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PRICES AND MARKET SHARES IN INTERNATIONAL MACHINERY TRADE

Irving B. Kravis

Robert E. Lipsey

Dennis M. Bushe

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Cambridge MA 02138

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ABSTRACT

We use new international price measures we have developed for machinery and transport equipment to explain changes in exports and export shares of the United States, Germany, and Japan.

The effects of relative price changes on export shares are fairly large, producing relative quantity changes that are 50 to 100 per cent and as much as 200 per cent greater than the price changes. The effects of price changes seem to stretch out over 3 to 5 years and possibly longer. We also find that delays between order and delivery may affect measures of export quantity and of its response to price.

Equations for individual countries suggest that exports by the United States are most responsive to relative price changes and those of Germany least responsive. The income elasticities are very sensitive to the inclusion or exclusion of a time variable to measure "unexplained" trends in exports.

A system of supply and demand equations is developed in which the supply of exports depends on a country's export and domestic prices for the same goods, as well as on its real income. The supply elasticities range from about 2½ for Germany to over 7 for the United States, implying that firms switch easily between domestic sales and exports.

Dr. Irving B. Kravis
Department of Economics
368 McNeil Building
University of Pennsylvania
Philadelphia, Pennsylvania 19174

(215) 243-5692

Dr. Robert E. Lipsey
National Bureau of Economic Research
15-19 West 4th Street, 8th fl.
New York, New York 10012

(212) 598-3533

Mr. Dennis M. Bushe
National Bureau of Economic Research
15-19 West 4th Street, 8th fl.
New York, New York 10012

(212) 598-3185

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Irving B. Kravis
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Introduction

The last 25 years have seen great changes in shares of world markets for exports of manufactured goods, particularly the rise of German and Japanese shares, and the decline of those of the U.K., and, to a lesser extent of the United States. Over the same period there have been large changes in the relative export prices of these major industrial countries. Yet the considerable empirical work that has been done on trade flows has left much of the change in market shares unexplained, or "explained" in large part by trend terms or dummy variables. On the other hand, large price changes have taken place with apparently small effects on exports. This has been particularly the case for Germany and Japan since the DM and Yen revaluations of the 1970's. The apparent lack of response to large price changes is as paradoxical on the face of it as the phenomenon of large quantity shifts unrelated to price changes.

Attempts to fit equations explaining quantity changes have failed to come to any consensus regarding the size of price or substitution elasticities, income elasticities of demand for exports, or the length of lags between price changes and the corresponding changes in the volume of exports. A disturbing proportion of the equations, in fact, produce positive relationships between price and export or export share changes.

Those who place their faith in the smooth operation of perfect or near-perfect markets might not find the lack of clear relationships surprising. If the "law of one price" held in international markets, all export prices of closely related goods would have to move together. The elasticity of substitution between any two exporters would be so high that price differences could never appear except ephemerally, and the response that price differences would produce would never be observed. In such a world, shifts in trade would come about as the result of changes in the relation of domestic costs to internationally determined prices. However, the law of one price is not a useful empirical generalization,[1] and this explanation too fails to explain the apparent paradox.

Studies of the determinants of exports and imports generally have relied on "price" index proxies in which the individual commodity data either are not prices at all and do not behave like prices (unit value indexes) or are prices but refer to domestic rather than international trade (wholesale price indexes). In both cases the indexes are usually inconsistent from country to country in coverage and weighting.[2] Although many investigators mention in passing the defects of the price measures they use, they rarely attribute the poor results to them.

We suspect that some of the difficulties in analyzing the relation between prices and trade flows stem from the defects of the price measures used. We have prepared a new set of price measures for machinery and transport equipment that we consider to be more appropriate to the analysis of trade flows than those used in previous studies and we try in this paper to see if these new indexes permit us to explain trade flows more successfully or to assign any different role to price changes and income changes than did previous studies. Some of these indexes are new and some are

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[1] Kravis and Lipsey (1978).

[2] Kravis and Lipsey (1974).

extensions of indexes we previously published. They refer to the prices of both exports and the corresponding domestic products in the United States, Germany, and Japan.[3] We confine ourselves here to machinery and transport equipment (SITC 7)[4] because these are the products for which the commonly used unit value data are most obviously deficient[5] and because both our earlier work on the period up to 1964 and the more recent work of the Bureau of Labor Statistics on U.S. export price indexes provide good coverage over a long period (1953-77) only for these products.

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[3] The early work was presented in Kravis and Lipsey (1971). The indexes used in the present paper are extensions, and interpolations of the indexes developed there and are revisions and extensions of those in Kravis and Lipsey (1977a and 1977b), making extensive use of the official export price indexes for individual commodities published by the United States, German, and Japanese governments.

[4] See U.N. Standard International Trade Classification, Revised (Statistical Papers, Series M, No. 34 (1961).

[5] Kravis and Lipsey (1971).

Recent export equations

As background to our experiments with the new price data it may be worth while to summarize some of the results produced using the proxy price measures. A systematic survey of export equations would be impossible here but the ones mentioned are typical of the genre.

Very few of the export equations that have been fitted for this period, or parts of it, even attempt to explain trade shares or relative exports. An exception is Junz and Rhomberg (1965), in which export unit values, wholesale prices, and labor cost are used as proxies for price. Out of nine of their equations for exports of Germany, Japan, and the United States, 1953-63 (one for each price proxy variable for each country), five show perverse (positive) price coefficients for current year changes. However, only two out of nine coefficients are positive when "prices" and quantities are measured over three-year spans. The general impression from their equations is that German exports are most sensitive and U.S. and Japanese exports less sensitive or totally insensitive to price changes. In a later paper by the same authors (1973) equations calculated from pooled data for industrial exporters in general, with unit values as the price proxy, suggest quite strong price response and long lags in response to relative unit value changes. The peak response is in the third year after price changes. However, no elasticities were calculated for individual countries.

Most export equations are for the exports of individual countries, typically fitted to export levels, rather than changes. We summarize some of these in Table 1, omitting dummy variables, constant terms, and trend terms.

Table 1

Price Elasticities and Income Elasticities
of Demand from Export Equations

Single equations based on annual data, except as noted
Dependent variable: volume of total exports

	Houthakker-Magee	OECD[a]	Goldstein-Khan[b]	LINK-Wharton	Hooper[b]	Balassa
	(1)	(2)	(3)	(4)	(5)	(6)
Price Elasticities						
Germany	+1.70	-0.99	-0.52	-0.39	NA	NA
Japan	-0.80	-1.25	0.07		NA	NA
to U.S.				-4.39[b]		
to ROW				-2.03[b]		
U.S.	-1.51	-1.00	-2.13	+0.85	-0.74	NA
Income Elasticities of Demand						
Germany	2.80	1.23	NA	1.35	NA	2.27
Japan	3.55	1.97	NA		NA	2.00
to U.S.				3.07[b]		
to ROW[f]				1.84[b]		
U.S.	0.99	0.81	NA	0.88	1.22	2.02
Period	1951-66	1955-69	1955-70	c/	1958-77	1955-71
Lags	None	None	None	d/	e/	None
Dummy variables	None	D,S,V,T	None	D	D	None

[a] Equations based on semiannual data.

[b] Equations based on quarterly data.

[c] Germany: 1957-70; Japan: 1958-71; U.S.: 1958-75.

[d] Japan: 3 quarters; U.S.: 1 year.

[e] 7-quarter polynomial lag distribution.

[f] Rest of world.

Dummy variables: D = Dock strike
S = Suez crisis
V = Vietnam war shock
T = Trend, 1955-58 for Germany

Sources: Col. (1) Houthakker and Magee (1969).
(2) OECD (1970).
(3) Goldstein and Khan (1978).
(4) Germany (LINK) from Krelle (1976), Japan (LINK) from Tatemoto and Yajima (1976), and the U.S. (Wharton) from Itzkovich (1977).
(5) Hooper (1978).
(6) Balassa (1979).

Among the estimates of price elasticities for German exports, Houthakker and Magee calculated a large perverse coefficient while the other investigators found negative coefficients, all for the current year only, ranging from -0.4 to -1.0. The Japanese export equations were in general a little more plausible, but the estimated export price elasticities ranged from zero up to -4.4 (for exports to the U.S.) in the LINK equation, the only one which used lagged prices (with a lag of three quarters). Most of the equations for the United States produced fairly large negative price coefficients, from -0.7 to -2.1, the exception being the Wharton annual model with a positive coefficient. The Wharton equation used a one-year lag, the Hooper paper a seven-quarter polynomial lag distribution, and the others, no lags.

We can summarize the price terms in the equations as including the possibility of no response or perverse response to price changes in each of the three countries, as well as the possibility of elasticities over 2 for U.S. and Japanese exports, but only 1 at most for German exports. The period within which the price effects took place, according to these equations, was only the year of the price change, for Germany, and that year and one year back for Japan and the United States. None of these investigators reported any effects beyond one year after a price change.

Estimated income elasticities for exports show a similarly wide range of coefficients, although none is perverse in sign. Houthakker and Magee produced the most extreme differences between the United States and the other two countries, the latter estimated to have income elasticities of demand for their exports almost three times that of the United States in the case of Germany and three and a half times as great for Japan. This is a puzzling result in view of the concentration of all three countries on manufactured goods exports, although that concentration is much higher for Germany and Japan (90 per cent or more) than for the United States (about two thirds). Other equations again show the highest income elasticities of demand for Japanese exports and the lowest for the United States, and several find the U.S. elasticity to be below one, again a surprise for a country exporting a high proportion of products, such as machinery, for which world demand seemed to be growing comparatively quickly. A contrast to the other studies is the constant-market-share analysis by Balassa which finds a U.S. elasticity above 2 and those of the other two countries very similar.

There is, then, as little consensus on income elasticities of demand as on price elasticities. Most of the studies calculate considerably higher income elasticities for Germany and Japan than for the United States, and low elasticities for the United States, but the range is very large. The idea that income elasticities of demand for U.S. exports are low does seem to have been widely accepted as a reason for U.S. balance of payments problems.

Another method of estimating these price-quantity relationships is by fitting systems of supply and demand equations for either relative exports or individual countries' exports. The relative quantity equations from Artus and Sosa (1978) suggest almost no response to price changes during the first year but substitution elasticities of about a half for Germany and one for the United States over three years. Elasticities of supply are estimated to be over 3 for the United States and over 4½ for Germany.

A somewhat similar set of equations for each country's exports individually, from Goldstein and Khan (1978), shows a high perverse (positive) price coefficient for Japanese exports, a price elasticity of demand of about 0.8 for German exports and over 2 for U.S. exports. The estimated supply elasticities were high and in the case of Japan, infinite. The income elasticities of demand for exports were similar to the single equation estimates: about one for the United States, 1.8 for Germany, and over 4 for Japan.

A common characteristic of these elasticity estimates, except those of Artus and Sosa, is that the proxy price variables bear only a vague resemblance to what would be appropriate, and it is therefore difficult to interpret the coefficients. Most use unit value indexes, which have serious deficiencies as measures of price change, as we indicated earlier. Even if the individual price observations were valid, ambiguity would be introduced by the fact that the combinations into indexes use different weights from country to country and between export and domestic price indexes. That means that it is impossible to know whether a relative price change is a change in the relationship between, say, the price of Japanese automobiles and the price of U.S. aircraft, in which case a low elasticity might be expected, or the prices of different sellers of the same commodities, in which case a high elasticity would be expected.

If the price data used in these studies are as defective as we believe they are, not only the price elasticity estimates but also the income elasticity estimates may be unreliable. For example, if a large increase in Japanese exports was caused by a decline in relative Japanese prices but that decline was not visible in a defective price index, the rise in exports may appear instead to have been associated with a rise in foreign income, and attributed to a high income elasticity of demand for Japanese exports. Thus, the estimates of both the income and the price elasticities may be distorted by defective price data.

We do not imagine that we have solved all the problems in calculating price and income elasticities and in understanding the determinants of the flow of trade. We do think we have produced much better price data for machinery and transport equipment than have been available before.[6] We therefore wish to investigate whether the use of these new data will produce different measures of price and income responses and enable us to better explain the workings of competition in these products. The methods of analysis and forms of equations are fairly standard, except for the supply and demand systems, and we have not taken the space to justify all the particular forms used.

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[6] For an explanation of the export price indexes see Kravis and Lipsey (1977a and 1977b).

Relative Prices and Quantities

There are two standard ways of measuring quantity-price relationships. One, the more typical, deals with one country at a time and produces measures of that country's price and income elasticities of demand for exports (and imports). The other is concerned with the competitive relationships between pairs or among groups of countries and produces measures of elasticities of substitution for the exports of one relative to the exports of the other or of a group of others. Each approach has its own advantages and drawbacks and each is put to use in what follows.[7]

The use of the elasticity of substitution, by its focus on relative quantities and relative prices, reduces the number of variables needed for a demand equation. It also tends to reduce the importance of variables other than relative price. For example, omitting relative income change of countries purchasing from the two different suppliers in a relative export equation would be much less serious than omitting purchasing countries' income from a single country's export equation. In the elasticity-of-substitution context, the assumption is that all excluded variables affect exports of the two countries proportionately. In fact, if, as is often the case, the competing countries specialize in somewhat different markets, the growth of income and changes in prices in various third countries may affect their exports differently even where there is no change in their relative prices.

The chief disadvantage of working with substitution elasticities is that they assume that observed quantity and price changes reflect observations

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[7] For discussions of these two types of analysis see Kravis and Lipsey (1972) and the accompanying comments by Stern and the exposition by Leamer and Stern (1970).

of relative demands.[8] Supply is assumed to vary through time but always to be infinitely elastic, and supply variables are difficult to incorporate into a relative quantity equation.

The one-country-at-a-time approach lends itself much more readily to incorporating supply influences, although, in fact, advantage has seldom been taken of this possibility. The data requirements for single-country equations are greater in that instead of comparisons of prices or price movements for pairs of countries, comparisons are needed between the given country and the rest of the world. The number of countries preparing price indexes for foreign trade is increasing but it will be some time before an annual time series covering even 15 or 20 years can be prepared in which the export prices or price changes of one country can be compared, trade category by trade category, with those of a sufficient number of other countries to account for the bulk of the trade of the rest of the world. The makeshift we employ here is to use a single country instead of the world as the basis of comparison; for Germany and Japan, it is the ratio of their export price movements to those of the United States; for the United States, prices are related to those of both Germany and Japan each taken in turn.

The quantity-price relations for machinery and transport equipment as a whole are summarized in Table 2 for the entire period and for selected sub-periods. The export quantities are obtained by dividing relative export

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8 If destination income is not explicitly included in the relative quantity equation, the effects of changes in income may be incorporated in the coefficient of the price variable. To the extent that export prices respond to changes in demand, as we have found they do [Kravis and Lipsey (1977a) and (1977b)], a rise in relative destination income may produce a rise in relative export price and, simultaneously, a rise in relative quantity. That change in price would be positively, rather than negatively, associated with quantity change, but it would be incorrect to attribute the quantity change to the price change. Although the introduction of destination activity measures might help in separating these effects, the difficulty stems fundamentally from our treatment of export price as exogenous, as we discuss later.

Table 2

Movements of Export Prices and Quantities: Germany and Japan Relative to United States, Selected Periods 1953-77

	1960/53	1970/60	1977/70	1977/53
Germany/U.S.				
Price	.95	1.16	1.51	1.66
Quantity	2.51	1.17	.88	2.58
Japan/U.S.				
Price	.78	.85	1.09	.73
Quantity	5.73	4.43	2.82	50.8

N.B. The variables are in the form of period to period relative changes. For example, the price entry for Germany for 1960/53 is

$$\frac{(P_{60}/P_{53})_G}{(P_{60}/P_{53})_{U.S.}}.$$

value changes by relative own-country-weighted export price changes.[9] The most striking feature of the figures is the large gains in the German volume of exports relative to the United States mostly in the 1950's and 1960's and the enormous gains of Japan, declining through time to be sure, but still very large even in the 1970's. However, what concerns us here is not these quantity changes per se but their relation to price changes.

Some of the figures in Table 2, such as for Germany in 1953-60 and Japan in 1953-70, suggest very high elasticities of substitution but there are also what appear to be perverse relationships, such as for Germany in 1960-70 and Japan in 1970-77, when relative price increases are accompanied by large increases in relative quantity over fairly long periods. Our problem is to explain this mixture of normal and seemingly perverse relationships.

A more systematic way of summarizing the crude quantity-price relationship is with a regression of relative quantity changes on relative price changes. In equations (1) and (2) the dependent variable (Q) is the annual percentage change in the quantity of exports relative to that of U.S. exports, and the independent variable (P) is the annual percentage change in price relative to that of the United States. The subscripts G and J refer to Germany and Japan, respectively, each taken relative to the

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These export price change indexes are not the ones that make up the explanatory price variable in our equations and in Table 2. That price measure is based on price change comparisons between countries at the 4-digit SITC level, weighted up by a single set of weights based on exports of the OECD countries as a group. Therefore, the price and quantity changes of Table 2 do not necessarily multiply out to the value change. Each value and quantity comparison with the United States is based on trade with third countries. The U.S. export values and quantities therefore differ between the German and Japanese comparisons.

United States.[10] The period covered is 1953-77 (t-ratios are in parentheses).

$$\ln Q_G = \underset{(1.80)}{0.057} - \underset{(1.12)}{0.433} \ln P_G \qquad \bar{R}^2 = .01 \quad DW = 1.95 \qquad (1)$$

$$\ln Q_J = \underset{(6.70)}{0.140} - \underset{(1.09)}{0.546} \ln P_J \qquad \bar{R}^2 = .01 \quad DW = 1.89 \qquad (2)$$

Little of the variation in quantity change is accounted for by price change in these equations. In the German case, the price change from 1953 through 1977 and the price coefficient of equation (1) suggest a decline of relative quantity by about 15 per cent, while what took place was an increase of over 150 per cent. For Japan, the price change over the whole period and the price coefficient of equation (2) suggest a relative quantity increase of about 35 per cent while the actual increase in relative quantity was over fifty-fold. In both cases, most of the quantity change implied by the equations is accounted for by the constant term; that is, it is accounted for by a very large, but unexplained, trend increase in Japanese and German exports relative to those of the United States.

The importance of the trend term is even clearer if we fit the equations to price and quantity indexes as is customary in the literature, rather than to price and quantity changes. Equations (3) and (4), using indexes with a

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[10] The variables are in the form of logarithms of year-to-year changes. For example, the German price, P_G, is

$$\frac{\left(P_t/P_{t-1}\right)_G}{\left(P_t/P_{t-1}\right)_{U.S.}}$$

The German equation has been corrected for first order serial correlation. The $\bar{R}^2$ are not comparable between corrected and uncorrected equations because the dependent variable in the corrected equation is no longer the actual quantity change.

$$\ln q_G = \underset{(4.29)}{7.34} - \underset{(2.15)}{0.81} \ln p_G + \underset{(3.46)}{0.05}\, T \qquad \bar{R}^2 = .30 \quad DW = 1.63 \qquad (3)$$

$$\ln q_J = \underset{(10.49)}{17.34} - \underset{(8.88)}{3.06} \ln p_J + \underset{(22.49)}{0.12}\, T \qquad \bar{R}^2 = .99 \quad DW = 2.27 \qquad (4)$$

1963 base,[11] explain the (corrected) quantities of exports fairly well, with $\bar{R}^2$ of .30 for Germany and .99 for Japan, after correction for serial correlation.[12] However, the explaining is done more by the time trend than by price, as can be seen from the Beta coefficients:

	β	
	Price	Time
Germany/U.S.	0.55	1.39
Japan/U.S.	0.31	0.74

That is the case even for Japan, with its high price coefficient in this form. Thus, a large part of the difference in the degree of explanation of quantity change between the first pair of equations (1) and (2) and this set is cosmetic as far as any economic explanation of the quantity changes is concerned.

We investigate here two sets of problems that may obscure quantity-price relationships in international trade and explain these poor results. One set of problems, common to all the different statistical approaches, involves the formulation of the quantity and price variables themselves. These include the need to take account of any time lags between quantity

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11 For example, the German price index, p_G, is

$$\frac{(p_t/p_{1963})_G}{(p_t/p_{1963})_{U.S.}}$$

12 The German equation includes a first order correction for serial correlation and the Japanese equation a second order correction.

and price variables. Account must be taken too of the possibility that differences in the level of prices rather than only time to time changes may be important in bringing about quantity changes. In addition, a given change in relative prices might have quantity effects that vary according to the market shares of the sellers. An even more fundamental problem is posed by the possibility that the method of deriving quantities used here and in other studies of quantity-price relations--viz., dividing the export value in current prices for the year t by a price index also referring to the year t--may involve a mismatching if the prices embedded in the observed values are prices for a previous period or mixture of periods.

The other set of problems is to take account of the general economic setting in which the quantity-price relationships are observed. It is quite usual, for example, to include income or activity variables as additional independent variables in equations in which prices are used to explain quantities, but it is much less common to take account of the simultaneous character of demand and supply or indeed of the influence of supply at all. Most of the standard works cited in this field of investigation simply assume, as do equations of the character of (1) and (2), that the historically observed prices and quantities trace out a demand curve.

In what follows we begin with the elasticity of substitution approach and resort to the one-country-at-a-time approach to introduce supply variables into the explanation of quantity change.

Formulating the price and quantity variables

There are several reasons why we might expect some lags in response to price changes. Buyers may be slow to react to price changes and continue to order from the same suppliers for some period even though other sellers are offering lower prices. There may be some interval before relative price changes are recognized and then some further time before the relative price change is considered sufficiently permanent for the buyer to undertake the costs of changing suppliers. The costs may be very high for some of these products such as aircraft, for which a change in suppliers requires new stocks of spare parts and possibly the retraining of personnel.

There is in addition a mechanical reason: the price data are as of date of order while the values of exports are as of date of delivery, and there may be a considerable lag between order and delivery, especially for complex machinery, some of which is produced to order. This will impart a bias to the measure of the dependent variable, quantity change, when the quantity change is derived from the division of the value of exports in the period t by the price in period t. If, in fact, value in t is the price of t-1 (or t-2 or t-n or some combination of previous periods) times the quantity in t, then the derived quantity will be wrong.[12a]

Aside from these bases for lags in quantity responses there are reasons to expect that the lags may be difficult to measure. Buyers may not only be slow to respond to price changes, but may treat them as containing a good deal of random variation not relevant for long-term purchasing decisions. If that were the case, they might react only to cumulations of price changes over several years, with no consistent response to each individual year's price movements. Another possibility is that there is some underlying pattern of response to price changes, but that it will be obscured by random variation in quantities. A third is that both the price and the quantity data on an annual basis contain a good deal of random error or variation, the effect of which we might reduce by comparing prices and quantities over time spans greater than a year or two.

The results of experiments involving a number of ways of coping with these problems of formulating the price and quantity variables are summarized in Table 3. We include here, along with the equations for SITC 7 shown up to this point, corresponding equations for the pooled subdivisions SITC 71, 72, and 73. The elasticities implied by equations 1 and 2 are set out again for comparative purposes in columns (1) and (2).

The results of adding P_{t-1} as an independent variable to the equation containing P_t[13] are shown in columns (3) and (4); the $\bar{R}^2$'s rise substantially

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[12a] For some comments on delivery lags with reference to the use of unit values in conjunction with price data see Magee (1975).

[13] Where P_t in an equation for Germany, for example, is what we have referred to earlier as P_G, or

$$\frac{(P_t/P_{t-1})_G}{(P_t/P_{t-1})_{U.S.}}$$

Table 3

Summary of Elasticities of Substitution and $\bar{R}^2$ from Equations Relating Relative Quantity Change to Relative Price Change Germany/U.S. and Japan/U.S.

	Dependent Variable = $\frac{V_t}{P_t}$ and independent variables are:								Dependent Variable = $\frac{V_t}{P_{t-1}}$ and independent variables are:					
	P_t		P_t & P_{t-1}		Polynomial Lag of P		Averages of P_t P_{t-1} & P_{t-2}[c]		P_{t-1}		P_{t-1}, P_{t-2}		Averages of P_{t-1} P_{t-2} & P_{t-3}	
Commodity Coverage (SITC)	Price Coef-ficient (1)	$\bar{R}^2$ (DW) (2)	Price Coef-ficient (3)	$\bar{R}^2$ (DW) (4)	Price Coef-ficient (5)	$\bar{R}^2$ (DW) (6)	Price Coef-ficient (7)	$\bar{R}^2$ (DW) (8)	Price Coef-ficient (9)	$\bar{R}^2$ (DW) (10)	Price Coef-ficient (11)	$\bar{R}^2$ (DW) (12)	Price Coef-ficient (13)	$\bar{R}^2$ (DW) (14)
Germany														
7	-.43 (1.12)	.01 (1.95)[d]	-1.25 (3.90)	.41 (2.04)	-1.59 (4.32)	.39 (1.99)[d]	-1.47 (4.45)	.47 (1.85)	-1.71 (5.46)	.57 (1.81)	-1.86 (5.10)	.58 (1.73)	-1.82 (3.64)	.38 (1.86)
71,72,&73	-.63 (2.69)	.09 (1.70)	-1.25 (5.50)	.34 (1.90)	-1.46 (4.97)	.31[a] (2.00)	-1.41 (5.24)	.31 (1.90)	-1.65 (7.88)	.49 (1.76)	-1.81 (7.03)	.49 (1.72)	-1.78 (5.45)	.33 (1.97)
Japan														
7[f]	-.55 (1.09)	.01 (1.89)	-1.54 (3.41)	.43 (2.15)	-2.62 (3.26)	.38 (2.51)	-2.12 (6.67)	.69 (1.45)[d]	-1.92 (4.29)	.45 (2.10)	-2.46 (8.04)	.76[e] (1.79)	-2.77 (6.74)	.69 (1.66)[d]
71,72,&73[g]	-.26 (.57)	-.01 (2.04)[d]	-.97 (2.09)	.06 (2.23)[d]	-2.05 (2.85)	.10[b] (1.58)	-1.32 (2.55)	.08 (2.22)[d]	-1.31 (3.41)	.14 (2.13)[d]	-1.69 (3.91)	.18 (2.17)[d]	-2.08 (3.97)	.20 (2.16)[d]

[a] Includes P_t and 3 lagged price terms.

[b] Includes P_t and 5 lagged price terms.

[c]

$$P = \sqrt[3]{\frac{P_t}{P_{t-1}} \cdot \frac{P_{t-1}}{P_{t-2}} \cdot \frac{P_{t-2}}{P_{t-3}}} = \sqrt[3]{\frac{P_t}{P_{t-3}}}$$

[d] Equations with first order corrections for serial correlation.

[e] Equations with second order corrections for serial correlation.

[f] Excluding one year of extremely large relative quantity increase.

[g] Excluding two years of extremely large relative quantity increases in SITC 73.

and the total response of Q to P, measured by the sum of the coefficients of P_t and P_{t-1}, increases markedly in every case. The underlying equations, not shown to save space, have coefficients for P_{t-1} that are at least three times larger than that of P_t; also the P_{t-1} coefficients are more than twice their standard errors while those for P_t are less than their standard errors. The addition of P_{t-2} (not shown) tends to raise the cumulated price coefficients in every case and the $\bar{R}^2$ at times, but the coefficient for price lagged two years is never statistically significant by itself. Additional lagged price terms tended to produce coefficients that were erratic in their year to year behavior, but with some significant terms for fairly long lags.

Since there seemed to be some long-lasting price effects that were being obscured by erratic quantity changes and the smallness of our numbers of observations, we experimented with the use of a fitted second degree polynomial lag pattern. These patterns, in columns (5) and (6), produced higher summed coefficients for the price terms, but slightly lower $\bar{R}^2$s. They suggested that price terms out as far as t-3 and, in the case of Japan, t-5, could add to the explanation of relative quantity change.

Another technique, which economizes on degrees of freedom, is to relate annual quantity change to price changes over a span of years or, in effect, to the cumulation of price changes over several preceding years as in columns (7) and (8). For Germany these results are similar to those based on the fitted polynomial lag patterns and they produce the highest $\bar{R}^2$s we can obtain for SITC 7 using V_t/P_t as the dependent quantity variable.[14]

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[14] The implication of using a three-year average of price changes is that buyers are reacting to a cumulation of price changes over three years, that each year's price change has an equal effect on the quantity change in the current year, but that the price change one year further back (that is, P_{t-3}) has no influence at all. A compromise between such an arbitrary structure and letting the data establish the lag pattern completely is to fit a structure to the lags that has some limits, such as maximum length, but also allows the data to determine some aspects of the weights to be assigned to current and past price changes, as in the polynomial lag distributions we fitted for the equations shown in columns (5) and (6).

The introduction of lagged price terms and the use of average price changes over three years tend to reduce the effect of the possible mismatching of price and value data (i.e., assuming that $V_t = P_t Q_t$ and therefore $Q_t = \frac{V_t}{P_t}$ if in fact $V_t = Q_t P_{t-1}$ or $Q_t P_{t-n}$). In columns (9) to (14) the mismatching problem is attacked directly by assuming that V_t embodies on the average the prices of the previous year and that Q_t thus may be derived from the expression $\frac{V_t}{P_{t-1}}$.

It seems clear that this assumption, arbitrary though it is, merits favorable consideration relative to the usual tacit acceptance that V_t embodies t prices. When lagged price for one year is used as the independent variable to explain V_t/P_{t-1}, as in columns (9) and (10),[15] the coefficients are higher than those that result from the use of two years' prices to explain V_t/P_t, in columns (3) and (4), and the $\bar{R}^2$ is also higher in all of the four cases. The best results for Germany/U.S., among a number of experiments we tried, come from the use of prices lagged one year or one and two years, treated as separate variables. For Japan/U.S., the best equations were those using an average of one-, two- and three-year-lagged price changes.

For both Germany and Japan the inference appears quite strong that a one per cent change in relative prices will, over a four year period (allowing for a one year average lapse between order and delivery time), be accompanied by something like a 2 per cent change in relative quantities.

There are some grounds for believing that the quantity response might be even greater if a longer time period were considered. To examine this possibility it is necessary to pool data for Germany/U.S. and Japan/U.S.

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15 Since it is assumed that goods ordered in period t-1 are delivered in period t, the most recent relative prices that can affect quantities in period t are those of period t-1. The prices of period t thus play no part in these equations.

for the three sets of two-digit categories, in order to have enough observations. When relative quantity changes are related to relative price changes over successively longer periods of time,[16] the results are as follows:

Time Span (years)	Coefficient of Prices	$\bar{R}^2$
3	-1.31 (3.76)	.26
5	-1.67 (3.18)	.28
7	-2.69 (3.80)	.51
10	-2.93 (3.05)	.48

The elasticity of substitution rises monotonically and reaches almost 3 for the ten-year spans, well above those of the earlier equations. The $\bar{R}^2$ also increases as the length of the span rises, even though the number of observations decreases sharply from 36 for the three-year spans to 10 for the ten-year spans.

The tentative conclusion we draw from these experiments is that price changes have a substantial impact on relative export quantities that takes years to unfold. We confirm the findings of Junz and Rhomberg (1965) that price effects are stronger over three-year spans than in annual changes but with more consistently appropriate signs and a somewhat different

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16 Note that in these equations both the P's and Q's are averaged over the periods, whereas in Table 3 only the P's were averaged.

The period covered by these equations is determined by the time spans and the availability of data. All the equations begin with 1953. Those for Japan for 3- and 5-year spans end with 1977 (the last a 4-year span), those for Germany for 3- and 7-year spans and for Japan for 7-year spans end in 1974, and those for Germany for 5- and 10-year spans and for Japan for 10-year spans end in 1973.

formulation of the variables. We also confirm their later finding (for a different group of countries)[17] that price effects stretch out as far as five years. In fact our pooled German and Japanese data, referred to above, offer evidence that they may last longer than that. These long lags greatly handicap the effort to measure the price-quantity relationships since the short time span for which export price data are available limits the number of degrees of freedom. The use of quarterly instead of annual data would provide more observations, but the problem of matching values and prices would be greatly exacerbated and quarterly data would require the estimation of four times as many lagged terms as annual data. Also, the publication of quarterly export price series for SITC 7 for the United States did not begin until the mid-1970's.

Limitations of data prevented us from fully exploring two other aspects of the price variable. One is the possibility that the long lags may reflect not only slow responses to price change but also a response to a cumulation of price changes that eventually open up a wide gap in price levels. Since changing suppliers may be costly, a decision to shift should depend on a comparison of the gains with these costs, and the gains should depend on the difference between the suppliers' price levels, rather than on the change in relative prices. A large fall in prices by a high-priced supplier may not induce buyers to shift to him if his prices are still above or only a little below those of traditional sources of supply. A small fall in price may finally tilt the balance in favor of an already somewhat lower-priced supplier.

There is a host of anecdotal evidence for the use of low price levels, particularly by Japan, as a way of breaking into new markets or expanding market shares. The economic and financial press frequently reports cases

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17 Junz and Rhomberg (1973).

of notable differences in prices charged by different sellers in the same market, even for homogeneous products like copper, and we encountered many such cases for machinery in our earlier study (Kravis and Lipsey, 1971).

Experiments with the use of the level of prices (L)[18] alone suggested that quantity changes do respond to price level differences, and the equations are improved by the addition of current price change. However, when lagged price change is added, the price level effect is often obliterated or at least greatly reduced.

The fact that our price level data for SITC 7 were limited to Germany/U.S. and that those for Japan/U.S. were limited to SITC 72 was particularly constraining because the price levels for one commodity group for one country, L_t, L_{t-1}, L_{t-2}...., show strong serial correlation, and the price levels and price changes are also correlated in many cases.[19] Our feeling is that price levels do sometimes play significant roles,[20] but we are unable to provide strong support for that belief.

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[18] The L variable corresponding to P $\left[\frac{(P_t/P_{t-1})_G}{(P_t/P_{t-1})_{U.S.}}\right]$ is $\frac{(P_{t-1})_G}{(P_{t-1})_{U.S.}}$.

[19] In fact the price levels for different years are estimated from a single year's price levels and the price competitiveness index, which is our measure of relative price change.

[20] For Japan/U.S. in SITC 72 with correction for first-order serial correlation:

	Coefficient	t-ratio	
P	-1.27	2.20	$\bar{R}^2$ = .16
P_{t-1}	-0.02	0.04	DW = 2.02
L	-1.78	2.11	

Another factor that could affect the quantity response to a given price change is the market share of the exporting country.[21] We suppose that small shares should be associated with high elasticities, the reasoning being that a country with a small export share is virtually in the position of being able to export as much as it wishes at the going international price, without affecting the price. A country with a large share, however, could not easily draw customers away from others by lowering prices.

Since market shares tend to be fairly stable over time we did not attempt to use this variable with annual data but only with time spans of three or more years. The form of the equation was

$$Q = aP^{b_1 + b_2 MS}$$

where MS is the market share and Q and P are quantity and price changes, as before. Equation (5) is for three-year spans, for Germany and Japan, SITC 7.

$$\ell n\ Q = \underset{(4.70)}{0.28} - \underset{(2.66)}{2.93}\ \ell n\ P + \underset{(1.11)}{6.90}\ (MS \cdot \ell n\ P) \qquad \bar{R}^2 = .51,\ n = 16 \qquad (5)$$

The export shares and implied elasticities of substitution for SITC 7 in the first and last periods were as follows:

	Share		Elasticity of Substitution	
	First Period (1953-55)	Last Period (1974-76)	First Period (1953-55)	Last Period (1974-76)
Germany	14	21	-1.95	-1.45
Japan	2	14	-2.82	-1.95

21

Several possible relationships between market share, direction of price change, and substitution elasticity were explored in an earlier paper using somewhat different commodity groups and a much shorter time period (Kravis and Lipsey, 1972), but the hypothesis we investigate here is that the elasticity is a function of market share alone.

Although the market share term was never statistically significant at the 5 per cent level for either the 1-digit or 2-digit equations or for any of the time spans, it did imply large and plausible differences in the estimated substitution elasticities. In particular the equation implied a substitution elasticity of almost 3 for Japan relative to the United States in the early years when the Japanese share was very low, and a substitution elasticity of about 1½ for Germany relative to the United States in the later years, when the German market share was high.[22]

Again we have a price-related variable that we think plays a substantial role, but one which we cannot demonstrate convincingly.

Another experiment we tried with these data was to break down the relative price change in dollars into two elements: the relative change in own-currency prices and the change in exchange rates, to test whether quantities responded in different ways to them. The experiment could only be performed on pooled data for three two-digit SITC classes because it doubled the number of independent variables used. It gave some not very conclusive indications of greater response to exchange-rate changes than to own-price changes. However, especially in the case of Japan, there were only a few exchange rate changes in our whole period, all concentrated in the last five years.

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22 The market shares used in these equations were those of Germany and Japan. The U.S. market share was ignored even though it should have some effect on the elasticity. One reason for excluding the U.S. market share is that it is correlated with the other two, since the three countries combined account for such a large part of exports of these products. However, it would probably be worth while to experiment with including both market shares or a variable representing relative market shares.

Price and Quantity Changes in a Broader Economic Setting

Up to this point we have concentrated exclusively on equations to explain relative exports, and have succeeded in explaining a large part of the variation in relative export quantity changes in SITC 7. For Germany/U.S. the proportion explained was nearly 60 per cent. For Japan/U.S. it was over 40 per cent in equations without corrections for serial correlation and 80 per cent in corrected equations. However, the $\bar{R}^2$s are not comparable after correction because the dependent variable is not the original quantity change.[23]

We have also found elasticities of substitution usually above 1.5 and ranging up to 3 when we took V_t/P_{t-1} as the dependent variable and allowed for lags in response or the influence of market shares. Even elasticities at the upper end of this range, however, cannot alone explain the more than five-fold increase in Japanese export quantities relative to the United States between 1953 and 1960 and the 50-fold increase between 1953 and 1977 in terms of the 22 per cent diminution in Japan's export price relative to the United States in 1953-60 and 27 per cent in 1953-77. Price, as it affected quantities demanded by third countries, obviously was not the only influence at work. For a search for other factors, we turn to the one-country-at-a-time approach.

The simplest explanation of a country's exports is usually cast in terms of relative prices and foreign incomes. The results of equations for SITC 7 incorporating these variables are shown in Table 4. As already noted, a substantial limitation of this and other work on single countries reported subsequently is the need to form the relative price variable as the ratio of each country's export price movements for SITC 7 to that of a single foreign country rather than with reference to those of the rest of the world.

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23 See Table 3. The levels of explanation are lower for pooled data for the three two-digit divisions of SITC 7. In connection with both SITC 7 and the pooled data it should be kept in mind that the equations deal with changes and that equations for export quantity levels produce much higher $\bar{R}^2$, as was pointed out earlier.

Table 4

Equations Relating Changes in German, Japanese, and U.S. Exports to Changes in Relative Prices and Destination Activity

	Current Terms Only			Current and Lagged Terms			Fitted Polynomial Lag in Price			Price Term Average of P_t, P_{t-1}, P_{t-2}		
	Coefficients of			Coefficients of			Coefficients of			Coefficients of		
	Relative Price (1)	Activity Variable* (2)	$\bar{R}^2$ (DW) (3)	Relative Price (4)	Activity Variable* (5)	$\bar{R}^2$ (DW) (6)	Relative Price (7)	Activity Variable* (8)	$\bar{R}^2$ (DW) (9)	Relative Price (10)	Activity Variable* (11)	$\bar{R}^2$ (DW) (12)
DEPENDENT VARIABLE: $Q_t = \frac{V_t}{P_t}$												
Germany	-0.19 (0.83)	0.65 (2.10)	.11 (1.91)[2]	-0.32 (2.26)	1.90[a] (4.71)	0.55 (2.05)	-	-	-	-0.42 (2.18)	1.60[a] (3.81)	0.48 (1.93)
Japan**	-0.11 (0.31)	0.77 (2.30)	.14 (2.11)	-0.76 (1.53)	3.79[b] (3.72)	0.39 (2.15)	-1.18[c] (2.74)	2.33[b] (2.40)	0.48 (2.50)[3]	-1.21 (4.56)	2.61[b] (4.16)	0.61 (1.92)
U.S. with Prices Relative to												
Germany	-0.40 (1.38)	2.33 (1.94)	.17 (2.02)[2]	-1.22[b] (4.21)	5.57[a] (4.14)	0.59 (2.14)[3]	-1.39[d] (6.32)	5.62[a] (4.89)	0.74 (1.98)[1]	-1.20 (3.93)	3.02 (3.24)	0.50 (1.70)
Japan	-0.88 (2.22)	1.25 (1.02)	.23 (2.08)[2]	-2.10[b] (4.38)	7.36[a] (6.46)	0.79 (2.02)[2]	-2.38[d] (7.37)	5.90[a] (5.62)	0.83 (2.12)[2]	-1.77 (4.57)	2.98 (3.46)	0.57 (1.89)

(cont.)

TABLE 4 (concl.)

	Current Terms Only			Current and Lagged Terms			Fitted Polynomial Lag in Price			Price Term Average of P_t, P_{t-1}, P_{t-2}		
	Coefficients of			Coefficients of			Coefficients of			Coefficients of		
	Relative Price (1)	Activity Variable* (2)	$\bar{R}^2$ (DW) (3)	Relative Price (4)	Activity Variable* (5)	$\bar{R}^2$ (DW) (6)	Relative Price (7)	Activity Variable* (8)	$\bar{R}^2$ (DW) (9)	Relative Price (10)	Activity Variable* (11)	$\bar{R}^2$ (DW) (12)
DEPENDENT VARIABLE: $Q_t = \frac{V_t}{P_{t-1}}$												
Germany	-0.68[e] (2.44)	0.72[e] (1.58)	.20 (1.65)	-0.62[e] (2.94)	2.38[a] (4.10)	0.51 (2.04)	-	-	-	-0.50[e] (2.02)	1.88[a] (2.85)	0.44 (1.99)[1]
Japan**	-1.25[e] (1.96)	1.74[e] (2.94)	0.31 (1.97)	-0.86[e] (2.35)	4.25[b] (5.03)	0.53 (2.07)	-1.28[f] (3.76)	3.30[b] (4.02)	0.65 (2.01)[1]	-1.31[e] (3.92)	3.24[b] (4.44)	0.68 (2.03)[1]
U.S. with Prices Relative to												
Germany	-.91[e] (3.16)	2.57[e] (2.29)	.44 (2.22)	-1.61[f] (5.03)	5.99[a] (4.07)	.65 (2.00)[1]	-1.62[g] (5.40)	5.96[a] (4.23)	0.68 (1.96)[1]	-1.62[e] (4.94)	6.13[a] (5.81)	0.63 (2.27)
Japan	-1.18[e] (2.89)	1.82[e] (1.50)	.42 (2.26)	-2.54[f] (6.53)	6.15[a] (4.33)	.75 (2.47)[3]	-2.44[g] (8.71)	5.57[a] (5.21)	0.84 (1.87)[1]	-2.62[e] (6.84)	6.90[a] (6.79)	0.76 (2.23)

Notes to Table 4

[a] Current and lagged one year.

[b] Current and lagged one and two years.

[c] Current period and lagged one and two years; second degree polynomial with tail restricted to zero.

[d] Current period and lagged one, two, and three years; second degree polynomial with tail restricted to zero.

[e] Independent variable is lagged one year. There is no current observation.

[f] One, two, and three year lags; no current observation.

[g] One, two, and three year lags; second degree polynomial with tail restricted to zero.

[1] Equations with first order correction for autocorrelation.

[2] Equations with second order correction for autocorrelation.

[3] First and second order corrections failed to eliminate autocorrelation.

*Destination income for the United States and destination leading cyclical indicators for Germany and Japan.

**Japanese equations exclude one large quantity increase.

The income variable is the real income in a country's markets for a product, calculated for each country's exports of every 1-, 2-, 3-, and 4-digit SITC group. For each of these groups the calculation produced the average change in destination income by weighting each destination country's change in real GDP by its 1963 share in the exports of the given commodity group from the country of provenance.[24]

An alternative to the destination income variable, based on business cycle conditions, was calculated from indexes of leading business cycle indicators for each country compiled by Geoffrey H. Moore and Philip A. Klein as part of the National Bureau's studies of International Economic Indicators.[25] The destination indicator indexes were calculated in much the same way as the destination income indexes, weighting by the country's exports of each product to each destination; however, only seven destination countries were included instead of over 100, as in the income index. The seven countries were the United States, the U.K., Canada, Japan, France, Germany, and Italy.

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[24] Thus the destination income variable for U.S. exports of commodity j in 1970 relative to the base year, 1963, would be

$$\sum_{i=1}^{n} w_{ij} \left(Y_{i(1970)} / Y_{i(1963)} \right)$$

where w_{ij} is the share of country i in U.S. exports of commodity j in the base year, 1963, $Y_{i(1970)}$ is country i's real GDP in 1970, $Y_{i(1963)}$ is country i's real GDP in 1963, both measured in constant local currency prices, and n is the number of countries.

[25] See Moore and Klein (1977).

The sample of results presented in Table 4 shows the coefficients of the relative price and activity terms for the best examples of the following sets of equations:

Col. (1) to (9): Quantity derived as current year value (V_t) divided by current year price (P_t)

- Col. (1) to (3): current year only
- Col. (4) to (6): current and lagged, including fitted polynomial lag patterns for price
- Col. (7) to (9): average of current and two previous years on price; various lags on activity

Col. (10) to (15): Quantity derived as current year value (V_t) divided by price lagged one year (P_{t-1})

- Col. (10) to (12): same as (4) to (6)
- Col. (13) to (15): same as (7) to (9)

On a current basis, when quantities are measured as V_t/P_t, all the demand elasticities are less than unity and in only one of the U.S. equations is the price coefficient significant at the 5 per cent level.

The corresponding equations when quantity is defined as V_t/P_{t-1}, in which the "current" price and activity terms are actually lagged by one year to correspond with the assumed date of order, explain much more of the quantity variation. Both price and activity terms are significant in most equations and well above those estimated from the more usual deflation.

The advantage of the V_t/P_{t-1} deflation diminishes when longer lags are added to the equations although the $\bar{R}^2$ still tend to be a bit larger. The German price elasticity is consistently the lowest and always below one and that of the United States pretty consistently the highest, although there are exceptions.

United States income elasticities in these equations are generally the highest among the three countries,[26] and some are extremely high, as much as 6 or 7. We do not have much confidence in these income elasticities, mainly because we are not at all sure we can distinguish well between the effects of the trend-like movement of destination income and the effects of other trends in omitted variables. The latter are supposed to be incorporated into the constant term in the equations that are the basis for Table 4, but might well have crept into the income coefficients. This use of a constant term is equivalent to including a time variable in the more usual equations in which price and quantity are indexes on a single base. The inclusion of a constant term (or time variable in the other form) may produce activity coefficients related more to cyclical fluctuations in income and less to trend movements than those from equations without such a term.

If we omit the constant terms from the single-country equations, we estimate quite different coefficients, as can be seen in Table 5, which gives coefficients from equations analogous to those of Table 4 rather than from the best equations without constant terms. There are some differences in price coefficients but the largest ones are in the destination activity coefficients, sharply higher for Japan and lower for the United States. The activity coefficients also appear more consistent from equation to equation once the constant term is omitted.

To a disturbing degree, the activity terms are sensitive to the inclusion of a constant term. We are particularly skeptical of both the high

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26 The business cycle indicators are not income indexes but they were constructed in such a way that their trends are equal to those of real GNP. However, the cyclical amplitude need not be the same. It is probably larger, since the leading indicators emphasize investment activities.

Table 5

Comparison of Coefficients of Relative Price and Destination Activity in Equations With and Without Constant Terms

DEPENDENT VARIABLE: $Q_t = V_t/P_t$

	Current and Lagged Terms			Fitted Polynomial Lag in Price			Price Term Average of P_t, P_{t-1}, P_{t-2}		
	Coefficients of			Coefficients of			Coefficients of		
	Relative Price	Destination Activity	$\bar{R}^2$	Relative Price	Destination Activity	$\bar{R}^2$	Relative Price	Destination Activity	$\bar{R}^2$
With Constant Term									
Germany	-0.32	1.90[a]	0.55	-	-		-0.42	1.60[a]	0.48
Japan	-0.76	3.79[b]	0.39	-1.18[c]	2.33[b]	0.48[3]	-1.21	2.61[b]	0.61[1]
U.S. with Price Relative to									
Germany	-1.22[b]	5.57[a]	0.59[3]	-1.39[d]	5.62[a]	0.74[1]	-1.20	3.02	0.50
Japan	-2.10[b]	7.36[a]	0.79[2]	-2.38[d]	5.90[a]	0.83[2]	-1.77	2.98	0.57
Without Constant Term									
Germany	-0.32	2.15[a]	0.59	-	-		-0.35	2.11[a]	0.52
Japan	-1.41	6.07[b]	0.47[1]	-1.71[c]	5.94[b]	0.55	-1.74	5.49[b]	0.60[1]
U.S. with Price Relative to									
Germany	-1.02[b]	0.94[a]	0.43	-1.16[d]	0.78[a]	0.46	-0.98	0.98	0.42
Japan	-1.68[b]	1.75[a]	0.58	-2.13[d]	1.72[a]	0.69[1]	-1.73	1.76	0.55

[a]Current and lagged one year.

[b]Current and lagged one and two years.

[c]Current and lagged one and two years; second degree polynomial with tail restricted to zero.

[d]Current and lagged one, two, and three years; second degree polynomial with tail restricted to zero.

[1]Equations with first order correction for autocorrelation.

[2]Equations with second order correction for autocorrelation.

[3]First and second order corrections failed to eliminate autocorrelation.

U.S. income elasticities in equations with constant terms and the high Japanese income elasticities in equations without constant terms. In the former case the high estimated income elasticity for U.S. exports is accompanied by a large negative constant term, implying an important omitted negative influence on the trend of U.S. exports, which we cannot readily identify. In the case of Japan, the large positive constant term, perhaps picking up the effects of increases in the supply function for Japanese exports, seems more plausible than the extremely high income elasticity estimated in the equation without a constant term.

Given our preferences among the equations, we find that income elasticities of demand for Japanese exports were somewhat higher than those for German and U.S. exports and that the latter two were similar, with those for Germany possibly a bit higher.

It may be pointed out again that we would have obtained higher $\bar{R}^2$ by shifting the form of the P and Q variables from year to year changes to linked index numbers with a common base. For example, if we fit equations to the linked quantity, relative price, and income data (1963=100) even with no lags or time trends, as in equations (6)[27] and (7),[28] where Y is

$$Q_G = \underset{(4.52)}{-6.31} - \underset{(1.08)}{0.18}\,P_G + \underset{(9.06)}{2.51}\,Y \qquad \bar{R}^2 = .78 \quad DW = 2.77 \tag{6}$$

$$Q_J = \underset{(2.43)}{-9.38} - \underset{(2.10)}{1.34}\,P_J + \underset{(14.96)}{4.34}\,Y \qquad \bar{R}^2 = .94 \quad DW = 1.64 \tag{7}$$

destination income, the $\bar{R}^2$ are extremely high even though the corresponding equations in terms of changes produced low $\bar{R}^2$.

Owing to our concentration on machinery and transport equipment, the coefficients from single-country equations summarized in Tables 4 and 5, based on our new price indexes, cannot be compared directly with those of previous investigators for total exports summarized in Table 1. One important difference--our finding of lags of at least up to three years,[29]

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[27] With second order correction for autocorrelation.

[28] With first order correction for autocorrelation.

[29] Longer lags were not tested.

in contrast with lags of not more than one year in the equations reported there--may be partly due to the difference in commodity coverage. It is at least as likely to be attributable to our use of genuine export prices in constructing our indexes. With respect to price elasticities, our estimate for Germany is close to the average of the three that calculated negative price coefficients. Our estimate for the United States price elasticity using prices relative to Germany is similar to several others but that based on prices relative to Japan is higher than all but one of them.

The higher income elasticities we find for the United States even in the equations without constant terms may again be due to the fact that our data are limited to machinery and transport equipment. Within these groups we find no clear indication that the income elasticity of demand for U.S. exports is much lower than that for German exports at least. Since we are looking at the same commodity groups in all three countries, although with different weights, we would expect the income elasticities to be similar. At least part of the reason for the large differences between the United States and other countries in estimated income elasticities for total exports may be the fact that the United States is the only one of the three countries in which commodities other than manufactures are of major importance, and that those commodities probably have lower income elasticities of demand.

Some of the results up to this point may reflect the bias arising out of the use of a single demand-type equation that ignores supply influences.[30] Clearly it is more appropriate to estimate separate demand and supply equations that recognize the likelihood that export quantities and export prices are determined simultaneously. We have taken a step in this direction by fitting a demand equation

$$Q_d = F(P_{X\$}, P_{W\$}, A_D)$$

and a supply equation

$$Q_s = F(P_{XH}, P_{DH}, A_H)$$

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30 To the extent that an exporter behaves as a small country in international markets, its prices would simply follow those of other countries and there would be no relative price variation to explain shifts in quantity. We assume that in such cases, changes in the quantity of exports can only be explained if we know (or assume) the characteristics of the export supply function and changes in it.

where

$P_{X\$}$ = Export price, in \$U.S.

$P_{W\$}$ = World export price (actually, U.S. price for German and Japanese equations, German price in U.S. equations), in \$U.S.

A_D = Destination activity variable, either destination real income (Y_D) or destination business cycle indicator (CBC_D).

P_{XH} = Export price in own currency.

P_{DH} = Domestic price in own currency.

A_H = Home country activity variable, either real income (Y_H) or business cycle indicator (CBC_H)

Q = Quantity of exports.

We expect that in the demand equation, the coefficient of P_X will be negative and that those of P_W and A_D will be positive. In the supply equation we expect that the coefficient of P_X will be positive and that of P_D negative. The home country activity variable is hard to predict. To the extent that it is dominated by trend, that is by a general increase in productivity or capacity, shifting the supply curve to the right, the coefficient should be positive. To the extent that it is dominated by cyclical forces, so that a rise represents a movement toward capacity output or a rise in the income of home country buyers, the coefficient should be negative. Even the business cycle indicator contains both elements since it is scaled in such a way as to incorporate each country's trend in real output.

The equations are estimated by two-stage least squares, first creating an instrument, $\hat{P}_X$, from the variables treated as exogenous for this purpose: home-country domestic price in own currency, the exchange rate, world price in dollars, destination income or the destination business cycle indicator index, and home country income or the home country business cycle indicator index.[31]

These equations go only a short distance in dealing with the issue of simultaneity. In particular, it would be desirable eventually to make not only export price but also domestic price endogenous, perhaps making use of the fact, discussed in an earlier paper,[32] that the relationship between unit labor costs and domestic prices is considerably stronger than that between unit labor costs and export prices.

The three demand equations were:[33]

$$Q_{dG} = \underset{(1.93)}{-8.316} - \underset{(1.43)}{0.248}\hat{P}_{X\$G} + \underset{(0.62)}{0.251}P_{X\$US} + \underset{(4.56)}{2.802}Y_{DG} \qquad \bar{R}^2 = .553 \quad DW = 2.13 \qquad (8)$$

$$Q_{dJ} = \underset{(0.18)}{-0.673} - \underset{(2.06)}{0.553}\hat{P}_{X\$J} + \underset{(0.86)}{0.578}P_{X\$US} + \underset{(3.10)}{1.154}CBC_{DJ} \qquad \bar{R}^2 = .399 \quad DW = 2.47 \qquad (9)$$

$$Q_{dUS} = \underset{(2.50)}{-9.765} + \underset{(1.72)}{0.996}\hat{P}_{X\$US} + \underset{(2.73)}{0.636}P_{X\$G} + \underset{(3.20)}{1.468}CBC_{DUS} \qquad \bar{R}^2 = .467 \quad DW = 1.70 \qquad (10)$$

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[31] The major determinants of $\hat{P}_X$ are, as might be expected, domestic price in home currency and the exchange rate. The domestic price coefficients are all positive, and the exchange rate coefficients are close to 1, as we expect. Foreign price is close to being significant at the 5 per cent level only in the German equation, where it is positive, as expected. None of the coefficients for activity variables is significant and the only one that is even larger than its standard error, the domestic business cycle variable for Japan, has a negative sign. The implication would seem to be that, given the effect of domestic prosperity on domestic price, its influence on export price is negative. In other words, domestic prosperity in Japan raises domestic price more than it raises export price and leads to a decline in the ratio of export to domestic price.

[32] Kravis and Lipsey (1977a).

[33] Equation (8) has been corrected for second order serial correlation. Equation (9) excludes the extremely large quantity increase in 1956/55. That exclusion has the same effect as the practice sometimes followed of introducing a Suez dummy for 1956, although the interpretation of such a term depends on the formulation of the variables. In equations for the

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All the coefficients in the three demand equations have the "correct" signs with the exception of the U.S. export price coefficient. For Germany and Japan, the own and competitors' price coefficients are not only opposite in sign but are almost equal. We might conclude from that virtual equality that buyers respond to the relationship between prices rather than to the individual price movements and that they are indifferent between a rise in the U.S. price and a fall in the German price. It would therefore be appropriate to use a price ratio in place of the separate country prices or, in this form, to constrain the own and foreign price coefficients to be equal.

The three supply equations were:

$$Q_{SG} = \underset{(0.35)}{1.130} + \underset{(1.50)}{2.516}\hat{P}_{XDMG} - \underset{(2.01)}{2.649}P_{DDMG} + \underset{(3.34)}{0.902}Y_G \qquad \bar{R}^2 = .542 \quad DW = 1.81 \qquad (11)$$

$$Q_{sJ} = \underset{(0.49)}{-3.686} + \underset{(0.62)}{4.731}\hat{P}_{XYenJ} - \underset{(0.59)}{4.772}P_{DYenJ} + \underset{(0.95)}{1.864}CBC_J \qquad \bar{R}^2 = .151 \quad DW = 2.44 \qquad (12)$$

$$Q_{sUS} = \underset{(2.29)}{-14.105} + \underset{(2.12)}{10.872}\hat{P}_{X\$US} - \underset{(1.86)}{7.382}P_{D\$US} + \underset{(1.83)}{0.564}CBC_{US} \qquad \bar{R}^2 = .257 \quad DW = 2.25 \qquad (13)$$

Although only a few of the price coefficients are statistically significant, they are surprisingly large and all have the expected signs: positive for export price and negative for domestic price. The implication of the large

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Fn. 33 (cont.)

level of exports, linked indexes in our terms, a Suez dummy would imply a temporary bulge in Japanese exports, later reversed completely. In equations for changes in exports, such as ours, a single dummy term for 1956/55 would imply an increase in Japanese exports that was not reversed after the crisis. A temporary increase, completely reversed, could be represented by two dummy terms, constrained to be equal, but with opposite signs.

coefficients for the price variables, if we accept the idea of interpreting export and domestic prices as elements of a supply equation, is that sellers are very sensitive to changes in the relation between export and domestic prices and readily shift sales to the more profitable of the two markets. The virtual equality of the two price terms, except in the U.S. equation where the difference is larger but not statistically significant, suggests that sellers respond to the ratio of export to domestic prices and respond about equally to a rise in export prices and a fall in domestic prices.

The home country activity terms all have positive coefficients, implying that a rise in home country income or output is on the whole associated with an increase in exports. We suspect that this is because trends in income and output outweighed cyclical fluctuations, although there is strong evidence that the relation of manufactured exports to business cycles is also in this direction.[34]

An important test of the supply and demand equations is their ability to track changes in export quantities. We can measure the tracking ability by regressions of actual export quantity change on that predicted by the equations. The $\bar{R}^2$ from these equations were:

	$\bar{R}^2$
Germany	.580
Japan	.484
U.S.	.508

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34 Ilse Mintz, in her study of U.S. exports and business cycles (Mintz, 1967, pp. 205-220) found that even after the influence of foreign cyclical fluctuations had been accounted for "All the evidence indicates that U.S. finished manufactured exports have tended to fare better during cyclical upswings in domestic business activity than during downswings." She attributed the result to a failure to account fully for the effects of concurrent changes in foreign demand, but concluded that the negative supply effects of U.S. expansions, even if they were there, could not have been substantial. Among groups of manufactured exports, she found that iron and steel products, including machinery and vehicles, displayed this behavior most consistently over many cycles. However, her explanations for the phenomenon are not all confirmed by our results. In particular, her suggestion that "...substitution of domestic for export sales, or vice versa, is a sluggish process for many highly differentiated manufactured goods.", seems to be contradicted by our high export supply elasticities.

For Germany and Japan these results are far better than the earlier ones from single equations without lags and even compare favorably with equations using lags of various lengths. For the United States, almost all the single equations include corrections for autocorrelation, making the $\bar{R}^2$ not directly comparable. However, we did explain as much or more of the quantity variation with one of the single equations that did not include such a correction. The tracking of fluctuations is clearly best in the German equation. As can be seen in Chart 1 the predicted quantity change follows all the main fluctuations in the actual, although it lags in a couple of instances. The Japanese equations (Chart 2) miss the sharpness of the swings in export quantity changes, even though we eliminate one outlying value from the quantity changes (1956/55). It is curious that of the four cases in which actual Japanese quantity change was far lower than the predicted, three of them, 1958, 1962, and 1975, were also overpredicted by the German equation.

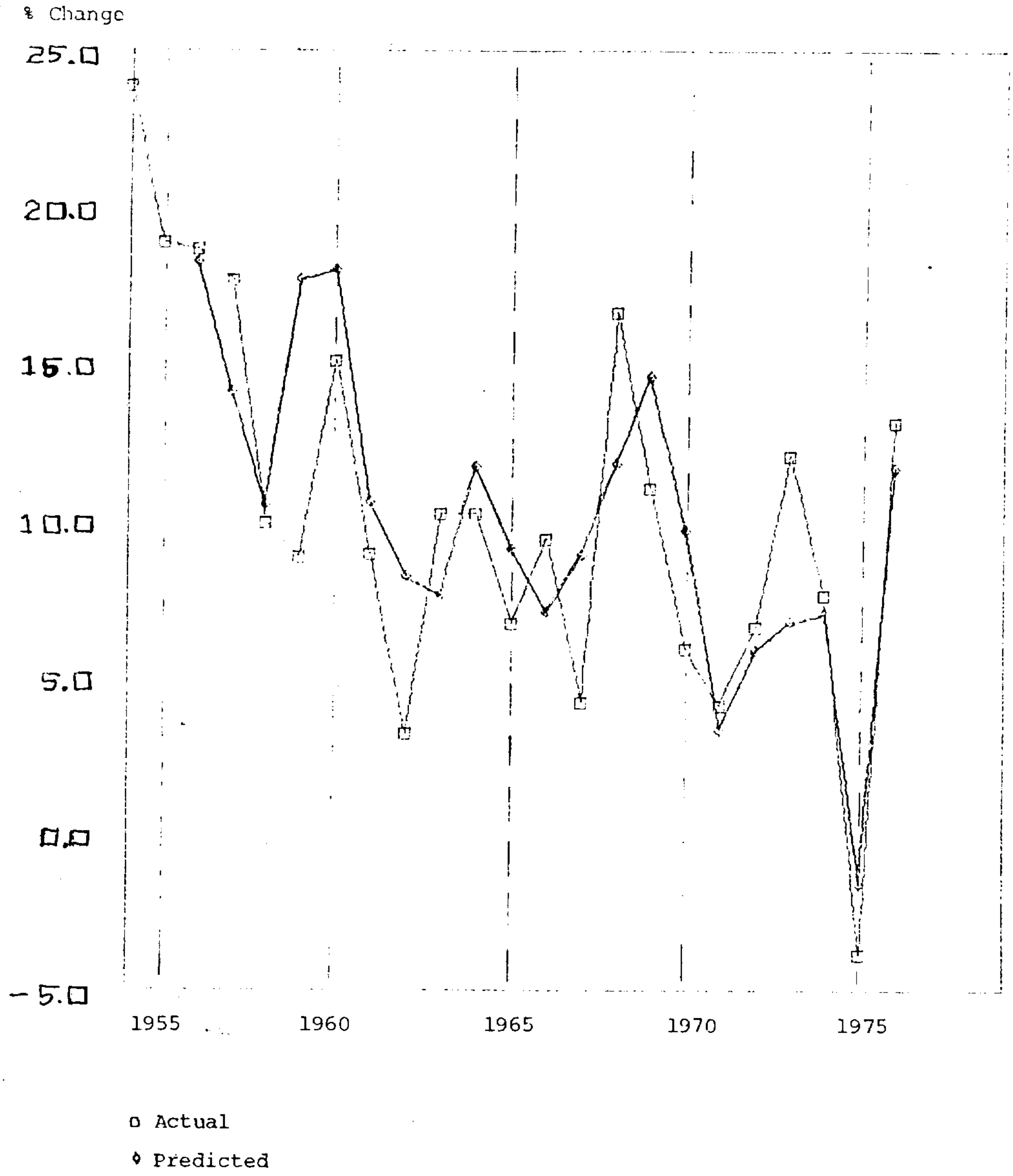
The U.S. equations appear to have been fitted mainly to the large quantity swings in 1955-58 and 1972-76 (Chart 3). The predictions do not match the fluctuations at all well through the 1960's, and from 1964 through 1969 export quantity change was underpredicted in every year.

The high income elasticity of demand for Japanese exports in some earlier equations does not come out in the demand equations here; in fact Japan has the lowest estimated income elasticity. Japan does show the highest income coefficient, by far, in the supply equations, although the coefficient is not significant.

A puzzling feature of these results is that while fairly long lags in quantity responses to price changes appeared necessary for explaining relative quantity change, and at least a one-year lag in prices and activity variables for the individual country export equations, the individual country export quantities seem to be almost as well explained using both demand and supply equations without references to any lagged response. However, we were limited by the small number of observations in testing lagged relationships in the demand and supply equations for SITC 7 and hope to experiment further in that direction using the disaggregated data.

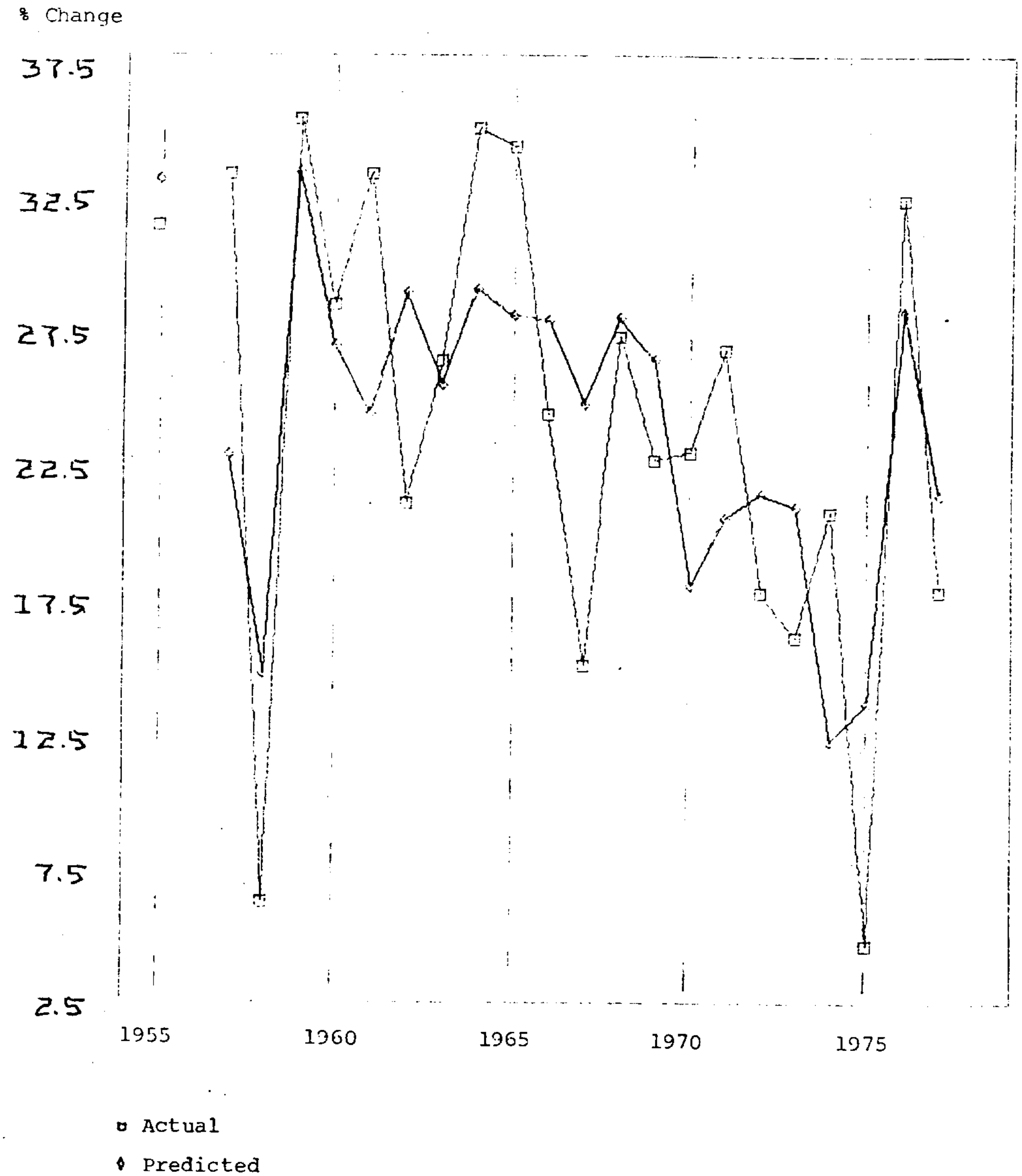
GERMANY: Actual vs. Predicted Change in Export Quantity
SITC 7

Chart 1



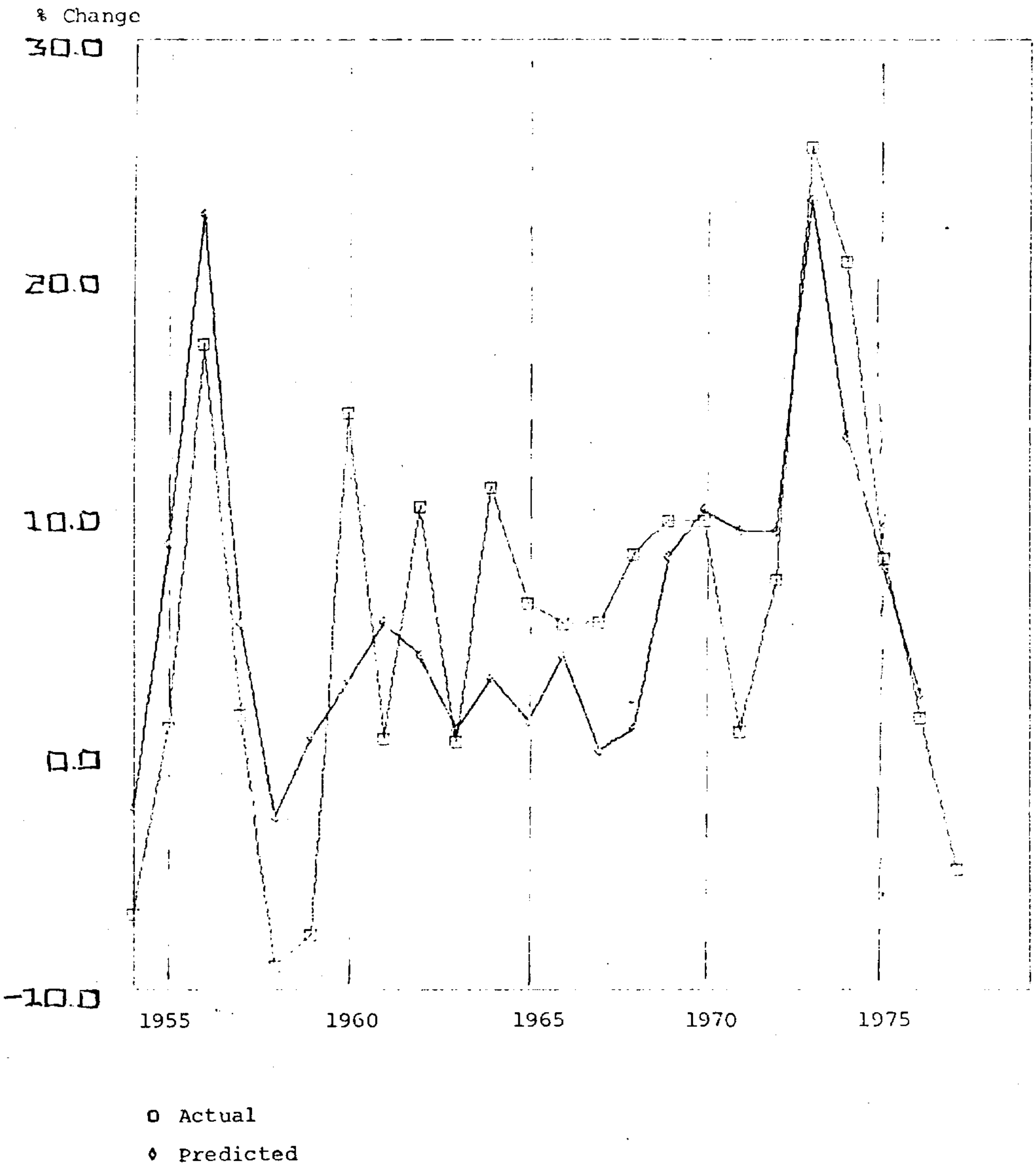
JAPAN: Actual vs. Predicted Change in Export Quantity
SITC 7

Chart 2



UNITED STATES: Actual vs. Predicted Change in Export Quantity
SITC 7

Chart 3



There are not many supply-demand systems with which we can compare our results. Those of Artus and Sosa (1978) use market share as the dependent variable and the demand equation elasticities are therefore closer to elasticities of substitution than to elasticities of demand. Those of Goldstein and Khan are closer in method to ours, although they cover all exports. Their German demand elasticity is considerably higher than ours, their Japanese elasticity is perverse in sign while ours has the correct sign, and their U.S. demand elasticity is high, with the proper sign, while ours is perverse. We find higher income elasticities of demand than they do for both Germany and the United States, possibly because of the difference in commodity coverage, but a much lower income elasticity for Japan. Their extremely high Japanese figure, over 4, may be related to their perverse price elasticity coefficient.

Our supply elasticities are lower for Germany but higher for the United States than either Goldstein-Khan or Artus-Sosa, while only the former has a Japanese estimate, which they assume to be infinite. We would expect, in general, to have a higher supply elasticity than others find, because of the difference in price measures. Our supply elasticity is the response to a change in the relation of export and domestic prices of the same goods, while others compare export and domestic prices for different bundles of products. If that measure makes any sense,[35] it should reflect the response to differences in price movements between export goods and all goods. Since producers should more readily be able to switch from selling a good at home to selling it abroad than from selling

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35 The significance is very doubtful if the export "price" is an export unit value series, often with changing weights based on export values and the domestic price is a wholesale price index with fixed weights based on importance in domestic trade but in a vague and uncertain framework.

a domestic-type product to exporting a different product, we would expect a higher elasticity from our measure.

The ability of our single equations to predict annual changes in export quantities and relative export quantities is described by the $\bar{R}^2$ of the equations presented earlier. For export quantity they reached over 2/3 for the United States, and more than half for Germany and Japan. For relative export quantity they were about half for Germany and Japan relative to the United States in equations without corrections for autocorrelation.

We can also ask how well both the single equations and the supply and demand equations predict for longer periods, in view of our initial statement that the export movements had no obvious relation to the current relative price changes. The answer to this question is given by Table 6 which shows the actual and predicted quantity and relative quantity changes for three sub-periods of the period from 1957 through 1976 for the single equations of Tables 3 and 4 and the supply and demand equations.

On the whole, the predictions of quantity change, which here include the influence of constant terms as well as of both price and destination activity, were respectable, although there were some large errors. Predictions from the single equations tended to be closer than those from the supply and demand equations perhaps because they resulted from more experimentation with various types of deflation and lag patterns. The supply and demand equations depended less heavily on constant terms, however, and we suspect that they represent the best direction for future research.

Table 6

Comparison of Actual Changes in Quantity and Relative Quantity With Those Predicted by Equations: Sub-Periods of 1957-1976[a]

	1964/1957	1971/1964	1976/1971
	Per Cent Change in Export Quantity		
Germany			
Actual	87.8	73.5	39.9
Supply and demand equations	120.7	84.7	33.3
Single equation[b]	107.8	71.7	40.8
Japan			
Actual	410.6	368.8	129.4
Supply and demand equations	404.9	370.4	140.4
Single equation[c]	429.1	334.6	131.4
United States			
Actual	19.3	55.9	78.4
Supply and demand equations	15.4	38.9	68.4
Single equation[d]	27.8	69.7	71.5
	Per Cent Change in Relative Export Quantity[e]		
Germany/United States			
Actual	62.7	4.2	-27.3
Single equation[f]	47.4	35.8	-36.6
Japan/United States			
Actual	293.0	149.8	26.8
Single equation[g]	306.5	205.3	15.7

[a] Since some equations involved lags in response to prices, the first year for which prediction could be obtained from all equations was 1958/1957.

[b] Equation with relative export price change, current year, and destination leading business cycle indicators, current and lagged one year.

[c] Equation with average price change over three years and destination leading business cycle indicators, current and lagged one and two years.

[d] Equation with average price change over three years and destination income, current year.

[e] Quantity measured as V_t/P_{t-1}.

[f] Equation with price lagged one and two years.

[g] Equation using average price change over three years, lagged one year (P_{t-1}, P_{t-2}, P_{t-3}).