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ESTIMATES OF BOUNDS FOR EXPORT PRICE ELASTICITIES IN AN UNDERIDENTIFIED SIMULTANEOUS TWO EQUATION SYSTEM

by

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ESTIMATES OF BOUNDS FOR EXPORT PRICE ELASTICITIES IN AN UNDERIDENTIFIED SIMULTANEOUS TWO EQUATION SYSTEM

Introduction

International comparisons of estimates of price and income elasticities in international trade often indicate substantial differences in these elasticities between different countries. In some surveys[1] we find export price elasticities for Sweden close to -2 whereas for most other countries they are around -1.

This implies that international demand is much more sensitive to changes in the Swedish export price than for changes undertaken by exporters from other countries. It would also mean that changes in the Swedish exchange rate would be a more efficient means to correct imbalance in the current account. Do we have any reason to believe that this is the case?

This paper shows that the results mentioned above can very well depend on some basic assumptions concerning the supply side. In this study we also find that Swedish export price elasticities are the highest among the eleven countries in the sample. Export price elasticities for Sweden are

-1.2 whereas for all other countries, but Japan, they are between -1 and 0.

The result depends heavily on the use of ordinary least squares estimates (OLS) and the assumption that supply is perfectly elastic. When we relax this very strict assumption and allow export supply to respond on price changes, demand price elasticities will be less biased towards zero and the ranking of the countries will change substantially.

In the paper we show the relation between the OLS-estimate of the demand equation in a simultaneous equation system and the maximum likelihood estimate given the explicit inclusion of the supply side.

We interpret the OLS-estimate as the upper bound for the set of maximum likelihood estimates in the simultaneous system (Maddala 1977 p. 243).

Following article by Edward E. Leamer (Leamer 1981) we obtain the lower bound for the true price elasticity by calculating the inverse of the output coefficient in the reverse regression, i.e. the OLS regression of output on prices.

An empirical illustration of the simultaneous equation bias in the estimation of export price elasticites constitutes the main part of the paper whereby estimates of the intervals within which the "true" estimate will fall are presented for Sweden and for ten other industrialized countries using 1958-80 annual data on prices and quantitites for manufacturing exports (SITC 5-8)[2]. The result is particularly interesting as far as Swedish exports are concerned, since the interval between the two bounds obtained by direct and reverse regression is fairly short. In the final section of the paper we show the connection between assumptions regarding supply elasticities and estimates of demand elasticities for each of the eleven countries by numerical examples and compare these to the scarce information on supply elasticities available from other sources.

Bias in the least squares estimate of export price elasticities

Estimates of demand price elasticities in international trade has often been made under the assumption that supply is perfectly elastic. Only then will an OLS regression of prices on quantities give an unbiased estimate of the true price elasticity of demand. This assumption of horizontal supply curves is found in other fields of demand analysis as well, for example in the estimates of price and income elasticities in consumer demand theory.[3] In the case of consumer demand the underlying assumption is that prices are given on a world market and supply is unlimited from the viewpoint of the individual country. Domestic and international prices are assumed to be identical. This assumption concerning unlimited supply can also be applied in the case of imports to a small country. The perfect elasticity of supply is harder to defend when we analyze export demand elasticites and efforts have consequently been made in the direction of the inclusion of the supply side (Goldstein-Khan 1978).

In the case when supply is less than perfectly elastic the most desirable method to obtain asympthotic unbiased estimates would be simultaneous estimation of export demand and supply equations by a full information maximum likelihood method (FIML). The disadvantage of FIML is its computational difficulties and sensitivity to specification errors or specification changes. It has consequently been of little practical use in the estimation of export price elasticities. Reduced form estimates and two stage least squares methods have been of more frequent use.

This paper shows the relation between the common, one equation estimate of export demand price elasticities and the FIML estimate by extracting the maximum of information from an OLS estimate of the demand side.

We do this by following a recent article by Edward E Leamer (Leamer 1981). Leamer argues that the exceedingly simple regressions of output on price and vice versa can give us some information about the price-elasticities as well as about the relative variability of the supply and the demand curves respectively, in spite of the identification and of the simultaneity problems.

In order to illustrate this we use a very simplified model of a market where demand and supply are determined only by a price variable.

$$X^d = \alpha + \beta P + u \qquad (1)$$

$$X^s = \gamma + \Theta P + v \qquad (2)$$

An OLS regression of the logaritm prices on the logaritm of quantities will give us an estimate of the price elasticity, b, that we interprete as an estimate of the demand elasticity β or of the supply elasticity Θ if it is positive.

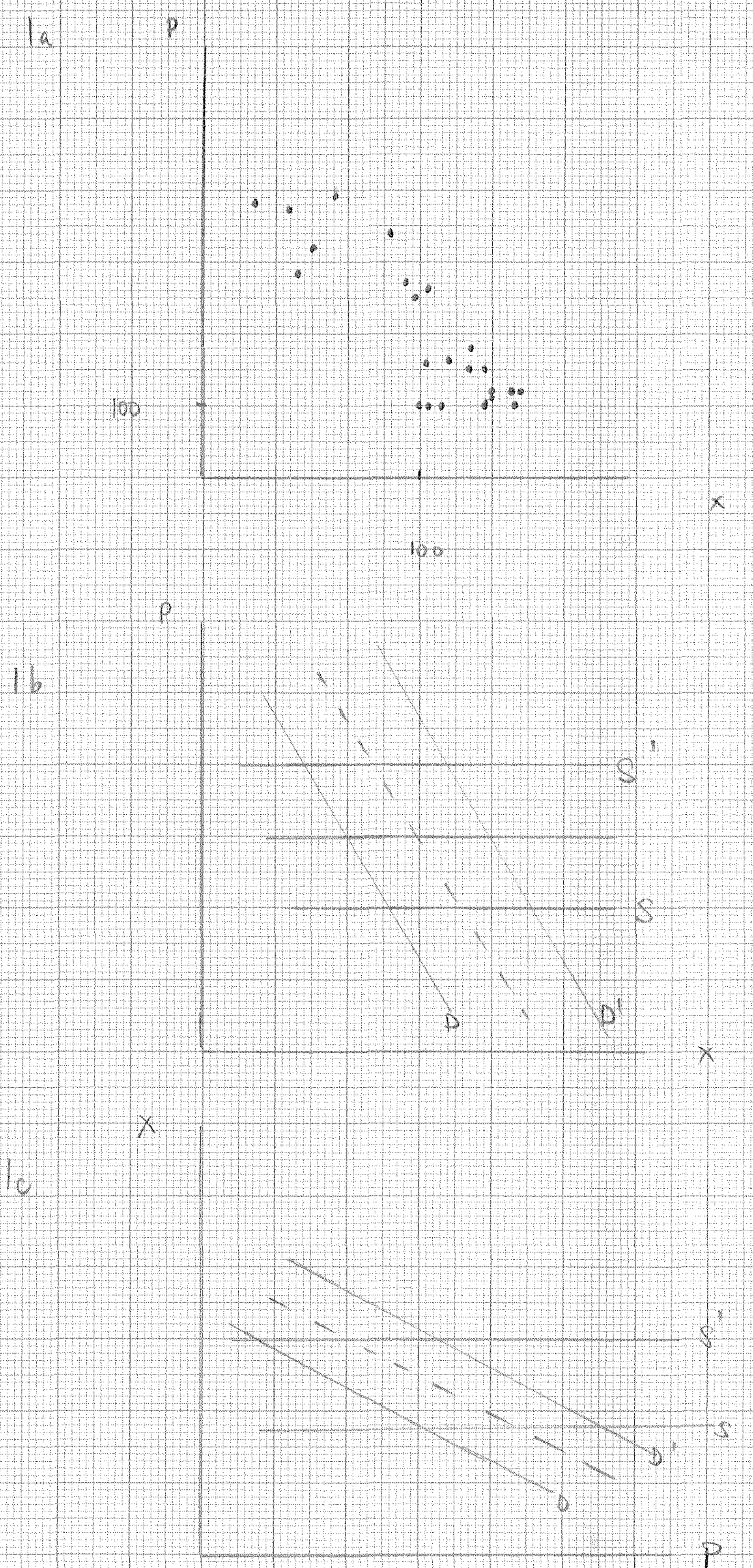
Given that the OLS estimate b is negative we can use it as a starting point in discussing the true price elasticity of demand, β. The simultaneity problem results in inconsistent estimates of the parameters when the structural equations are estimated by OLS, but it can be shown that the bias will be positive under certain assumptions (Maddala, 1977 p. 243).[4]

β is consequently lower than the b obtained by an OLS estimate of one equation in the simultaneous system. Maddala also shows that the bias will diminish as truly exogenous explanatory variables are included in the demand equationThis justifies to some extent the conventional one equation approach to export demand functions reported below.

The extension made in the Leamer article is that using the same data we can easily obtain the lower bound for β by calculating a reverse regression.

The least squares bias and the method of reversing the regression used by Leamer is illustrated in some simple figures. The OLS procedure amounts to fitting a line through the observations in Fig. 1a that will minimize the sum of squared horisontal deviations from the observed value of x. This line will only be an unbiased estimate of the demand elasticity when the supply curve is totally elastic (1b) (Leamer Stern 1970 p. 31). The reverse

Figure 1



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regression amounts to shifting the axes. In Fig. 1c an unbiased estimate of demand price elasticity is obtained when the supply curve is completely inelastic.

The true estimate of β can consequently be bounded by the two estimates obtained by OLS i.e. under the assumption that supply is perfectly elastic and the reverse OLS i.e. the assumption that supply is totally inelastic.

Maximum likelihood estimates

The extention by Leamer is not limited to indicating the relation between demand elasticities β and supply elasticities θ at the end points of the interval. He uses the full information maximum likelihood estimate FIML to show that there is a direct relation between estimates of β and estimates of θ over the interval bounded by the end points obtained by OLS estimates.[5] This relation states that the set of maximum likelihood estimates of β and θ in eqs. (1) and (2) are related by the hyperbola

$$(\hat{\theta}-b)(\hat{\beta}-b) = (r_{px}^2-1)\frac{s_x{}^2}{s_p{}^2} \qquad (3)$$

where b is the least squares estimate s_{px}/s_p2. $s_p{}^2$ and s_x2 sample variances and r_{px}^2 the squared sample correlation $s_{px}2/s_p2s_x2$. Figure 2 shows the hyperbola (3) as well as the use of the least squares estimates b and b_r as limits.

Within the bounds given by theory i.e. $\beta < 0$ $\theta > 0$ any estimate of β is possible, but given one there is a unique maximum likelihood estimate of θ. In particular, the intuitive results from Fig. 1 are supported by eq. (3), if θ is known to be infinite, the right hand side of eq. (3) will approach zero (when divided by $(\hat{\beta}-b)$), i.e., the estimate of β is the least squares estimate b. If θ is known to be zero then the estimate of β is the reverse regression estimate[6]

$$b_r = s_x^2/s_{px} = b/r_{px}^2 \ . \qquad (4)$$

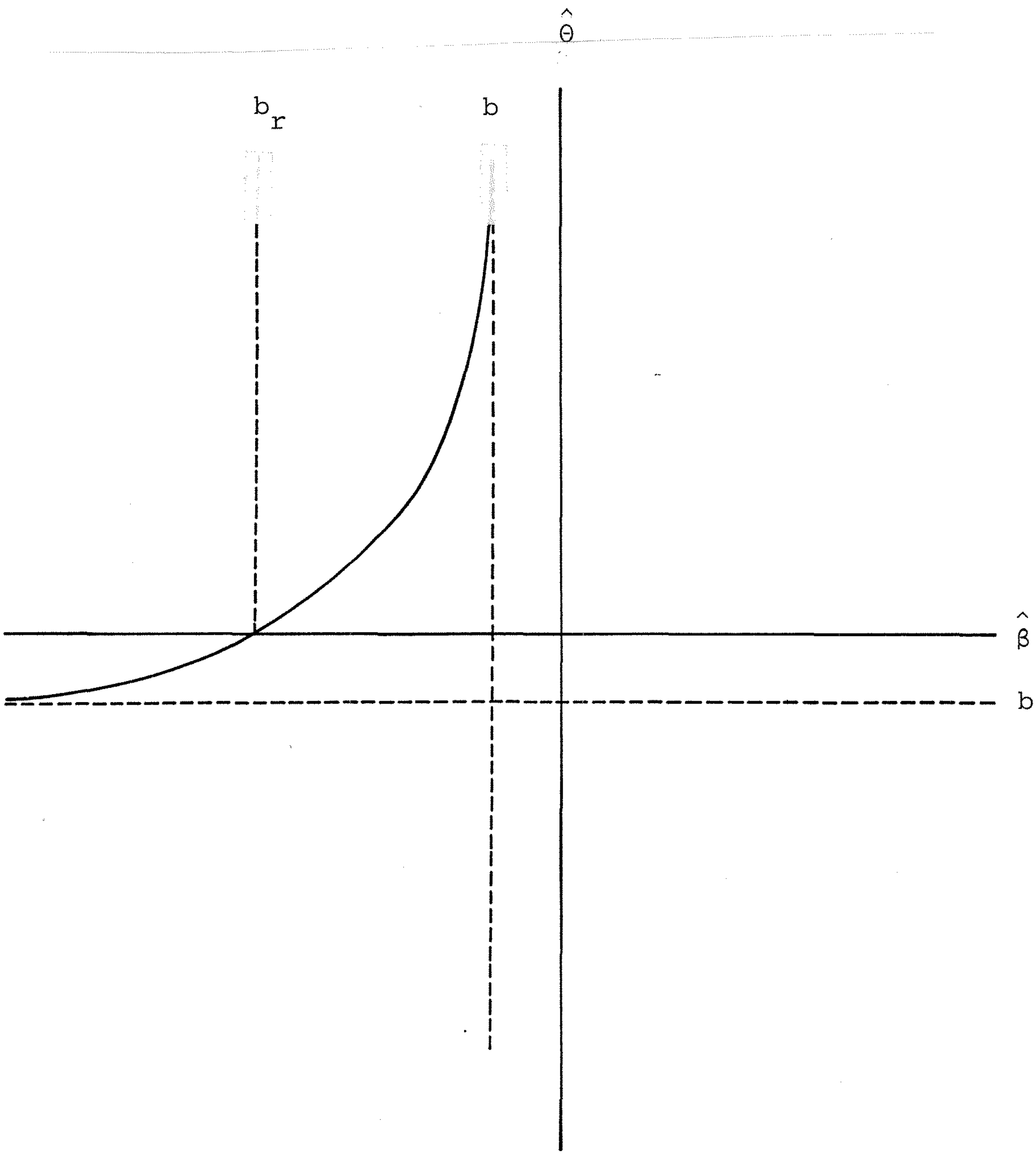
We find the maximum likelihood estimate of β in Figure 2 on the interval of the hyperbola between the least squares and the reverse least squares

$$b_r < \hat{\beta} < b < 0$$

Figure 2 Maximum likelihood estimates of β and θ

$b = s_{px}/s^2_p$

$b \;\; = s^2_x/s_{px}$



Relative price and export performance

We will now use the relation between supply and demand elasticities to measure export demand price elasticities for different countries. Figure 1 assesses the position of the 11 countries in Table 1 according to their relative export and price performance over the 1958 to 1980 period. An observation close to the origin indicates a performance over the period close to the average of all countries. Countries above the horizontal line have increased their relative export prices over the period. Countries to the right of the vertical axis have increased their relative export market shares. The position of the countries in Figure 1 indicate, as expected, a negative correlation, i.e., countries with lower price increase gain market shares, and countries that increase their relative price lose market shares. The correlation coefficient is 0.65. A crosscountry regression of relative prices (RP) on relative export volumes (REX) presented under the heading in Figure 1 points to an export price elasticity of -1.6.

A conventional approach to the estimate of export price elasticities

We will use our data for exports of 11 countries in Figure 1 to estimate export price elasticities. Besides the obligatory price and income variable present in all demand specifications and used for example by Houthakker-Magee (1969) and Goldstein-Khan (1978) we have followed Sato (1977) and included a factor to account for non-price competitiveness.

Figure 3 Relative export price and export volume changes of 11 industrilized countries

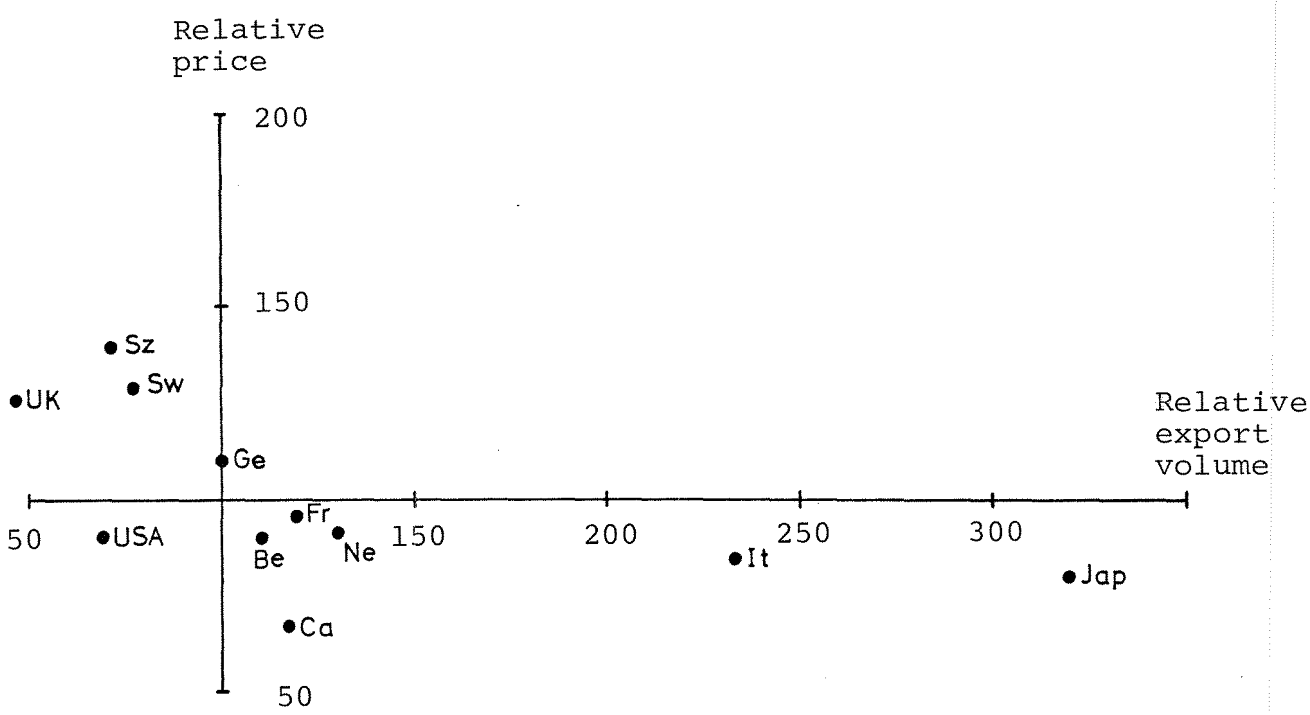
(Average change 1958-80 = 100)

Log REX = 12.04 - 1.602 log RP

t-value (-2.58)

$R^2 = 0.42$

DW = 1.45



World demand for an individual country's exports is specified in loglinear form as

$$X = \alpha_0 + \beta \, RP + \alpha_1 \, YW + \alpha_2 \, (Q/QW) \qquad (5)$$

where

X = quantity of exports

RP = price of exports relative to the average of the export prices of the country's trading partners

YW = a world real income variable

Q/QW = proxy for non-price competitiveness.

The dependent variable is the constant dollar value of exports of manufactured goods. The relative price is composed of the unit value index, used to deflate the export value, divided by a world index. The world index is the sum over all countries using their share in total trade as weights. The denominator of RP is consequently the same for all countries. Total export volume of the 11 countries is used as a proxy for world real income.

The non-price factor is made up of the exporting countries production in relation to competitors production. Total production has been calculateed using the same trade weights as for the price index.

The results in Table 1 give expected negative price coefficients for ten out of the eleven countries. Six of these are statistically significant in the sense that t-ratios assure that the "true"

Table 1. Exports of manufactured goods (SITC 5-8), OLS estimate of equation (3) (logarithms of annual data 1958-80), t-values in brackets

	$\hat{\alpha}_0$	$b = \hat{\beta}$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	R^2	DW
USA	3.848 (2.86)	-0.871 (-4.30)	0.738 (34.12)	-0.039 (-0.16)	0.99	1.13
Germany	-0.910 (-0.71)	-0.493 (-2.10)	1.038 (51.77)	0.298 (1.35)	0.99	1.18
UK	4.643 (1.84)	-0.267 (-1.84)	0.448 (4.76)	-0.621 (-1.66)	0.99	1.35
France	-3.406 (-1.29)	-0.790 (-1.84)	1.062 (57.69)	0.935 (2.40)	0.99	1.42
Japan	-0.005 (-0.00)	-1.114 (-4.36)	1.349 (18.88)	0.300 (2.50)	0.99	1.42
Italy	-6.078 (-1.60)	-0.883 (-1.48)	1.082 (18.55)	1.538 (4.76)	0.99	1.41
Belgium	-2.564 (0.97)	-0.972 (-2.44)	1.046 (45.22)	0.865 (2.36)	0.99	1.16
Canada	-8.055 (-2.94)	0.372 (1.75)	1.152 (15.82)	0.592 (1.02)	0.99	1.14*
Netherlands	-5.502 (-2.63)	-0.230 (-0.61)	1.071 (24.77)	0.666 (2.26)	0.99	1.58*
Sweden	-1.185 (-1.17)	-1.230 (-5.82)	1.050 (31.53)	0.694 (6.77)	0.99	1.48
Switzerland	-1.153 (-0.63)	-0.279 (-1.08)	0.831 (20.56)	-0.048 (-0.25)	0.99	1.20

* Adjusted for first order autocorrelation.

value is different from zero. Significant estimates of price elasticities range from -0.50 for Germany to -1.2 for Sweden. The income elasticity-is significant for all eleven countries. It is low in the case of the U K, 0.4, and high for Japan, 1.3, a finding completely in accordance with other studies. The non-price variable is positive and significant for six countries.

Many studies of export price elasticities stop at this stage. Few successful results have been reported where the supply side has been specified and included in the estimation procedure.

Lower bounds for export price elasticities

The practical useful conclusion from the discussion above is that the OLS regression of eq (5) with some simple extra calculations can give us more information about the true price elasticities of demand even if we do not specify a supply equation.

In order to find the intervals for demand price elasticities for different countries we form the reverse regression.

$$RP = c_0 + c_1 X + c_2 YW + c_3 Q/QW \qquad (6)$$

The last column in Table 2 ,i.e., the inverse of the coefficient for the quantity variable $b_r = 1/(s_{px}/s_x^2)$ gives the lower bound of the FIML estimate of demand price elasticities. In Table 3, combining the results from Table 1 and Table 2, we

Table 2. Estimates of reverse regression
t-values in brackets

	$\hat{c}_0$	$\hat{c}_1$	$\hat{c}_2$	$\hat{c}_3$	$\bar{R}^2$	$\bar{I}/\hat{c}_1$
USA	4.164 (4.60)	-0.566 (-4.30)	0.383 (3.63)	0.080 (0.41)	0.65	-1.77
Germany	2.339 (2.31)	-0.383 (-2.10)	0.452 (2.47)	0.289 (1.50)	0.68	-2.61
UK	11.27 (3.71)	-0.569 (-1.84)	0.068 (0.33)	-1.172 (-2.26)	0.20	-1.76
France	3.167 (2.76)	-0.193 (-1.85)	0.211 (1.91)	0.198 (0.92)	0.04	-5.19
Japan	2.611 (4.27)	-0.437 (-4.36)	0.599 (4.27)	0.052 (0.61)	0.72	-2.28
Italy	4.755 (4.78)	-0.117 (-1.48)	0.072 (0.79)	-0.054 (-0.31)	0.81	-8.54
Belgium	3.108 (2.70)	-0.246 (-2.44)	0.236 (2.18)	0.186 (0.90)	0.38	-4.07
Canada	7.937 (2.87)	0.602 (3.40)	-0.872 (-4.33)	-0.080 (-0.13)	0.74	1.66
Netherlands	3.217 (2.77)	-0.180 (-1.31)	0.144 (0.97)	0.230 (1.14)	0.37	-5.55
Sweden	0.896 (1.30)	-0.521 (-5.82)	0.599 (7.65)	0.337 (3.51)	0.94	-1.92
Switzerland	5.993 (7.51)	-0.208 (-1.08)	0.304 (1.99)	-0.558 (-5.08)	0.96	-4.81

see that the interval thus spanned is quite wide for many of the countries. But for some countries, among them Sweden, we find a more limited range for the maximum likelihood estimate of the demand price elasticity.

The relation between supply and demand price elasticities - A summary of the results

We will now make use of the relations between supply and demand elasticities expressed in eq.(3) to illustrate the sensivity of demand elasticities as to assumptions about supply elasticities. Table 3 indicates the limits of the estimates i.e. the values for the estimates of demand price elasticity β when the supply elasticity θ is infinite or zero. The values in between can easily be computed using eq. (3) and the data in table 3.

In table 4 we compute the demand elasticity for various values of the supply elasticities. The assumption of supply elasticities equal to, for example, 4 will change the demand price elasticity from -0.87 to -1.03 in the case of the US, from -0.49 to -0.72 in the case of Germany etc.

Looking at the OLS estimates under the perfect elasticity of supply assumption only two countries - Japan and Sweden - register demand price elasticities below -1. Under the assumption of supply elasticities of 4, demand price elasticies for six out of the eleven countries are lower than -1.

Table 3. Export demand price elasticities (β) under different assumptions regarding supply elasticities (θ)

	$\hat{\theta} = 0$	$\hat{\theta} = 1$	$\hat{\theta} = 2$	$\hat{\theta} = 4$	$\hat{\theta} = 6$	$\hat{\theta} = \infty$
USA	-1.77	-1.29	-1.14	-1.03	-0.98	-0.87
Germany	-2.60	-1.19	-0.91	-0.72	-0.65	-0.49
UK	-1.77	-0.59	-0.45	-0.36	-0.33	-0.27
France	-5.20	-2.74	-2.04	-1.52	-1.30	-0.79
Japan	-2.25	-1.71	-1.52	-1.36	-1.29	-1.11
Italy	-8.54	-4.48	-3.23	-2.27	-1.86	-0.88
Belgium	-4.06	-2.49	-1.98	-1.40	-0.98	-0.97
Canada	-	-	-	-	-	-
Netherlands	-5.61	-1.24	-1.79	-0.52	-0.43	-0.23
Sweden	-1.92	-1.61	-1.49	-1.39	-1.35	-1.23
Switzerland	-4.84	-1.24	-0.81	-0.56	-0.47	-0.27

Note: The table is based on eq. (3) the hyperbola indicating the relation between β and Θ. Most data needed are obtained by the OLS regression of eq. (5) and (6).

One of the few studies where estimates for export demand as well as export supply price elasticities are presented for several countries is Goldstein and Khan (1978). Using a simultaneous estimating procedure (FIML) they obtain export demand and export supply price elasticities for eight countries presented in the first two columns of table 5. Lundborg (1981) has made a similar study for Sweden so his estimates are added to the table.

In these studies supply elasticities range from 1.1 to 6.6 and demand elasticities from -0.48 to -3.29. The findings suggest that for most countries supply elasticities are in fact rather low, so OLS estimates of demand elasticities would be severely biased. A comparison between demand elasticities obtained by Goldstein-Khan and the conventional one-equation OLS estimate by Houthakker--Magee (1969) (not reported) shows that demand elasticities obtainedby the FIML estimate are lower (i.e. more negative) than the one equation estimates as expected.

In the last column of table 5 we use exogenous information about supply elasticities from the Goldstein-Khan study to obtain demand price elasticities using eq (3) of this study. Results from the two studies are consistent for most countries i.e. Germany UK, France, Italy, Belgium and the Netherlands, in the sense that demand elasticities lie within the range in table 4.

In the case of the US a relatively high figure for the elasticity of supply would indicate that the bias in an OLS estimate was relatively small. The demand price elasticity obtained by Goldstein-Khan lies however outside the range obtained in this study (see table 4). Another country for which the results differ is Japan. The study by Lundborg (1981) for Sweden also gives demand elasticities outside the range obtained in this study. The low estimate of the elasticity of supply would suggest demand price elasticities of about -1.6 i.e. a finding more in line with other studies of export demand price elasticities for Sweden than the -0.5 obtained by Lundborg.

Table 4 Demand price elasticities given less than infinite supply elasticities

	Simultaneous estimate Goldstein-Khan study Supply elasticity	Demand elasticity	Hyperbolic calculation of demand elasticity[2]	Ols estimate
USA	6.6	-2.32	-0.98	-0.83
Germany	4.6	-0.83	-0.69	-0.49
UK	1.4	-1.32	-0.51	-0.27
France	1.9	-1.33	-2.09	-0.79
Japan	∞	+2.47	-1.11	-1.11
Italy	1.1	-3.29	-4.30	-0.88
Belgium	1.2	-1.57	-2.35	-0.97
Netherlands	2.5	-2.73	-0.68	-0.23
Sweden[1]	1.4	-0.48	-1.55	-1.23

[1] Simultaneous equation estimate by Lundborg (1981).

[2] Supply elasticities from the Goldsteiner study (ol 3) applied to this study i.e. to eq. (3) and data from table (3).

NOTES

[1] "Price Elasticities in International Trade" by Stern, Francis and Schumacher (1976).

[2] Data used in this exercise come from several issues of UN Monthly Bulletin of Statistics, "Manufactured goods exports" table D and IMF "International Financial Statistics".

[3] Deaton-Muellbauer, (p.x).

[4] $$\text{plim } \hat{\beta} = \beta + (\beta - \theta) \frac{\sigma_{uv} - \sigma^2_u}{\sigma^2_v + \sigma^2_u - 2\sigma_{uv}}$$

$$\sigma_{uv} = 0 \rightarrow \text{plim } \hat{\beta} = \beta + (\beta - \theta) \quad - \frac{\sigma^2_u}{\sigma^2_u + \sigma^2_v}$$

Since $(\beta-\theta)$ is expected to be negative we get plim $\hat{\beta} = \beta$ + positive term

A stable demand curve implies $\sigma^2_u \rightarrow 0$ and plim $\hat{\beta} = \beta$. In this case b is an unbiased estimate of β irrespective of the slope of the supply curve.

[5] This follows from the first order condition when we maximize the likelihood function.

[6] This can easily be derived from eq. (3) and the definitions used above.

$$(-b)(\hat{\beta}-b) = (r_{px}^2-1)\frac{s_x^2}{s_p^2} \cdot$$

$$(\hat{\beta}-b) = \frac{s_x^2}{s_p^2} \cdot \frac{s_p^2}{s_{px}} - r_{px}^2 \cdot \frac{s_x^2}{s_p^2} \cdot \frac{s_p^2}{s_{px}}$$

$$(\hat{\beta}-b) = \frac{s_x^2}{s_{px}} - r_{px}^2 \cdot \frac{s_x^2}{s_{px}}$$

$$(\hat{\beta}-b) = \frac{s_x^2}{s_{px}} - \frac{s_{px}^2}{s_p^2 s_x^2} \cdot \frac{s_x^2}{s_{px}}$$

$$(\hat{\beta}-b) = \frac{s_x^2}{s_{px}} - b$$

$$\hat{\beta} = \frac{s_x^2}{s_{px}}$$

[7] The Goldstein-Khan study indicates perfect elastic supply elasticities which in this study would indicate that the OLS estimate of -1.11 would be a satisfactory estimate for the demand price elasticities. Demand elasticities in their study are positive, a result that is excluded by assumption in this study, since a positive sign for the price term is interpreted as giving information about the supply curve ragher than the demand curve.

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