

Structural Shifts in Foreign Trade and Economic Growth:

A Bayesian Test of Parameter Shifts with an Application to Korea

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I. Introduction

Since mid-1960s, South Korea has achieved an outstanding economic growth record. The average annual growth rate of GNP between 1965 and 1979 was 10.1 percent. Export performances of South Korea (hereafter Korea) are more spectacular and the average annual rate of export growth over the same period was 24 percent.

The most noticeable feature of this remarkable economic performance is the role played by export of manufactured products. Manufactured exports, in 1970 prices, grew at 34.8 percent per year over that 15-year period.¹ They accounted for 89.2 percent of total exports in 1979, while the share of total exports in GNP reached 38 percent in 1979.

This paper first detects and verifies empirically the existence of a structural shift in the export sector within the framework of a Bayesian Test of Parameter Shifts, and then explores its ramifications in relation to the economic growth of Korea. The test results indicate that manufactured exports of Korea has experienced a structural shift around 1965, and we argue that this shift has made Korean economy more stable in foreign exchange earnings and less vulnerable to fluctuations in world income.

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¹ Derived from statistics in Bank of Korea, *Economic Statistics Yearbook*, various volumes.

This paper is divided into four sections. Section II presents a Bayesian Parameter-Shifts model. In Section III this Bayesian model is applied to the regression equations of export sector of Korea. The summary and conclusions of the study are given in Section IV.

II. The Theoretical Framework: Bayesian Approach to Test of Parameter Shifts.

Since it is not adequate to assume homoscedastic behavior of the error terms associated with all the observations in our analysis, and since we are interested in comparing parameters in one equation with those of another, we use the Bayesian test formulated by H. Tsurumi.²

$$(1) \quad Y_1 = b_{11}X_{11} + b_{12}X_{12} + \dots + b_{1k}X_{1k} + U_1$$

$$(2) \quad Y_2 = b_{21}X_{21} + b_{22}X_{22} + \dots + b_{2k}X_{2k} + U_2$$

where, Y_1 and Y_2 represent dependent variables, X_{ij} is j th explanatory variable in i th equation, b_{ij} is j th parameter in i th equation, and U_i is an error term in i th equation. We now assume that U_1 and U_2 are mutually independent and that each of U_i is distributed as a joint multivariate student-t distribution with a zero location vector. If we further assume a diffuse prior probability distribution function for b_i and S_i , then the marginal posterior pdf for $b_i = (b_{i2}, b_{i2}, \dots, b_{ik})$ is given by

$$(3) \quad P(b_i/\text{data}) \propto \{V_i S_i^2 + (b_i - \hat{b}_i)' X_i' X_i (b_i - \hat{b}_i)\}^{- (V_i + K_i)/2}$$

² For a complete treatment of the model and its application, see Tsurumi (1977, 371-380). One of well-known tests of structural shifts is the Chow test developed by G. Chow and alternatively by Fisher. See, for example, Chow (1960, 591-605); and Fisher, (1970, 361-366). This test, however, is inappropriate for our purpose, as it is designed to test sets of coefficients in two regressions whose error terms have mutually independent normal distributions with a common variance.

where $\hat{b} = (X_i' X_i)^{-1} X_i' Y_i$

$$V_i S_i^2 = (Y_i - X_i \hat{b}_i)' (Y_i - X_i \hat{b}_i)$$

$$V_i = N_i - K_i$$

and where

Y_i = a $(N_i \times 1)$ vector of dependent variables

X_i = a $(N_i \times K_i)$ matrix of explanatory variables

b_i = a $(K_i \times 1)$ vector of parameters.

From equation (3) we obtain posterior pdf of the j th parameter of b_i , b_{ij} , given as

$$(4) \quad P(b_{ij}/\text{data}) \propto [1 + (b_{ij} - \hat{b}_{ij})^2 / C_{ij}]^{- (V_i + 1)/2}$$

where C_{ij} is the j th diagonal element of the variance-covariance matrix of the i th equation. Under the assumption that U_1 and U_2 are mutually independently distributed, the joint marginal posterior pdf of b_{1j} and b_{2j} is given by

$$(5) \quad P(b_{1j}, b_{2j}/\text{data}) \propto \prod_{i=1}^2 [1 + (b_{ij} - \hat{b}_{ij})^2 / C_{ij}]^{- (V_i + 1)/2}$$

To test the hypothesis that $b_{1j} = b_{2j}$ for all j , we transform b_{1j} and b_{2j} by the linear operation, $r_j = b_{2j} - b_{1j}$ and $d = b_{2j}$. Then, the joint distribution of (r, d) is given by

$$(6) \quad P(r_j, d/\text{data}) \propto [1 + (d - \hat{d})^2 / c_{1j}]^{- (V_1 + 1)/2} \\ \times [1 + (r_j - d - \hat{r}_j + \hat{d})^2 / C_{2j}]^{- (V_2 + 1)/2}$$

We now obtain the posterior distribution of r by integrating out d from the joint distribution equation (6) as

$$(7) P(r_j/\text{data}) \propto \int_{-\infty}^{\infty} [1+(d-\hat{d})^2/C_{1j}]^{-(V_1+1)/2} \\ \times [1+(r_j-d-\hat{r}_j+\hat{d})^2/C_{2j}]^{-(V_2+1)/2} dd$$

which is a form of the Behrens-Fisher distribution.

Following V. Patil, we approximate the pdf of r_j as the t-distribution,³

$$t[r_j, a(C_{1j} + C_{2j}), B].$$

Thus, the pdf of r_j is approximated by a t-distribution having B degrees of freedom, centered at r with a scaling factor of $\sqrt{a^2(C_{1j} + C_{2j})}$, where

$$a^2 = (B-2)/B \times f_1$$

$$B = 4 + (f_1^2 / f_2)$$

$$f_1 = [V_2 / (V_2 - 2)] \cos^2 \phi + [V_1 / (V_1 - 2)] \sin^2 \phi$$

$$f_2 = V_2^2 / [(V_2 - 2)^2 (V_2 - 4)] \cos^4 \phi + [V_1^2 / (V_1 - 2)^2$$

$$(V_1 - 4)] \sin^4 \phi$$

$$\cos^2 \phi = C_{2j} / (C_{1j} + C_{2j})$$

The parameter shifts, if any, then will be detected by testing the null hypothesis, $H_0: b_{2j} = b_{1j}$ against the alternative hypothesis, $H_1: b_{2j} \neq b_{1j}$. If the posterior distribution of r_j does not include zero, then we reject the null hypothesis. If we reject the null hypothesis ($b_{2j} = b_{1j}$), then j th parameters in the first and second equations are assumed to be significantly different, that is, any

³ See Patil (1964, 21-30).

difference in the coefficients of the two equations is not resulting from sampling errors and biases.

The test results are presented in the following section.

III. Empirical Results

The hypothesis that Korea's exports have experienced a turning point through big push policies is statistically tested through application of the Bayesian parameter-shift model which is developed above.

The set of data used in this test consists of Korean exports of manufactured products to the world markets during the 1953-79 period. Demand for exports in foreign markets depends on consumers' income, and the price of exports relative to the price of other goods that can substitute for the exports. Following tradition, we adopt the simple linear form of demand function and specify it as

$$(8) \quad X = b_1 + b_2 (P_f/P_d) + b_3 (Y_f/P_w) + U$$

where, X = exports of a country, b_i = parameters, P_f = price of substitutes in world markets, P_d = price of exports, Y_f = world's money income, P_w = world's price level, and U = error term.

Since the growth rate, not the level, of the values of variables will specify our function more adequately, and will give us convenience in interpretation, logarithm transformation of the equation (8) is made as

$$(9) \quad \log X = b_1 + b_2 \log (P_f/P_d) + b_3 \log (Y_f/P_w) + U$$

Quarterly data are used to determine whether parameters for constant and explanatory variables are significantly different between two regressions, one for the subperiod of 1953-65 and another for that of 1966-79. The year 1965 appears to be a turning point for Korean economy.⁴ Concerted efforts of big push have been made around this time.

Some of them are:

- (1) Reform of the Foreign Exchange Rate (1964)
- (2) Interest Rate Reform (1965)
- (3) Tax Reform (1965)
- (4) Economic Stabilization Program (1963)
- (5) The first Five-Year Plan (1962-66)

For the dependent variable, we use the value of Korean exports of manufactured goods deflated by the export unit value index.⁵ Two independent variables represent relative price ratio and world income. The relative price ratio is constructed as P_f/P_d , where P_f is the trade-weighted export unit value index for manufactures of the U.S. and Japan and P_d is Korean unit value index of export.⁶ No adjustment for exchange rate changes are made since all the unit values are expressed in the U.S. dollar.

Table 1 below includes regression results for three time frames for the equation: the first for the entire period, the second for the period of Q1. 1953-Q4. 1965, and the third for the Q1. 1966-Q4. 1979.

The t-values for all coefficients are significant at 95 percent level except for those of RP in equations (10) and (11). The t-value for RP in equation (11) is significant at 80 percent level. Durbin-Watson statistics are satisfactory at the 1 percent significance level in all equations, and signs of coefficients for all variables are as expected.

Examination of equations (11) and (12) reveals that the coefficient of constant rose while that for income variable fell in the se-

⁴ A noticeable shift in the pace of economic growth in Korea is coincided with growth path of industrial sector whose annual rate of growth jumped to nearly 30 percent during the 1966-70 period from 19.0 percent in the 1961-65 period (based on 1970 factor costs).

⁵ Export unit value index of Korean manufactures would have served better for this purpose because we are dealing with manufactured exports. Since such index is not available, we substitute the unit value index of total exports for that of manufactured exports. However, the difference of two sets of indexes should be minimal as the share of the manufactured exports has been rising very rapidly and approaches the 90 percent level during 1976-79 period.

⁶ The U.S. and Japan are two major trading partners of Korea and they together import more than 60 percent of total Korean exports. Ideally, all those countries whose manufactured goods are competing with Korean manufacturers should be included. However, the data does not exist on a quarterly basis.

cond subperiod. The coefficients for price variable just slightly increased.

To test the null hypothesis $b_{2j} = b_{1j}$ against the alternative hypothesis $b_{2j} \neq b_{1j}$, where b_{ij} is the j th coefficient in the i th equation, we employ the Bayesian model developed in Section 2.

From Table 1 we obtain $V_1 = 49$, $V_2 = 53$, $r_1 = 33.95$, $r_2 = 0.76$ and $r_3 = -8.06$. The variance-covariance matrices provide us the following C_{ij} matrix.

Table 1
COCHRANE-ORCUTT ESTIMATES OF KOREAN EXPORT
PERFORMANCE (Q1. 1953-Q4. 1979)

Equation	Dependent Variable	Independent Variables				
		XMK	C	RP	GNPI	R ²
(10)	All	-25.60 (-6.40)	0.72 (0.67)	6.98 (7.40)	0.97	2.65
(11)	SUBP1	-45.65 (-3.23)	1.57 (1.32)	12.02 (3.31)	0.85	2.21
(12)	SUBP2	-11.70 (-11.35)	2.33 (2.63)	3.96 (16.91)	0.90	2.03

XMK = real Korean exports of manufactures in U.S. dollars derived at by deflating current values by Korean unit value index of exports.

C = intercept.

RP = the relative unit value ratio, P_f/P_d , as defined in the text.

GNPI = trade-weighted GNP index of Japan and the U.S. as defined in the text.

R² = the coefficient of determination.

DW = Durbin-Watson Statistic.

All = the entire period (Q1.1953-Q4.1979).

SUBP1 = the first subperiod (Q1.1953-Q4.1965).

SUBP2 = the second subperiod (Q1.1966-Q4.1979).

The figures in parenthesis are t-statistics.

C_{ij} Matrix			
i/j	<u>1</u>	<u>2</u>	<u>3</u>
1	200	1.41	13.23
2	1.06	0.79	0.55

Based on these information, the tests of parametric shifts are performed for each j .

For $j=1$:

The posterior distribution of $r_1 = b_{21} - b_{11} = 33.95$ can be approximated by a t-distribution,⁷

$t(33.95, 200.46, 49.40)$,

i.e., the difference in the coefficients of the constant can closely be approximated by a scaled t-distribution having $B=49$ degrees of freedom centered at $r=33.95$ with a scale factor of $\sqrt{200.46} = 14.16$. The 95 percent confidence interval is given by (5.47, 62.43). The two-tail test is depicted in Figure 1-A with the appropriate confidence interval. The criterion for testing is to see whether the 95 percent confidence interval includes zero. The figure shows that the difference in the coefficients of two equations is markedly different from zero at the 5 percent level of significance. Therefore, we reject the null hypothesis that $b_{21} = b_{11}$.

The meaning of this test is that in sampling the distribution of r_1 , 95 times out of 100, we will find the distribution that has a positive value, with that value most likely to be 33.95. That is, the intercept has increased during the second subperiod.

For $j=2$:

Using the same procedure, we obtain the posterior pdf of r_2 which is approximated by

$t(0.76, 2.24, 92.06)$.

⁷ $\cos^2 \phi = 1.06/(200 + 1.06) = 0.005$

$\sin^2 \phi = 0.995$

$\cos^4 \phi = 0.000025$

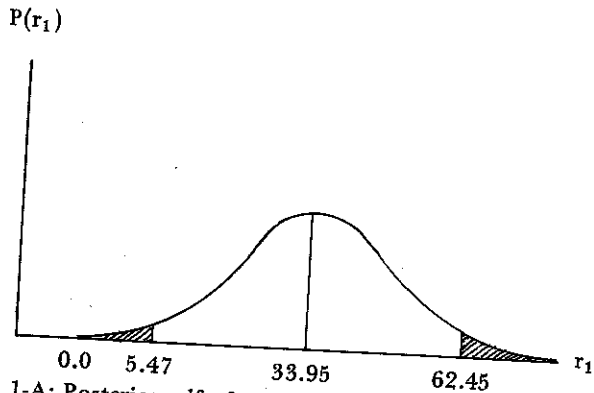
$f_1 = (53/51) \times 0.005 + (49/47) \times 0.995 = 1.04253$

$f_2 = 0.0239$

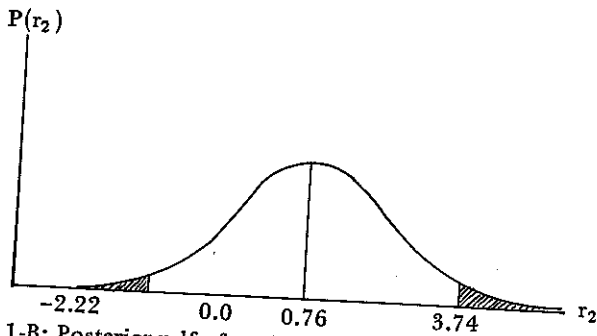
$B = 49.4$

$a^2 = 0.997$

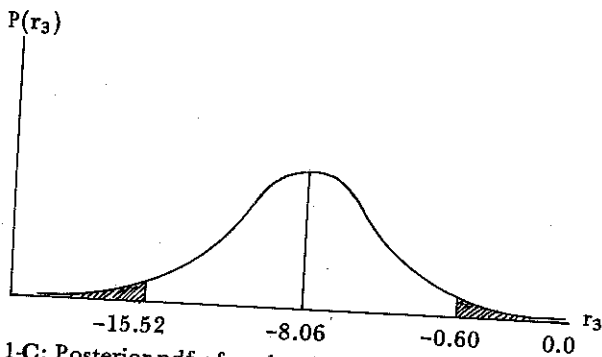
Figure 1: Posterior pdf's $r_j = b_{2j} - b_{1j}$ at 95% confidence interval



1-A: Posterior pdf of $r_1 = b_{21} - b_{11} = 33.95$



1-B: Posterior pdf of $r_2 = b_{22} - b_{12} = 0.76$



1-C: Posterior pdf of $r_3 = b_{23} - b_{13} = -8.06$

The two-tail test with the appropriate confidence interval is given in Figure 1-B. Since the 95 percent confidence interval does include zero in the figure, we do not reject the null hypothesis that $b_{22} = b_{12}$.

For $J = 3$:

The posterior pdf of r_3 is approximated by $t(-8.06, 13.78, 55.56)$

Since the 95 percent confidence interval does not include zero, as given in Figure 1-C, we reject the null hypothesis that $b_{23} = b_{23}$.

The results of our tests for $j = 1, 2, 3$ are delineated in Table 2.

Table 2
PARAMETERS OF THE APPROXIMATE t - DISTRIBUTIONS
AND CORRESPONDING 95 PERCENT CONFIDENCE INTERVALS

j	$r_j = b_{2j} - b_{1j}$	$a^2 (C_{1j} + C_{2j})$	B	95% Confidence Interval
1	33.95	200.46 (14.16)	49.40	[5.47, 62.43]
2	0.76	2.24 (1.50)	92.06	[-2.22, 3.74]
3	-8.06	13.78 (3.71)	55.56	[-15.52, -0.60]

Figures in parenthesis are the scale factors of the t -distribution. The posterior pdf of r_j is approximated by $t[r_j, a^2(C_{1j} + C_{2j}), B]$.

These results suggest that the parameter shifts occurred for the income coefficient and intercept, but not for the price coefficient.

IV. Conclusions

In this paper, we have examined the Korean export performance of manufactured goods, and have tested parametric shifts of the export equations. Using quarterly data for Korean manufactured exports to the world market from Q1, 1953 to Q4, 1979, two separate regressions were run against the two basic independent variables, the world income and the relative price ratio. Based on the regression results, a Bayesian test of parameter shift is performed to check for structural shifts. Perhaps the most common test for structural shifts may be the Chow test. However, the Chow test does not appear appropriate for our purpose, since its basic assumption is that the error variances in different groups are equal. This homoscedastic problem has been examined by T. Toyoda who concluded that the presence of unequal variances may be serious and that the Chow test may be misleading when heteroscedasticity exists between equation.⁸

Given unequal variances of error terms in the two equations of subperiods of Table 1, the Chow test, therefore, would result in an unfair comparison. The Bayesian test, applied to the results of the regression, confirms the existence of parameter shifts for both intercept and income variables.

The test results indicate that as the Korean economy passes the turning point of sustained growth around 1965 with heavy doses of stimuli, the intercept has begun to increase, i.e., for the given set of price ratio (RP) and world income (GNPI), the growth rate of exports value is higher during the period after 1965 than before.

The smaller size of income coefficient in the second subperiod suggests that income elasticity of demand for Korean exports has declined as the pace of Korean exports has made marked shifts around 1965, and that Korean exports have become less sensitive to fluctuations of world income. Thus, foreign exchange earnings became more stabilized in the second subperiod.

These results imply that a developing country can stabilize its export earnings through structural shifts in foreign trade. The

⁸ See Toyoda (1974, 601-608).

school of thought which maintains that instability in export earnings is detrimental to economic development of developing countries⁹ seems to be contradicted by the empirical evidence in the case of Korea.

Data Sources

- (1) Korean Exports (1953-79) — Total & manufactured, Bank of Korea, *Economic Statistics Yearbook*, 1969, 1976, 1980.
- (2) Export Unit Value Indexes for Korea, Japan & U.S. (1970 = 100), Bank of Korea, *Economic Statistics Yearbook*; IMF, *International Financial Statistics*; UN, *Monthly Bulletin of Statistics*, various volumes.
- (3) GNP Indexes for Japan and U.S. (1975 = 100). OECD, *Main Economic Indicators: Historical Statistics*, 1955-71 & 1960-79.

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⁹ See, for example, Singer (1950) and Prebisch (1959). G. Myrdal (1957), denying any positive effects of free trade on LDCs' development, argues that "it rather tends to have backwash effects and to strengthen the forces maintaining stagnation or regression."