation

For a simultaneous-equation model with time series data, a serious autocorrelation problem as well as identification problem must be considered. If the disturbance terms are autocorrelated, then generally the least square estimates are not efficient while they are still unbiased and consistent. Asymptotically, the least square estimates are not efficient. To consider further consequences of autocorrelation, assume the first-order autocorrelation.

For the first-order autoregressive scheme it is assumed that $\varepsilon_t = \rho\varepsilon_{t-1} + U_t$ where $U_t \sim N(0, \sigma_u^2)$, $EU_t U_s = 0$; $t \neq s$, $EU_t \varepsilon_{t-1} = 0$, and $|\rho| \neq 1$. The consequences are then $E\varepsilon_t = 0$, $\text{Var}(\varepsilon_t) = \sigma_\varepsilon^2 =$

³⁶Savin and White (Nov. 1977, pp. 1989-96).

³⁷Griliches (1961, pp. 65-73).

$\sigma_u^2/(1-\rho^2)$, $\text{Cov}(\varepsilon_t, \varepsilon_{t-1}) = \rho\sigma_\varepsilon^2$ and thus $\rho = \frac{\text{Cov}(\varepsilon_t, \varepsilon_{t-1})}{\text{Var}\varepsilon_t \text{Var}\varepsilon_{t-1}}$ by homogeneity, and $E\varepsilon_t\varepsilon_{t-s} = \rho^s\sigma_\varepsilon^2 = \rho^s$.

With the first-order autocorrelation the consequence of Ordinary Least Square Estimates is

$$\text{Var}(\hat{\beta}) = \frac{\sigma_\varepsilon^2}{\Sigma X^2} \left(1 + 2\rho \frac{\sum_{t=2}^T X_t X_{t-1}}{\Sigma X^2} + 2\rho^2 \frac{\sum_{t=3}^T X_t X_{t-2}}{\Sigma X^2} + \dots + 2\rho^{T-1} \frac{X_T X_1}{\Sigma X^2} \right)$$

where $\sigma_\varepsilon^2 = \frac{\sigma_u^2}{1-\rho^2}$ while $\text{Var}(\hat{\beta}) = \frac{\sigma_u^2}{\Sigma X^2}$ under nonautocorrelation. The difference between $\text{Var}(\hat{\beta})$ under autocorrelation and $\text{Var}(\hat{\beta})$ under nonautocorrelation is: if $\rho > 0$ (ε_t and ε_{t-1} are positively correlated), then X_t and X_{t-1} are also positively correlated. Then, where

$$\text{Var}(\hat{\beta}) = \frac{\sigma_\varepsilon^2}{\Sigma X^2} \left(1 + 2\rho \frac{\sum_{t=2}^T X_t X_{t-1}}{\Sigma X^2} + 2\rho^2 \frac{\sum_{t=3}^T X_t X_{t-2}}{\Sigma X^2} + \dots + 2\rho^{T-1} \frac{X_T X_1}{\Sigma X^2} \right)$$

$2\rho, 2\rho^2, \dots, 2\rho^{T-1}$ are positive and all terms except the last term ($\frac{X_T X_1}{\Sigma X^2}$) are positive. The sign of the last term, $\frac{X_T X_1}{\Sigma X^2}$, is not known since the numerator has no Σ . So, it can be said that, if $\rho > 0$ and thus X_t and X_{t-1} are positively correlated, then the terms in the parenthesis are almost positive. Thus, if we use $\frac{\sigma_\varepsilon^2}{\Sigma X^2}$ ignoring ρ 's terms, then the variance is underestimated comparing with $\text{Var}(\hat{\beta})$ under autocorrelation which is a true variance.

There are several tests for autocorrelations; Von Newman Ratio or Von Newman-Hart test, Durbin-Watson Statistic, and other tests.

(A) Von Newman Ratio

A statistic proposed by Von Newman³⁸ is

$$\frac{\delta^2}{s^2} = \frac{\sum_{t=2}^T (\varepsilon_t - \varepsilon_{t-1})^2 / (t-1)}{\sum_{t=1}^T \varepsilon_t^2 / T} = \frac{T}{T-1} \frac{\sum_{t=2}^T \varepsilon_t^2 - 2 \sum_{t=2}^T \varepsilon_t \varepsilon_{t-1} + \sum_{t=2}^T \varepsilon_{t-1}^2}{\sum_{t=1}^T \varepsilon_t^2}$$

$$\approx \frac{2T(1-\gamma)}{T-1}$$

where $\gamma = \frac{\sum_{t=2}^T \varepsilon_t \varepsilon_{t-1}}{\sum_{t=2}^T \varepsilon_t^2 \sum_{t=2}^T \varepsilon_{t-1}^2}$

For serial independence ($\gamma=0$), it should be $\frac{\delta^2}{s^2} \approx \frac{2T}{T-1}$ which is approximately 2 for large T . But $(\varepsilon_t - \varepsilon_{t-1})^2$ is unobservable.

Probabilities for the distribution of δ^2/s^2 under the hypothesis $H_0: E\varepsilon_s \varepsilon_t = 0, t \neq s$, are tabulated by Hart.³⁹ Values near 2.1 indicate acceptance of H_0 . For different probability levels and sample size, values of δ^2/s^2 computed from sample residuals can be tested for temporal independence. Generally speaking, values between 1.7 and 2.5 will suggest acceptance of H_0 . Values much below this critical level (1.0 and below) indicate the presence of positive first-order serial correlation while large values (3.0 or more) indicate the presence of negative first-order serial correlation.

³⁸Von Neumann (1941, pp. 367-95).

³⁹See Hart (1942, pp. 207-14).

(B) Durbin-Watson Statistic

Durbin and Watson devised a test for independence of disturbance in terms of OLS residuals e_t . The statistic is

$$d = \frac{\sum_{t=2}^T (e_t - e_{t-1})^2}{\sum_{t=1}^T e_t^2}$$

which is related to the Von Newman ratio by $d = \frac{\delta^2}{s^2} \frac{T-1}{T}$ where it must

be $T \geq 15$. Since $\frac{\sum_{t=1}^T e_t^2}{\sum_{t=2}^T e_{t-1}^2} = \frac{\sum_{t=2}^T e_t^2}{\sum_{t=1}^T e_t^2}$, $d = \frac{\sum_{t=1}^T e_t^2 - 2 \sum_{t=2}^T e_t e_{t-1}}{\sum_{t=1}^T e_t^2}$

where $\hat{\rho} = \frac{\sum_{t=2}^T e_t e_{t-1}}{\sum_{t=1}^T e_t^2}$ which is the correlation coefficient between e_t and e_{t-1} . If $\rho = 0$ (no serial correlation), then $d = 2$. As $\hat{\rho} \rightarrow 1$ (positive autocorrelation), $d \rightarrow 0$. As $\hat{\rho} = -1$ (negative autocorrelation), $d \rightarrow 4$.

Durbin-Watson found distributions for pairs T, K (number of observations and numbers of estimated parameters respectively) of two statistics d_L and d_U that contain d in an interval. This distribution is for $100 \geq T \geq 15$ and $K \leq 5$. The test is one-sided for testing the existence of positive autocorrelation; $H_0: \rho = 0$, $H_A: \rho > 0$. If $d < d_L$, then reject H_0 ; if $d > d_U$, then accept H_0 ; if $d_L < d < d_U$, it is inconclusive. A one-tailed test of $\rho = 0$ against $\rho < 0$ is obtained by using $4-d$ in place of d .

For economic time-series data, which almost invariably exhibit positive serial correlation, the positive alternative will be appropriate.

A large sample test for serial correlation when lagged dependent variables are present has been developed by Durbin.⁴⁰ A generalization of Durbin's article has been given by Sargan and Metha.⁴¹

(C) Other Tests

Theil and Nagar⁴² derived unique (though approximate) significant limits for d on the assumption that the behavior of the explanatory variables is smooth in the sense that their first and second differences are small compared with the range of the corresponding variable itself. The smoothness condition is not satisfied by dummy variables, nor by most of the regressions that are formulated in terms of the first differences of the original variables. The tabulated critical values in the Theil-Nagar article are on average closer to the d_u than to the d_L values in the D-W table.

Henshaw⁴³ improved upon the Theil-Nagar work to obtain a more accurate approximation to $p(d)$. He proposed to fit a beta distribution based on the first four moments of d . Although the test is accurate and conclusive, it is complicated and computationally burdensome.

⁴⁰Durbin (1970, pp. 410-21).

⁴¹Sargan and Metha (1983, pp. 1551-67).

⁴²Theil and Nagar (1961, pp. 793-806).

⁴³Henshaw (1966, pp. 646-60).

According to Theil's BLUS procedure,⁴⁴ one of the sources of difficulty with the least squares residuals is that even when the disturbances are independent, the residuals are not. Thus, instead of attempting to develop further tests on the least-squares residuals, Theil proposed to develop estimators of the disturbances which will be best linear unbiased (BLU) and have scalar(S) covariance matrix of the form $\sigma^2 I$, hence the name BLUS estimator. Best here refers to minimizing the expected sum of squares of the estimation errors ($\hat{\varepsilon} - \varepsilon$).

The BLUS procedure involves and substantial amount of calculation just to obtain a valid test of autocorrelation.

Phillips and Harvey⁴⁵ proposed a test based on a set of residuals which have similar properties to the BLUS residuals but which are easier to calculate and have a simpler interpretation. They call these residuals "recursive residuals." They show that for various types of data the power of the recursive test compares favorably with that of the BLUS test but that both tests appear to have substantially less power than can be obtained by applying Durbin and Watson's 1971 full procedure.

There are two other test methods (Chochrane-Orcutt method and Durbin's two step method). These two methods will be explained in the Chapter V.

⁴⁴Theil (1965, pp. 1067-79) and Theil (1971, pp. 242-51).

⁴⁵Phillips and Harvey (1974, pp. 935-9).

IV-3. Identification Problem

Using a matrix notation the formal simultaneous-equation model can be written as⁴⁶

$$\bar{B} \bar{y}_t + \bar{\Gamma} \bar{x}_t = \bar{U}_t$$

where

$$\bar{x}_t = \bar{X}$$

$$\bar{y}_t = \begin{pmatrix} y_{1t} \\ \vdots \\ y_{mt} \\ \vdots \\ y_{Mt} \end{pmatrix}$$

$$y_{mt} = \bar{y}_m = \begin{pmatrix} y_{m1} \\ \vdots \\ y_{mT} \end{pmatrix}$$

$$\bar{B} = \begin{pmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1M} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2M} \\ \vdots & \vdots & & \vdots \\ \beta_{M1} & \beta_{M2} & \cdots & \beta_{MM} \end{pmatrix}$$

$$\bar{\Gamma} = \begin{pmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1k} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2k} \\ \vdots & \vdots & & \vdots \\ \gamma_{M1} & \gamma_{M2} & \cdots & \gamma_{Mk} \end{pmatrix}$$

⁴⁶The equation is in terms of Kmenta's.

Identification problem is the problem of deriving $\bar{B}$ and $\bar{\Gamma}$ from $\bar{\Pi}$ where $\bar{y}_t = \bar{\Pi} \bar{x}_t + \bar{V}_t$, $\bar{x}_t$ and $\bar{V}_t$ are uncorrelated. $\bar{\Pi}$ has good properties. Thus, we want to derive $\bar{B}$ and $\bar{\Gamma}$ from $\bar{\Pi}$. The structural coefficients are partial derivatives assuming that others are hold constant. But the reduced-form coefficients measure the direct and indirect effects since those coefficients are total partial derivatives. The total derivative means that all other predetermined variables are held constant (in the denominator) but all the other endogeneous variables (in the numerator) are allowed to vary moving toward to equilibrium.

There are two classes of identification; Underidentified and Identified. If the simultaneous-equation model is underidentified, then information on $\bar{\Pi}$ is not sufficient to derive $\bar{B}$ and $\bar{\Gamma}$. If identified, then $\bar{B}$ and $\bar{\Gamma}$ can be derived from $\bar{\Pi}$. To see the determination of identification conditions, assume that the structural model $\bar{B} \bar{y}_t + \bar{\Gamma} \bar{x}_t = \bar{U}_t$. The reduced form is then reduced form is then $\bar{y} = \bar{\Pi} \bar{x}_t + \bar{V}_t$ where $\bar{\Pi} = -\bar{B}^{-1} \bar{\Gamma}$ or $\bar{B} \bar{\Pi} = \bar{\Gamma}$, i.e.,

$$\begin{pmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1M} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2M} \\ \vdots & \vdots & & \vdots \\ \beta_{M1} & \beta_{M2} & \cdots & \beta_{MM} \end{pmatrix} \cdot (\bar{\Pi}) = - \begin{pmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1k} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2K} \\ \vdots & \vdots & & \vdots \\ \gamma_{M1} & \gamma_{M2} & \cdots & \gamma_{MK} \end{pmatrix}$$

Thus, for the first equation,

$$(\beta_{11} \beta_{12} \cdots \beta_{1M}) \cdot \bar{\Pi} = - (\gamma_{11} \gamma_{12} \cdots \gamma_{1k})$$

$$\text{or } \bar{\beta}' \bar{\Pi} = - \bar{\gamma}'.$$

This tells us the relationship between structural coefficients and reduced-form coefficients in the first equation. And we need to consider only the first equation since the process for the first equation is the same to all other remaining equations.

Now assume the following,

$$\bar{\beta}' \bar{\Pi} = - \bar{\gamma}' \quad \text{where } \bar{\beta}' \text{ is the first row of } \bar{B} \text{ and } \bar{\gamma}' \text{ is the first row of } \bar{\Gamma},$$

$$\bar{y}_{M \times 1} = \begin{pmatrix} \bar{y}_{\Delta M^{\Delta} \times 1} \\ \bar{y}_{\Delta \Delta M^{\Delta \Delta} \times 1} \end{pmatrix} \quad \text{where } \bar{y}_{\Delta} \text{ is the endogenous variables vector included in the first equation (or any equation) and } \bar{y}_{\Delta \Delta} \text{ is the endogenous variables vector excluded from the equation, thus } M^{\Delta} + M^{\Delta \Delta} = M,$$

$$\bar{X}_{M \times k} = \begin{pmatrix} \bar{X}_{*} & M_{k \times k^{*}} \\ \bar{X}_{**} & M_{k \times k^{**}} \end{pmatrix} \quad \text{where } \bar{X}_{*} \text{ is the exogenous variables vector included in the equation and } \bar{X}_{**} \text{ is the exogenous variable vector excluded from the equation,}$$

$$\bar{\beta}_{M \times 1} = \begin{pmatrix} \bar{\beta}_{\Delta M^{\Delta} \times 1} \\ \beta_{\Delta \Delta M^{\Delta \Delta} \times 1} \end{pmatrix} \quad \text{where } \bar{\beta}_{\Delta \Delta} = \begin{pmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ 0 \end{pmatrix} \text{ since } \bar{\beta}_{\Delta \Delta} \text{ are the coefficient of } \bar{y}_{\Delta \Delta} \text{ which are excluded,}$$

$$\bar{y}_{K \times 1} = \begin{pmatrix} \bar{y}_{* K^{*} \times 1} \\ \bar{y}_{** K^{**} \times 1} \end{pmatrix} \quad \text{where } \bar{y}_{**} = \begin{pmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ 0 \end{pmatrix} \text{ are } K^{*} + K^{**} = K.$$

Now in order to get a partitioned matrix form of $\bar{\Pi}$, $\bar{\beta}' \cdot \bar{\Pi} = -\bar{\gamma}'$ can be written as $\bar{\Pi}' \cdot \bar{\beta} = -\bar{\gamma}$. In matrix form,

$$\begin{pmatrix} \bar{\Pi}_{*\Delta} & \bar{\Pi}_{*\Delta\Delta} \\ \bar{\Pi}_{**\Delta} & \bar{\Pi}_{**\Delta\Delta} \end{pmatrix} \begin{pmatrix} \bar{\beta}_{\Delta} \\ \bar{\beta}_{\Delta\Delta} \end{pmatrix} = \begin{pmatrix} -\bar{\gamma}_{*} \\ -\bar{\gamma}_{**} \end{pmatrix}$$

Thus,

$$\bar{\Pi}_{*\Delta} \bar{\beta}_{\Delta} + \bar{\Pi}_{*\Delta\Delta} \bar{\beta}_{\Delta\Delta} = -\bar{\gamma}_{*}$$

$$\bar{\Pi}_{**\Delta} \bar{\beta}_{\Delta} + \bar{\Pi}_{**\Delta\Delta} \bar{\beta}_{\Delta\Delta} = -\bar{\gamma}_{**}$$

Since $\bar{\beta}_{\Delta\Delta} = \bar{o}$ and $-\bar{\gamma}_{**} = \bar{o}$, the above equations can be written as

$$(4-1) \quad \bar{\Pi}_{*\Delta} \bar{\beta}_{\Delta} = -\bar{\gamma}_{*}$$

$$(4-2) \quad \bar{\Pi}_{**\Delta} \bar{\beta}_{\Delta} = \bar{o}$$

The equation (4-1) is the nonhomogenous equation system while the equation (4-2) is a homogenous equation system. Here, $\bar{\Pi}_{*\Delta}$ and $\bar{\Pi}_{**\Delta}$ are the reduced form coefficients and $\bar{\beta}_{\Delta}$ and $-\bar{\gamma}_{*}$ are the structural coefficients. The identification conditions depend on whether we can find unique solution of $\bar{\beta}_{\Delta}$ in terms of the reduced form coefficients like in equation (4-2). In equation (4-2), $\bar{\beta}_{\Delta}$ are unknowns. The number of equations is K_{**} and the number of unknowns (variables) is M^{Δ} i.e., $\bar{\beta}_{\Delta}$. Thus, $r(\bar{\beta}_{\Delta}) = r(\bar{\beta}_{\Delta}, \bar{o})$ in equation (4-2), where r indicates rank.⁴⁷ $\bar{o}$ has nothing to do with rank and so it is always $r(\bar{\beta}_{\Delta}) = r(\bar{\beta}_{\Delta}, \bar{o})$. Therefore, the equation (4-2) always has solution.

⁴⁷Kmenta (1971, pp. 539-50).

But this solution is a trivial solution since $\bar{\beta}_{\Delta} = \bar{0}$. Thus, the necessary and sufficient condition for equation (4-2) to have nontrivial solution is $r(\bar{\pi}_{**\Delta}) \leq M^{\Delta} - 1$. Note that for unique solution we must have $r(\bar{\pi}_{**\Delta}) = M^{\Delta} - 1$. Since $\bar{\pi}_{**\Delta}$ is $K_{**} \times M^{\Delta}$, the necessary condition for $r(\bar{\pi}_{**\Delta}) = M^{\Delta} - 1$ is $K_{**} \geq M^{\Delta} - 1$, i.e., $K_{**} \geq M^{\Delta} - 1$ is the necessary condition for identification.

Finally speaking, if $K_{**} < M^{\Delta} - 1$ or if $K_{**} \geq M^{\Delta} - 1$ and $r(\bar{\pi}_{**\Delta}) < M^{\Delta} - 1$, then the equation is underidentified. If $K_{**} = M^{\Delta} - 1$ and $r(\bar{\pi}_{**\Delta}) = M^{\Delta} - 1$, then the equation is just identified. If $K_{**} > M^{\Delta} - 1$ and $r(\bar{\pi}_{**\Delta}) = M^{\Delta} - 1$, then the equation is overidentified.⁴⁸

⁴⁸Kmenta (1971, pp. 544-5).

CHAPTER V

METHODS

V-1. Estimation Method

There are two system methods; Full Information Maximum Likelihood (FIML) method and 3 Stage Least Square (3SLS) method.

3SLS method involves using OLS three times. 3SLS is equivalent to 2SLS in Seemingly Unrelated Equations.⁴⁹

Seemingly Unrelated Equations are

$$\bar{y}_1 = \bar{x}_1 \bar{\beta}_1 + \bar{u}_1$$

$$\bar{y}_2 = \bar{x}_2 \bar{\beta}_2 + \bar{u}_2$$

$$\vdots$$

$$\bar{y}_M = \bar{x}_M \bar{\beta}_M + \bar{u}_M$$

$$\text{or } \bar{y} = \bar{Z} \bar{\delta} + \bar{U}$$

where

$$\bar{y} = \begin{pmatrix} \bar{y}_1 \\ \bar{y}_2 \\ \vdots \\ \bar{y}_M \end{pmatrix}$$

$$\bar{Z} = \begin{pmatrix} \bar{z}_1 & \bar{o} & \cdots & \bar{o} \\ \bar{o} & \bar{z}_2 & \cdots & \bar{o} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{o} & \bar{o} & & \bar{z}_M \end{pmatrix}$$

⁴⁹ Johnston (1984, pp. 439-49).

$$\bar{\delta} = \begin{pmatrix} \bar{\beta}_1 \\ \bar{\beta}_2 \\ \vdots \\ \bar{\beta}_M \end{pmatrix}$$

$$\bar{U} = \begin{pmatrix} \bar{U}_1 \\ \bar{U}_2 \\ \vdots \\ \bar{U}_M \end{pmatrix}$$

The advantage of estimating all equations together by GLS over the estimating the each question by 2SLS is that we can get a more efficient estimator, i.e., GLS will improve the efficiency of the estimate. That is, the advantage of 3SLS method over 2SLS is that 3SLS method will improve the efficiency of estimate.⁵⁰

From the above Seemingly Unrelated Equations, assume that the m th equation is written as

$$(5-1) \quad \bar{y}_m = -\hat{\bar{Y}}_m \bar{\beta}_m - \bar{X}_{*m} \bar{y}_{*m} + \bar{U}_m^*$$

where $\hat{\bar{Y}}_m$ is the OLSE of $\bar{Y}_m$ in the reduced form $\bar{Y}_m = \bar{\Pi}_m \bar{X} + \bar{V}_m$, $\bar{U}_m = \bar{U}_m - \bar{V}_m \bar{\beta}_m$, and $\hat{\bar{V}}_m = \bar{Y}_m - \hat{\bar{Y}}_m$. 2SLS estimates of $\bar{\beta}_m$ and $\bar{y}_{*m}$ are obtained by applying OLS to the equation (5-1);

⁵⁰ Johnston (1984, pp. 486-90).

$$(5-2) \quad \begin{pmatrix} \hat{\beta}_M \\ \hat{\gamma}_{*M} \end{pmatrix}_{2SLS} = - \begin{pmatrix} \hat{\gamma}_m^{-1} & \hat{\gamma}_m & \hat{\gamma}_m' \cdot \hat{\gamma}_m \\ \hat{\gamma}_{*m}' & \hat{\gamma}_m & \hat{\gamma}_{*m}' \cdot \hat{\gamma}_{*m} \end{pmatrix}^{-1} \begin{pmatrix} \hat{\gamma}_m' \\ \hat{\gamma}_{*m}' \end{pmatrix} \bar{y}_m$$

Assuming the model as

$$(5-3) \quad \bar{y} = \hat{Z} \bar{\delta} + U^*$$

where

$$\bar{y} = \begin{pmatrix} \bar{y}_1 \\ \bar{y}_2 \\ \vdots \\ \bar{y}_M \end{pmatrix},$$

$$\hat{Z} = \begin{pmatrix} \hat{Z}_1 & \bar{0} & \cdots & \bar{0} \\ \bar{0} & \hat{Z}_1 & \cdots & \bar{0} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{0} & \bar{0} & \cdots & \hat{Z}_M \end{pmatrix},$$

$$\hat{Z}_m = - \begin{pmatrix} \hat{\gamma}_m & \hat{\gamma}_{*m} \end{pmatrix},$$

$$U^* = \begin{pmatrix} U_1^* & U_2^* & \cdots & U_m^* \end{pmatrix},$$

$$\bar{\delta} = \begin{pmatrix} \bar{\delta}_1 \\ \bar{\delta}_2 \\ \vdots \\ \bar{\delta}_M \end{pmatrix},$$

$$\bar{\delta}_m = \begin{pmatrix} \bar{\beta}_{\Delta m} \\ \bar{y}_{*m} \end{pmatrix},$$

the GLSE of the equation (3) yields

$$(5-4) \begin{pmatrix} \hat{\delta} \end{pmatrix}_{\text{GLS}} = (\hat{Z}' \quad \Omega^{-1} \hat{Z})^{-1} \hat{Z}' \Omega^{-1} \bar{y}$$

where $\Omega = E(\bar{U}^* \cdot \bar{U}^{*'})$. 3SLS estimations of $\bar{\delta}$ in the model is (4) with Ω replaced by $\hat{\Omega}$;

$$(5-5) \begin{pmatrix} \hat{\delta} \end{pmatrix}_{\text{3SLS}} = (\hat{Z}' \hat{\Omega}^{-1} \hat{Z})^{-1} (\hat{Z}' \hat{\Omega}^{-1} \bar{y}),$$

where $\hat{\Omega}$ is estimated by 2SLS residuals.

Alternatively, (5-2) can be identically derived by applying GLS to

$$\bar{X}' \bar{y}_m = \bar{X}' \bar{Z}_m \bar{\delta}_m + \bar{X}' \bar{U}_m. \quad ^{51}$$

Then

$$(5-6) \begin{pmatrix} \hat{\delta}_m \end{pmatrix}_{\text{GLS}} = \left[\bar{Z}' \bar{X} (\bar{X}' \bar{X})^{-1} \bar{X}' \bar{Z}_m \right]^{-1} \bar{Z}_m' \bar{X} (\bar{X}' \bar{X})^{-1} \bar{X}' \bar{y}_m.$$

For the reason that (5-6) can be shown to be the same as (5-2), 2SLS can be regarded as an application of Aitken's GLS to the equation.

Now write the model alternatively,

$$(5-7) \quad \bar{P} = \bar{Q} \bar{\delta} + \bar{w}$$

where $\bar{P} = \begin{pmatrix} \bar{X}' \bar{y}_1 \\ \bar{X}' \bar{y}_2 \\ \vdots \\ \bar{X}' \bar{y}_M \end{pmatrix}$

⁵¹In the first stage

$$\bar{y}_m = \bar{Z}_m \bar{\delta}_m + \bar{U}_m.$$

$$\bar{Q} = \begin{pmatrix} \bar{X}' \cdot \bar{Z}_1' & \bar{0} & \dots & \bar{0} \\ \bar{0} & \bar{X}' \cdot \bar{Z}_2' & \dots & \bar{0} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{0} & \bar{0} & \dots & \bar{X}' \cdot \bar{Z}_M' \end{pmatrix}$$

$$\bar{W} = \begin{pmatrix} \bar{X}' & \bar{U}_1 \\ \bar{X}' & \bar{U}_2 \\ \vdots & \vdots \\ \bar{X}' & \bar{U}_M \end{pmatrix}$$

GLS estimates of $\bar{\delta}$ in (5-7) is

$$(5-8) \quad \left(\hat{\bar{\delta}} \right)_{GLS} = \left[\bar{Q}' \Sigma^{-1} X (\bar{X}' \bar{X})^{-1} \bar{Q} \right]^{-1} \bar{Q}' \Sigma^{-1} X (\bar{X}' \bar{X})^{-1} \bar{P}$$

where $\Sigma X (\bar{X}' \bar{X}) = E \bar{W} \bar{W}'$

3SLS estimates of the structural coefficients are (5-8) with Σ replaced by $\hat{\Sigma}$. That is,

$$(5-9) \quad \left(\hat{\bar{\delta}} \right)_{3SLS} = \left[\bar{Q}' \hat{\Sigma}^{-1} X (\bar{X}' \bar{X})^{-1} \bar{Q} \right]^{-1} \bar{Q}' \hat{\Sigma}^{-1} X (\bar{X}' \bar{X})^{-1} \bar{P}$$

where $\hat{\Sigma}^{-1}$ is estimated from 2SLS residuals. Note that (5-9) and (5-5) are equivalent.

However, if error terms in distinct equations are uncorrelated, 3SLS and 2SLS yield identical estimates and thus in this case there is no gain in efficiency of 3SLS over 2SLS.⁵²

⁵²Kmenta (1971, pp. 581-5).

V-2. Method Under Autocorrelation

According to Chochrane-Orcutt method,⁵³ in the first round, we can estimate, to obtain the residuals (e_1 's)

$$Y_t = \alpha + \beta X_t + \varepsilon_t$$

where Y = the endogenous variables

X = the exogenous variables.

In this round, we can also obtain $\hat{\rho}_1 = \frac{\sum e_t e_{t-1}}{\sum e_t^2}$ without considering the autocorrelation problem.

In the next round, we should estimate

$$Y_t - \hat{\rho}_1 Y_{t-1} = \alpha (1 - \hat{\rho}_1) + \beta (X_t - \hat{\rho}_1 X_{t-1}) + (\varepsilon_t - \hat{\rho}_1 \varepsilon_{t-1}).$$

In this round, we can find e_2 's and $\hat{\rho}_2 = \frac{\sum e_{2t} e_{2t-1}}{\sum e_{2t}^2}$. Then, we can continue this procedure until the estimates of α , β , and ρ are little different from the previous round. The difference depends on the probability, say, 0.01 or 0.05.

Durbin's two-step procedure⁵⁴ is almost the same as the Chochrane-Orcutt method, but simpler.

In the first step, we can estimate

$$Y_t = \alpha (1 - \rho) + \rho Y_{t-1} + \beta X_t - \beta \rho X_{t-1} + U_t$$

in order to obtain the estimate of ρ , i.e., $\hat{\rho}$. In this round we use OLS. Then, substitute $\hat{\rho}$ into ρ in the above equation.

In the second step, then, we will estimate

$$Y_t - \hat{\rho} Y_{t-1} = \alpha (1 - \hat{\rho}) + \beta (X_t - \hat{\rho} X_{t-1}) + \hat{U}_t.$$

⁵³Cochrane-Orcutt (1949).

⁵⁴Durbin (1960).

The present study uses the Chochrane-Orcutt method to reduce the autocorrelation problem.⁵⁵

⁵⁵This study assumes the first-order autocorrelation. However, according to Judge Griffiths, Hill, Lütkepohl, and Lee, processes of order higher than one are likely to be relevant when using monthly or quarterly data. We, therefore, reestimated the model by the fourth-order autocorrelation and found no major difference from the first-order autocorrelation. This may be supported by the Goldstein-Khan's (1978) findings. They found the average time lag as one quarter period.

CHAPTER VI

EMPIRICAL RESULTS

VI-1. Estimates of Simultaneous Equations

Using quarterly data for the periods of 1953 through 1985, the simultaneous export supply-export price equation system was estimated using the 3SLS method. The results are shown in the Table 1. Furthermore, our model has been tested by certain periods according to economic upswing (1962-1969) and economic downswing (1980-1983). By these tests we can show how the export supply responds to the export price and the domestic price in both economic expansion periods and economic contraction periods and how the export price responds to the export supply, the domestic price, and the domestic consumption in both periods. The Table 2 and Table 3 show the results of these two periods.

In the export supply equation for the periods of 1953 through 1985, the sizes of estimated coefficients of the export price and the domestic price are quite large. The estimated coefficients of PX and P are 3.742 and -3.862 respectively. The sign of estimate of PX is positive while the sign of P is negative. This shows that the export supply is increased when the export price increases and decreased when the domestic price decreases.

The estimated coefficient of imported resources in the export-supply equation is 0.321. This estimate has a positive

TABLE 1
THE SIMULTANEOUS-EQUATION SYSTEM (1953-1985)

Variables	Log X_t	Log PX_t
Intercept	1.864 (2.833)	-0.034 (-0.381)
Log PX_t	3.742 (4.814)	
Log P_t	-3.862 (-4.664)	0.643 (8.404)
Log M_t	0.321 (2.725)	
Log CY_t	0.349 (1.745)	
Log C_t^*	0.079 (2.051)	
Log X_t		0.044 (2.775)
Log PM_t		0.281 (5.339)
Log C_t		0.021 (2.272)
R^2	0.914	0.995
S.E.	0.028	0.001
D.W.	2.090	1.818

Notes: Regression estimates are based on 3SLS method.
t-statistics are in parentheses. S.E. stands for standard error.
D.W. indicates Durbin-Watson test.

TABLE 2
THE SIMULTANEOUS-EQUATION SYSTEM (1962-1969)

Variables	Log X_t	Log PX_t
Intercept	8.622 (1.143)	-0.324 (-0.358)
Log PX_t	7.342 (2.416)	
Log P_t	-7.325 (-2.673)	0.400 (2.214)
Log M_t	1.501 (3.988)	
Log CY_t	-0.932 (-1.954)	
Log C_t^*	-1.197 (-1.955)	
Log X_t		-0.032 (-2.572)
Log PM_t		0.558 (2.621)
Log C_t		0.119 (1.992)
R^2	0.899	0.855
S.E.	0.026	0.001
D.W.	1.991	2.368

Notes: t-statistic of each estimate is in parenthesis. S.E. stands for standard error of the model. D.W. indicates Durbin-Watson test. Dep. Mean stands for mean of the dependent variable.

TABLE 3
THE SIMULTANEOUS-EQUATION SYSTEM (1980-1983)

Variables	Log X_t	Log PX_t
Intercept	-4.077 (1.809)	2.172 (1.749)
Log PX_t	7.507 (3.822)	
Log P_t	-3.759 (-3.540)	0.105 (9.257)
Log M_t	0.874 (2.458)	
Log CY_t	-0.717 (-3.251)	
Log C_t^*	-1.715 (-4.844)	
Log X_t		0.051 (4.809)
Log PM_t		0.175 (6.757)
Log C_t		0.162 (2.616)
R^2	0.892	0.919
S.E.	0.015	0.001
D.W.	2.478	2.386

Notes: t-statistic of each estimates is in parentheses. S.E. stands for standard error of the model. D.W. indicates Durbin-Watson test. Dep. Mean stands for mean of dependent variable.

sign as expected, showing that an increase in the imports of resources increases the export supply.

For the estimated coefficient of foreign consumption, C^* , this study finds a positive sign as expected and the size of this coefficient is 0.079. Assuming that consumption depends on the income level, Harry Johnson (1958) has pointed out that under certain conditions the direction in which the trade balance moves over time depends critically on each country's income elasticity of demand for each country's exports. Johnson showed that if trade is initially balanced in a two-country model, if prices are constant and if income growth is the same in both countries, then the trade balance between them can still change through time if their respective income elasticities of demand for the other's exports differ. Thus, Houthakker and Magee (1969) showed that disparities in income elasticities appeared to be significant in the case of certain countries whose balance of payments performance is either much worse or much better than might be expected. In their findings they concluded that for the United States, it appeared that the income elasticity of demand for total imports was about the same so that of other developed countries, but that the income elasticity of other countries' demand for United States exports was abnormally low.⁵⁶ Based on their results, the estimated coefficient of foreign consumption should be low.

⁵⁶Sung Y. Kwack (Jan. 1972, p. 302).

The estimate of capacity utilization in this study is 0.349. This result is statistically significant and has a positive sign as expected.

For the export price equation, the results in this study are very similar to the results found by Goldstein-Khan and Haynes-Stone. The estimated coefficient of export supply in the export price equation is 0.044 which is statistically significant. This result states that the export price is not so much dependent on the export supply. In other words, it can be assumed that the export price is formulated, without knowing the amount of export supply, at the beginning of the period.

The estimated coefficient of domestic price in the export price equation is found as 0.643. This estimate is also statistically significant. Comparing with the estimate of export supply in the export price equation it can be said that the export price depends much more on the domestic price level than on the export supply. This may be true if firms are looking for profits in both markets.

Again assuming that the consumption is closely related to the income level, the estimated coefficient of domestic consumption, C , should be expected to have very similar result to the estimate of CY in the test of Haynes and Stone. In this study the size is 0.021 whereas it was 0.01 for Haynes and Stone. This result indicates that the export price is not sensitive to the domestic consumption level. Rather the export price is much dependent on the domestic price level.

According to the price formation based on the rational expectation, as it was described before, the independence of the export price to the domestic consumption must be held.

The estimate of the imported resources is 0.281, and it is statistically significant. This estimate must be considered together with the estimate of imported resources, M , in the export supply function. When the imported resources has a positive relationship with the export supply, the price of imported resources must have the same positive relationship with the export price because the export price has a positive relationship with the export supply. These relationships are upheld in this study.

To see more insight into our model, it is a worthwhile exercise to compare results of the present study to those obtained by the earlier investigators.

VI-2. Comparison

The signs of PX and P in the export-supply equation of the present study are supported by Dunlevy (1980) and Haynes-Stone (1983).⁵⁷ The difference between the present study and the earlier studies is the magnitudes of estimates. For the estimates of Dunlevy the estimate of PX/PH was 1.09 while the estimated coefficient of capacity was 1.27. This means that the export supply is more dependent on the capacity than on the export price. We

⁵⁷ Haynes-Stone estimated their model for the periods of 1947 through 1979. Thus, the model of this study was estimated for the same periods and the estimated coefficients of px and p had the same signs and were not much different from the ones in the Table 1.

can conclude with Dunlevy's results that the domestic capacity, which is the logarithms of production, and capacity utilization leads the export supply behavior in the United States. The question, however, is that capacity is free of cyclical influences whereas production is not, and that actual production is in part dependent on the volume of exports but the capacity is not. This is why the Dunlevy's results contrast dramatically with those of the earlier capacity pressure studies. The difference is due to the use of domestic capacity rather than actual production as an explanatory variable. Ball, Eaton, and Stener (1966), for example, include the ratio of British production (rather than capacity) to world production as an explanatory variable in their estimated relationship.

The Haynes-Stone (1983) estimates of PX and P were 3.81 and -1.97. The sizes of the estimates of PX 's in this study and Haynes-Stone test are almost same. However, the size of estimated coefficient of P in this study is much bigger than the estimate of P in the Haynes-Stone study. As it was indicated before, if a country pursues only quantity strategies for the export supply behavior and thus if only quantity equations are tested, then it is expected that the export supply depends more on the export price than on the domestic price. This is because the quantity equations show one-way relationship between the export supply and the domestic price, not the relationship between the export price and the domestic price.

Furthermore, according to Haynes-Stone's results, we can conclude that the export supply is much more dependent on the

export price than on the domestic price. This may be true if we assume that the quantity of exports supplied is only exported, not consumed in the domestic market, and that the United States is an export-oriented country and a small country and thus is a price-taker. However, if it is assumed that the firms look for their profits both in the domestic market and the world market, then it can be said that the firms in the United States will watch both the export price and the domestic price. They will look for more profit depending on the export price level or the domestic price level. These two prices do not make any difference to the firms. In this case the sizes of estimates of PX and P should not be much different. In this study the estimated coefficients of PX and P are 3.742 and -3.862 respectively and both are statistically significant.

Goldstein and Khan (1978) used the relative price ratio as the ratio of export price over the domestic price. The use of relative price ratio, however, has more difficulties to show the effect of export price or domestic price separately on the export supply behavior. This is because when the price ratio is changed, we can have several possibilities. First, the export price is constant but the domestic price is changed. Second, the export price is changed but the domestic price is constant. Third, the export price is increased (or decreased) but the domestic price is decreased (or increased). Fourth, both are increased (or decreased) but by a different rate. In other words, we cannot see an exact cause by which the export supply is changed. Since one purpose of this study is to show the response of export supply to the export

price, the export price and the domestic price should be considered separately.

Goldstein-Khan (1978) and Haynes-Stone (1983) did not include the variable, the imported resources, for their models. The model without this variable assumed that the input ratios for production are constant in the period. This assumption may be acceptable for a short-run export-supply model, but for a long-run supply function the fixed input-ratio assumption can be attacked as unrealistic. Furthermore including the variable of imported resources can show us the marginal rate of substitution between the imported resources and the abundant resources in the country.

The present study shows relationships between the export supply and the domestic and foreign consumptions whereas Goldstein and Khan (1978) examined the relationships between the export supply and the real incomes of the country's trading partners. For the test of Goldstein-Khan's model the estimate of the real income of the trading partner was 0.603. This may be caused by the use of income level. In other words, the use of income instead of consumption may lead to a greater size of estimate. This is because the income is not spent all only for consumption and the marginal propensity to consume is different in each country. And also the consumption should be compensated by an increase in price while the national income level may be increased by an increase in the price level. This

compensation will cause a small size of estimated coefficient of consumption. Thus, it is not a surprise to find a small size of estimate of consumption which is significantly different from zero.

The estimate of capacity utilization in this study shows 0.349. This is not much different from the result of Haynes-Stone which was 0.32. However, the Dunlevy's estimate (0.24) was somewhat lower than our estimate. This is because Dunlevy used a ratio of capacity to the production for the capacity utilization and this capacity utilization was used for measures of domestic capacity pressure.

For the export price equation the results in this study are very similar to the results found by Goldstein-Khan and Haynes-Stone. The estimated coefficient of export supply in the export price equation is 0.044 whereas that was 0.04 in the Haynes-Stone's test. The estimated coefficient is statistically significant.

Although Haynes-Stone did not include the variable of the domestic price level in the export price equation, Goldstein-Khan included that variable for their test. They found the estimate of the domestic price as 0.690 whereas this study shows 0.643. For the Haynes-Stone's equation, including this variable causes an underidentification problem to test the simultaneous-equation system for the export price and the import price. This may be why they excluded the domestic price variable from the equation. The estimate in this study is significantly different from zero.

VI-3. Economic Expansion and Contraction

In order to look at further insight into the export-supply behavior by using the present simultaneous-equation system, two economic periods are tested, one being for economic expansion (1962-1969) and are for economic contraction (1981-1983). For the periods of 1962-1969, the estimated coefficients of the export price and the domestic price in the export supply equation are 7.342 and -7.325 respectively. The difference between the sizes of these two estimates is very close to the difference between the sizes of these two estimates for the periods of 1953-1985. However, the estimated values of these two variables for the economic expansion periods (1962-1969) are much greater than ones for 1953-1985. During the economic expansion periods there may be an increase in aggregate spending which in turn causes an increase in consumption. The increase in consumption will increase total output which will require an increase in employment of resources for production. The increase in employment of resources will raise the income and thus another increase in consumption will be created. Assuming the multiplier effect in the period of economic expansion the increase in domestic consumption will lead the firms into the domestic market. In this case the firms will seek for more profit at the higher export price or at the higher domestic price. Then in the period of economic expansion the firms will be more price elastic than other periods. However, the firms in the United

States are still indifferent between the export price and the domestic price. This is true as long as in the domestic market the firms can make profits as much as the profits at the export price level.

For the export price equation of 1962-1969, it is interesting to find that the estimated coefficient of the prices of imported resources is greater than the estimate of the domestic price. This result indicates that in the period of economic expansion the export supply may be increased and the increase in supply will require more resources for production. Then the cost of production will be largely dependent on the prices of resources. Then, it can be said that the prices of imported resources are the main determinant of the export price, especially for the period of increasing in supply.

Another finding is the negative sign of the estimate of export supply in the export price equation. This negative sign shows a change in export supply curve with a fixed export demand curve. When the economy is expanded and there the export supply is increased, the export supply curve will shift rightward. This change in export supply will decrease the export price and the decrease in the export price will offset the increase in the export supply later.

For the periods of economic contraction (1981-1983), the most different results from the results of the periods of economic expansion are the estimates of the export price and the

domestic price in the export supply equation. The signs of estimates of PX and P are positive and negative respectively, as expected, but the difference of sizes of those two estimates are very big. The estimate of PX is much greater than the estimate of P . This result states that in the periods of economic contraction, the level of domestic consumption is quite low and the firms can be expected to turn their attentions to the world market. In this case, their supply of exports will be more dependent on the export price than the domestic price.

It is also time that for the periods of economic contraction the use of imported resources should be reduced and thus that the estimate of imported resources in these periods is smaller than the estimate in the periods of economic expansion.

For the export price equation for 1981-1983, we have all the expected positive signs for the variables. However, the sizes of all the variables are relatively small. This may indicate that the firms are price takers at the world market price level, i.e., in the case of economic construction any variable does not affect the export price as much as in the periods of economic expansion.

As it has been shown that the United States has pursued both quantity strategies and price strategies depending on the domestic economic situations. In other words, the United States has pursued more price strategies under the conditions

of economic upswings whereas more quantity strategies under the conditions of economic downswings.

Simply speaking while the test of the export equation for the periods of 1953-1985 looks more like the results of the estimated export supply equation for the economic expansion periods, the test of the export price equation for the periods of 1953-1985 is not like either of any results for both periods. This means that, although the United States was a price taker in the periods of economic contraction, the firms in the United States influenced their own export price in other periods.

The findings in the present study mostly show the two-way relationships of the export supply, the export price, and the domestic price in the quantity-price equations. These findings include most of the findings which were mentioned by the earlier studies as well as the roles of other variables which were not taken for the earlier models. For these findings in the present study, the assumption of market-clearing was dropped. The market-clearing assumption in the world market is sometimes attacked as unrealistic. Furthermore, in order to assume the market-clearing in the world market, one of quantity level or price level should be assumed to be constant as Goldstein-Khan (1978) and Haynes-Stone (1983) did. For the case of constant level of quantity the model should deal with the changes in price only whereas the changes in quantity only for the constant price level. The present study does not assume the market-clearing in

the world market dealing with the changes in quantity and price together. To show the simultaneous changes in the model the additional variables such as foreign consumption, domestic consumption, imported resources, and prices of imported resources are taken as the exogenous variables. When the quantity equation and the price equation form a simultaneous-equation system, a change in the level of quantity can be offset by a change in the price level. This is true when a country pursues both price and quantity strategies together. If, as Goldstein-Khan (1978) and Haynes-Stone (1983) did, quantity only or price only was adjusted to a change in the export supply, then the estimated adjustment of quantity or price is overestimated in the economic expansion periods or underestimated in the economic contraction periods. The present simultaneous-equation system can avoid the overestimation and underestimation by offsetting systematic changes in the quantity level and the price level.

CHAPTER VII

SUMMARY

This study is an empirical investigation of the export-supply behavior of the United States for the period of 1953-1985. Many studies in this field were undertaken within the framework of simultaneous quantity equations or simultaneous price equations under the assumptions of a small country or a big country, the market-clearing, or autarky prices. These assumptions, however, are so unrealistic that a model cannot show the exact behaviors of variables included in the model. The present study assumes constant production technology, constant returns to scale, none of domestic distortions, and fixed exchange ratio, but does not assume a small (or big) country, the market-clearing, or autarky prices.

Without the alternative (non-factor proportions) determinants of trade, the results in this study indicates that the United States is not always a price-taker as a small country. According to the results of 1953-1985, both the export price and the domestic price played a role on the export supply as Haynes and Stone (1983) mentioned in their conclusions. Furthermore, during 1962-1969 (the periods of economic expansion), the export supply was heavily dependent on the domestic price pursuing the price strategy. This suggests that firms in the United States formulate their own export prices looking at the domestic price during periods of economic expansion. This is true when firms in

the United States consider the domestic market to be as big as the world market. In other words, if the firms could make their profits in the domestic market as well as in the world market, they, as the price-makers, formulate their own export prices based on the domestic prices. However, for the periods of economic contraction (1981-1983), the export supply is much more dependent on the export price than on the domestic price. Then, it can be said that the firms in the United States, during the periods of economic contraction, adjust their export supply taking the export prices as their own prices. The firms become the price-takers in the world market.

The present study has highlighted the dynamic behaviors of the export supply and the export price without the restrictive assumptions of market clearing, a price-taker or a price-maker, and quantity or price strategy. However, for the more precise behaviors of the export supply and the export price, other variables can be considered for this study. For examples, tariff, political pressure, and trade liberalization can be good variables to investigate the behaviors of export supply and export price. Especially the variable of tariff is expected to play a role on the export price equation with production effect and subsidy effect as the effects of tariff.

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APPENDIX

APPENDIX

Goldstein-Khan (1978), assuming $X_t^d = X_t^s$, tended to obtain the effect of solely exogenous variables on the export supply and the export price by finding the reduced forms of the equations as the following.

$$\log X_t^s = \beta_0 + \beta_1 \log(PX/p)_t + \beta_2 Y_t^*$$

Normalizing for the price of exports, pX_t ,

$$\log PX_t = b_0 + b_1 \log X_t^s + b_2 Y_t^* + b_3 \log P_t$$

where
$$b_0 = -\frac{\beta_0}{\beta_1}$$

$$b_1 = -\frac{1}{\beta_1}$$

$$b_2 = -\frac{\beta_2}{\beta_1}$$

$$b_3 = -\frac{\beta_1}{\beta_1}$$

Since $\log X_t^d = a_0 + a_1 \log(PX/PXW)_t + a_2 \log YW_t$ and $X_t^d = X_t^s = X_t$,

$$\begin{aligned} \log X_t &= \frac{a_0 + a_1 b_0}{D} - \frac{a_1}{D} \log PXW_t + \frac{a_2}{D} \log YW_t + \frac{a_1 b_2}{D} Y_t^* \\ &+ \frac{a_1 b_3}{D} \log P_t \end{aligned}$$

$$\log PX_t = \frac{b_0 + a_0 b_1}{D} - \frac{a_1 b_1}{D} \log PXW_t + \frac{a_2 b_1}{D} \log YW_t + \frac{b_2}{D} Y_t^* \\ + \frac{b_3}{D} \log P_t$$

where $D = 1 - a_1 b_1$.

DATA SOURCES

Variable Definitions and Data Sources

Variable	Definition	Source
X = quantity of exports supplied	Index of the volume of exports; 1948=100	(3)
CY = capacity utilization	Index of deviation-from-trend income	(6)
PX = price of export	Index of the unit value of exports; 1948=100	(1)
P _d = domestic price	Index of wholesale prices; 1948=100	(1)
M = Imports of Resources	Index of the volume of imports; 1948=100	(3)
C* = foreign consumption	Index of foreign total consumption	(2)
C = domestic consumption	Index of domestic total consumption	(2)
PM = price of resources imported	Index of the prices of resources imported; 1948=100	(1)

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VITA

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