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—Research Paper—

Intervention Analysis with Application to Oil Shock and WPI of Korea

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Abstract

This paper is concerned with the application of the intervention analysis to the wholesale price index of Korea.

There were four big shocks on the WPI during the last two decades, which were caused by the series of oil price hikes and changes in the foreign exchange rate. Intervention analysis of these multiple shocks revealed the nature and causalities of each shocks to the general price level of Korea.

1. Introduction

One of the distinct features of the time series of economic or business phenomena in recent years can be characterized by the existence of sudden changes and/or sharp turning points in the "normal" pattern.

These sudden changes in the pattern are mainly due to the shocks such as the oil price hike, grain embargo, unexpected political events, disaster, etc., most of which were external previously but are now closely related to the variables in the system. The existence of these highly correlated external shocks inevitably creates difficulties in forecasting because all the statistical time series methods are based on the assumption that "there exists an unique pattern of observations and the pattern of the past observations will continue to be the same in the future."

Well acclaimed method such as the Box-Jenkins ARIMA model [5], which is known to be the most comprehensive and the "best-fit" method among the currently available statistical methods, can not alone account for these changes.

An extension of the Box-Jenkins model to take into account this gap called Intervention Analysis has been developed recently and applied to investigate the effects of legislation and governmental controls to the economic and environmental problems [1, 4, 6].

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The purpose of this paper is to investigate the effects of the multiple shocks of oil price hikes and changes of foreign exchange rates to the whole sale price index of Korea by using the intervention analysis.

2. Model

Suppose the observations are available as a series obtained at equal time intervals, i.e., $\cdots$, Y_{t-1}, Y_t, $Y_{t+1}, \cdots$. Then the general model has the form

$$Y_t = f(x, t) + N_t \tag{1}$$

where x is a set of exogenous variables including interventions and N_t represents stochastic background variation or noise.

The noise, N_t, may be modeled by the ARMA(p, q) process

$$\Psi(B) N_t = \theta(B) a_t \tag{2}$$

where

B is the backward shift operator such that

$$B^m Y_t = Y_{t-m}$$

$\{a_t\}$ is a sequence of independently distributed normal variables having mean zero and variance which is often called" white noise"

$\theta(B)$ is a moving average polynomial of order q, MA(q), such that

$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q \tag{3}$$

$\Psi(B)$ is an autoregressive polynomial of order p, AR(p), such that

$$\Psi(B) = 1 - \Psi_1 B - \Psi_2 B^2 - \cdots - \Psi_p B^p \tag{4}$$

The system represented by the ARMA is assumed to be the stationary process, i.e., it satisfies the stability and invertibility conditions; the roots of $\theta(B)$ lie outside, and those of $\Psi(B)$ lie on or outside the unit circle.

For a certain kinds of homogeneous nonstationary series with seasonality, it can be converted to a stationary process by the differencing transformation, i.e., the AR and MA operators can be represented by

$$\Psi(B) = \Psi_1(B)\Psi_2(B^s)$$

$$= \phi_1(B)\phi_2(B^s)(1-B)^d(1-B^s)^D \tag{5}$$

$$\theta(B) = \theta_1(B)\theta_2(B^s) \tag{6}$$

where

s represents the seasonality period

$\phi_1(B)$, $\phi_2(B^s)$ are AR (p_1) and AR(p_2), respectively

$\theta_1(B), \theta_2(B^s)$ are MA(q_1) and MA(q_2), respectively.

Then the final form of a noise model can be given by

$$\phi_1(B)\phi_2(B^s)(1-B)^d(1-B^s)^D N_t = \theta_1(B)\theta_2(B^s) a_t \tag{7}$$

Now, the effects of exogenous variables x can be modeled by a transfer function model of the form

$$f(x, t) = \delta^{-1}(B) W(B) X_{t-b} \tag{8}$$

where

$\delta(B)$ and $W(B)$ are the polynomial vector operator in B of degree r and s, respectively.

i.e.,

$$\delta_j(B) = 1 - \delta_{ij}B - \cdots - \delta_{r_j j}B^{r_j} \quad (9)$$

$$W_j(B) = W_{0j} - W_{1j}B - \cdots - W_{s_j j}B^{s_j} \quad (10)$$

and b represents time lag.

Thus, the general model is

$$\begin{aligned} Y_t &= f(x, t) + N_t \\ &= \delta^{-1}(B)\,W(B)X_{t-b} + \Psi^{-1}(B)\theta(B)a_t \end{aligned} \quad (11)$$

with the proper order of polynomial operators.

The exogenous variable X_t can be given by a general process, however, it often takes the known form of shock such as pulse or step (or ramp) for the Intervention Analysis, i.e., X_t takes the value 0 or 1 at time t depending on the absence or presence of the interventions.

3. Model Building

Modelling according to the Box-Jenkins approach is essentially an iterative process; it involves the three basic stages of identification, estimation, and diagnostic checking.

In identification stage, we want to suggest a subclass of parsimonious model worthy to be entertained by the observations. It consists of the tentative determination of the degrees of differencing, the degrees of the AR & MA operators, the degrees of the transfer function operators, and the lag parameters using the autocorrelation, partial autocorrelation, and cross autocorrelation functions.

The form of the external shock should be identified at the same time which may cause complications in the identification stage for the Intervention Analysis. One of the suggested approach is to start with the simplest form of the intervention such as a step or a pulse. Then the intervention identification can be modified one by one and completed until the residuals are considered to be reduced to an acceptable level of white noise. Estimation stage tries to estimate the parameters of the tentatively identified model by the maximum likelihood estimation or by the nonlinear least square estimation as an approximation to the maximum likelihood estimator. Diagnostic checking involves checking the fitted model in relation to the observations to reveal model inadequacies and to suggest the directions of model improvement. It can be achieved by investigating the "whiteness" of the individual residuals and Chi-square or Kolmogorov-Smirnov goodness-of-fit test for the set of residuals as a whole. If the model pass the test, in other words, if the test fails to prove the inadequacies of the model then the model can be used with a certain degree of confidence to forecasting and/or control.

4. Application to the WPI of Korea

4.1 Data

The monthly time series of wholesale price index (WPI) from January 1965 to December 1980 [3] was used since it is generally believed that WPI represents the price level better than CPI (consumer price index) in Korea [2].

The WPI was transformed into the monthly change rate which indicates the changes in

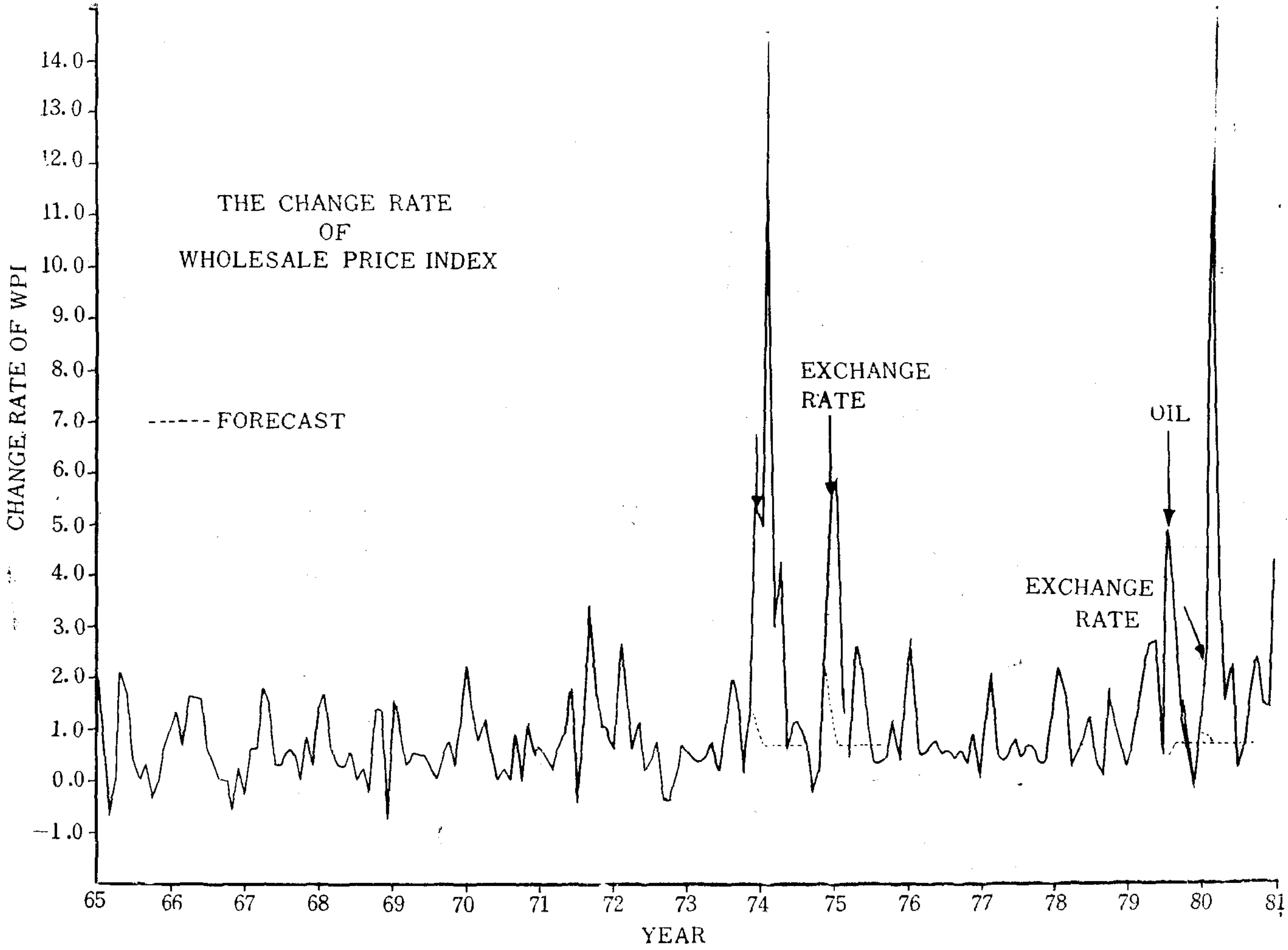

Fig. 1. The Change Rate of W.P.I.

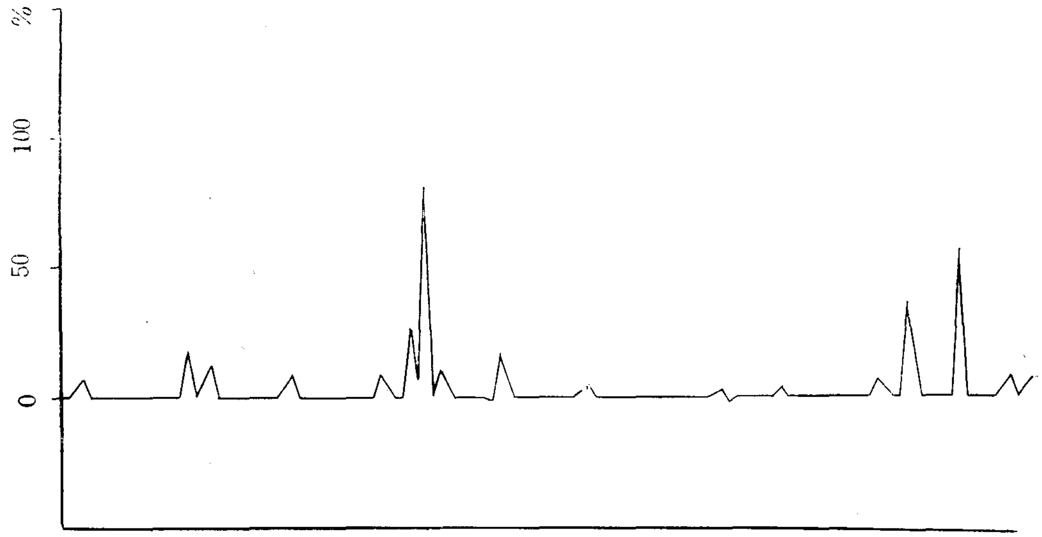

Fig 2(a) Oil Price Change Rate

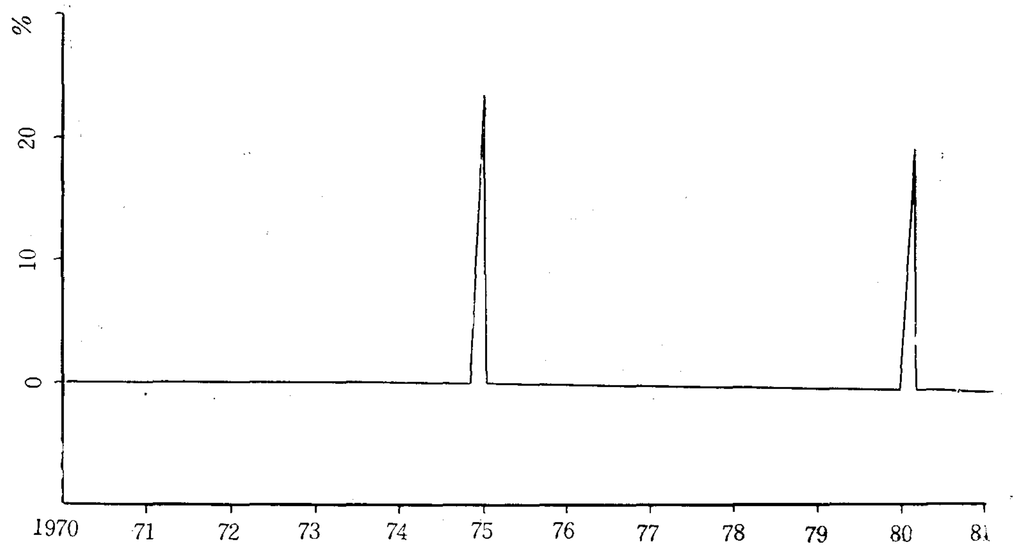

Fig. 2(b) Changes in the Foreign Exchange Rate the price level.

As can be observed in Figure 1, there were four big shocks during the last 16 years.

Figure 2 shows the price change rate of petroleum and related products and changes in the foreign exchange rate, which can clearly be approximated by the impluse function.

4. 2 Models and Estimation

If there were only the four major shocks and the structure of the noise part was not changed fundamentally, the complete simple intervention model describing the monthly change-rate of the WPI in Korea can be represented by

$$z_t=\theta_0+\sum_{j=1}^{4}\sum_{i=0}^{n_i}\frac{w_{ij}B^i}{\delta_{i+1,j}B^i}P_{t-b_j,j}+N_t \qquad (12)$$

where z_t is the monthly change rate of the WPI, and $P_{t-b_j,j}$ defined as follows represents the impulse function which is 1 at intervention time, and 0 elsewhere.

$P_{,1}$; the first oil shock in December 1972

$P_{,2}$; change in the foreign exchange rate in December 1974

$P_{,3}$; the second oil shock in July 1979

$P_{,4}$; change in the foreign exchange rate in January 1980

Estimation results are summarized in Table 1. The estimates and actual values of the change rate of the WPI can be observed in Figure 3 and estimation errors are shown in Figure 4. Figures 5 to 8 exhibit the differences between forecasts and actual values.

Table 1 Estimation Results

Models	Parameters	Estimate	S.E.	Statistics
Univariate Model	θ_0	0. 7144	0. 10	$\chi^2(22)=21.816$
	θ_1	−0. 4145	0. 0903	$Q(5)=428.8983$
Intervention Model I	θ_0	0. 73038	0. 0934	$\chi^2(22)=27.63$
	θ_1	−0. 37831	0. 0939	$Q(5)=73.2892$
	w_{01}	4. 2662	0. 7261	
	w_{11}	4. 1876	0. 7684	
	w_{21}	13. 8010	0. 7684	
	w_{31}	2. 2710	0. 7684	
	w_{41}	3. 5883	0. 7164	
Intervention Model II	θ_0	0. 79767	0. 0758	$\chi^2(22)=17.94$
	θ_1	−0. 34254	0. 0786	$Q(5)=43.1395$
	w_{02}	4. 4954	0. 6979	
	w_{42}	2. 8248	0. 6935	
	δ_{12}	0. 90478	0. 1291	
	δ_{22}	0. 49686	0. 1323	
Intervention Model III	θ_0	0. 79152	0. 0758	$\chi^2(34)=33.478$
	θ_1	−0. 34035	0. 0779	$Q(5)=390.4675$
	w_{03}	4. 5251	0. 7234	
	δ_{13}	0. 41182	0. 1317	
Intervention Model IV	θ_0	0. 85647	0. 0822	$\chi^2(34)=36.178$
	θ_1	−0. 39325	0. 0782	
	w_{04}	1. 2629	0. 7791	
	w_{14}	14. 039	0. 8352	
	w_{24}	3. 0210	0. 7759	

4. 3 Discussion of Results

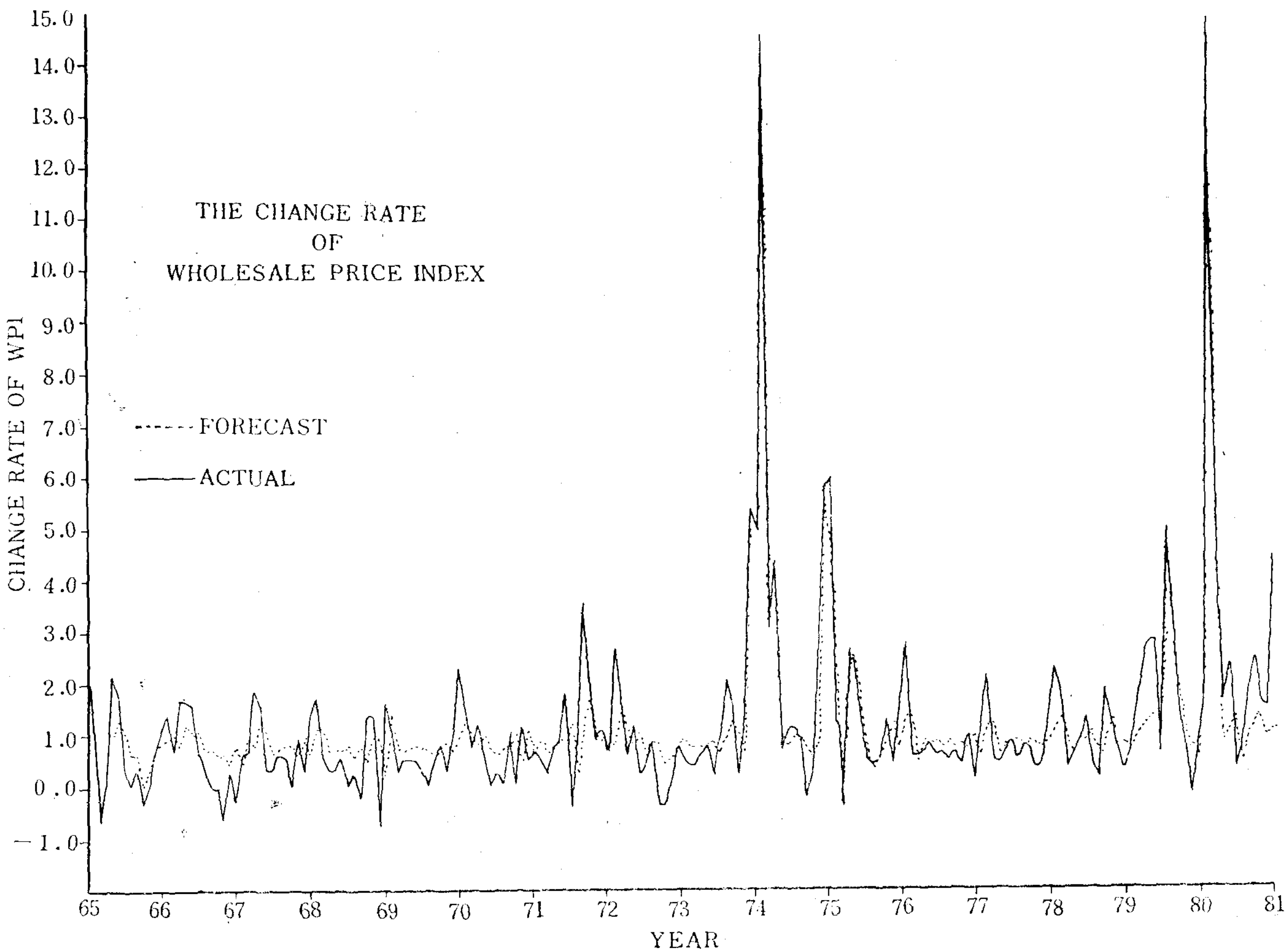

Fig. 3. The Forecast and Actual Values of the Change Rate of W.P.I.

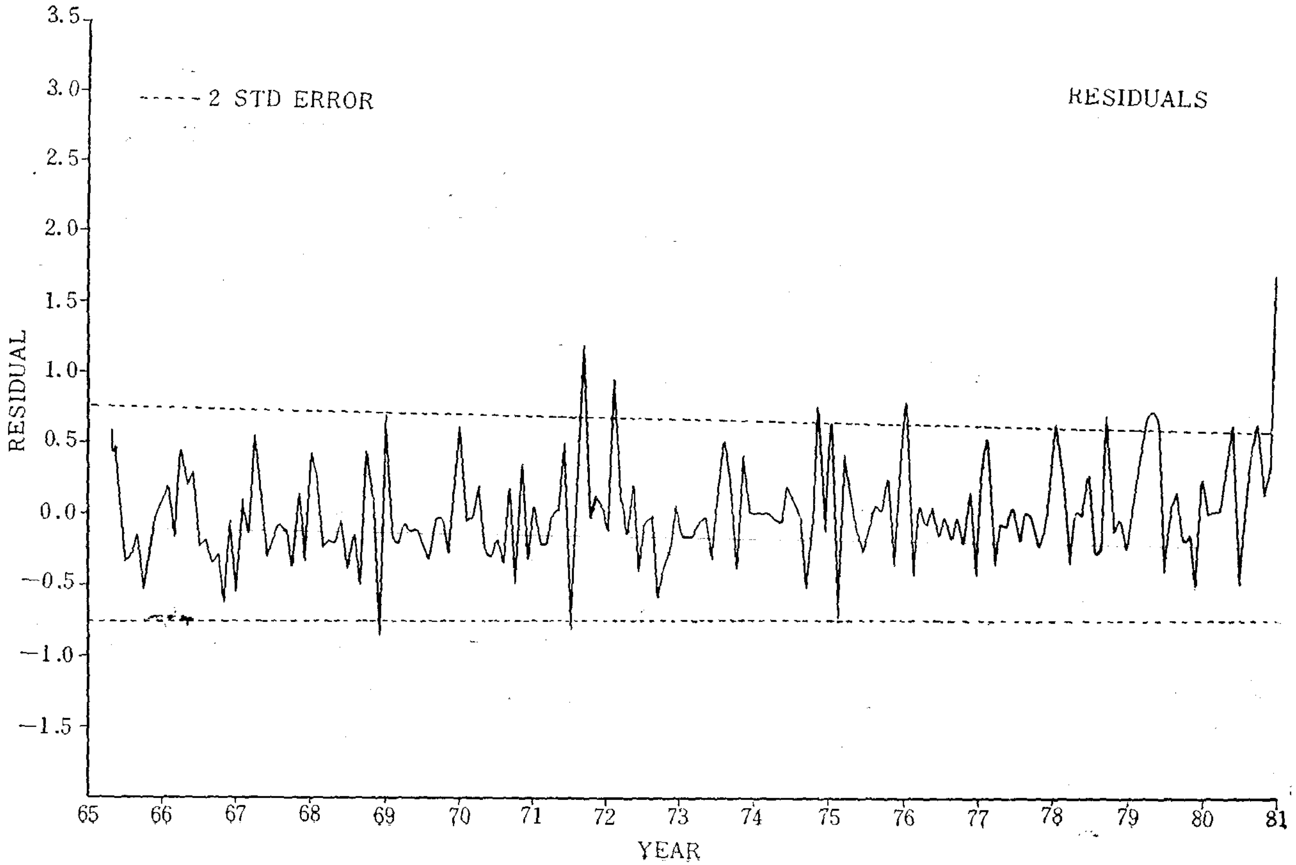

Fig. 4. Residuals of Forecast

(1) Univariate Model

The monthly change rate of the WPI before the first intervention in December 1973 was estimated by the MA(1) model as can be seen in Table 1.

$$Z_t = 0.7144 + (1 + 0.4145B)a_t \qquad (13)$$

This model shows that the rising rate of the price level was 0.7144% a month on the average during the prior-shock periods. The equation (13) can be rewritten as a distributed lag form.

$$(Z_t - 0.7144) = (1 + 0.4145B)a_t$$

$$\text{let } Z_t = Z_t - 0.7144$$

$$\text{then, } Z_t = a_t + 0.4145Z_{t-1} - 0.1718\, Z_{t-2} + \cdots \qquad (14)$$

In equation (14), it is shown that the present change rate is affected by the previous change rate, and the weights are alternatively damping. It can be said that the present rising rate is affected positively by the rising rate of the month lagged by one and affected negatively by the rising rate of the month lagged by two, but the effect of the latter is less than that of the former by 0.2427. Other weights were negligible. Models such as AR (2) can also be used for this process, however, none of the models fit the process significantly better than the MA(1) model. Hence, the MA(1) model was selected by the principle of parsimony.

(2) Intervention Model I

This model describes the effect of the first oil shock in December 1973. The estimated effect is given in Figure 5. Oil price has risen in January 1974 and the peak is shown in February 1974. The first oil price hike triggered by the OPEC countries in 1973 was a real shock to the world so that everyone could expect a sudden rise in domestic price. This expectation made price rise in December 1973 ahead of the domestic oil price in January 1974.

(3) Intervention Model II

The change in the foreign exchange rate in December 1974 can be considered as a consequence of the first oil shock.

As shown in Figure 6, the effects of the change in the foreign exchange rate occurred twice. The second effect was delayed three months from the first effect.One of the possible explanations is that the first effect was caused by the import price which was affected directly by the change in the foreign exchange rate, and the second effect resulted from the price of products which were made from the imported goods.Alternatively, the first can also be interpreted as that resulted from the expectation while the second was caused by the realized impacts.

The average rising rate was fairly higher than that of the univariate model, which means that the rate rose considerably due to the change in the foreign exchange rate and the first oil shock.

(4) Intervention Model III

The effect of the second oil shock was relatively smaller than that of the first oil shock and the effect of the shock was absorbed more quickly than the first oil shock as shown in Figures 5 and 7. This seems to reflect the learning effect,*i.e.*, the adaptiveness to the oil shock which acquired from the previous similar experience.

(5) Intervention Model IV

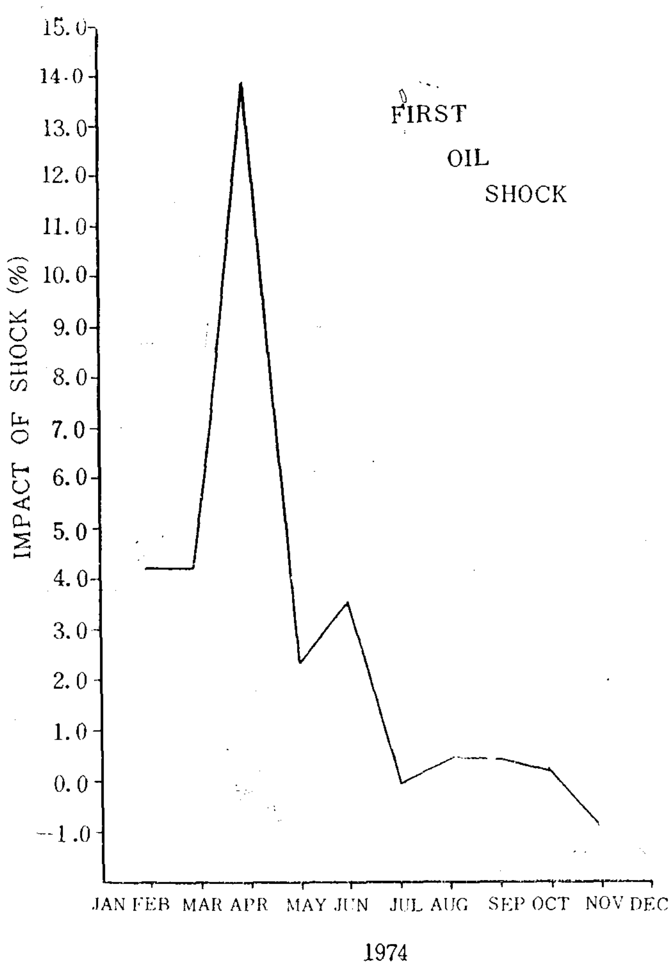

Figure 5. Effects of the First Oil Shock

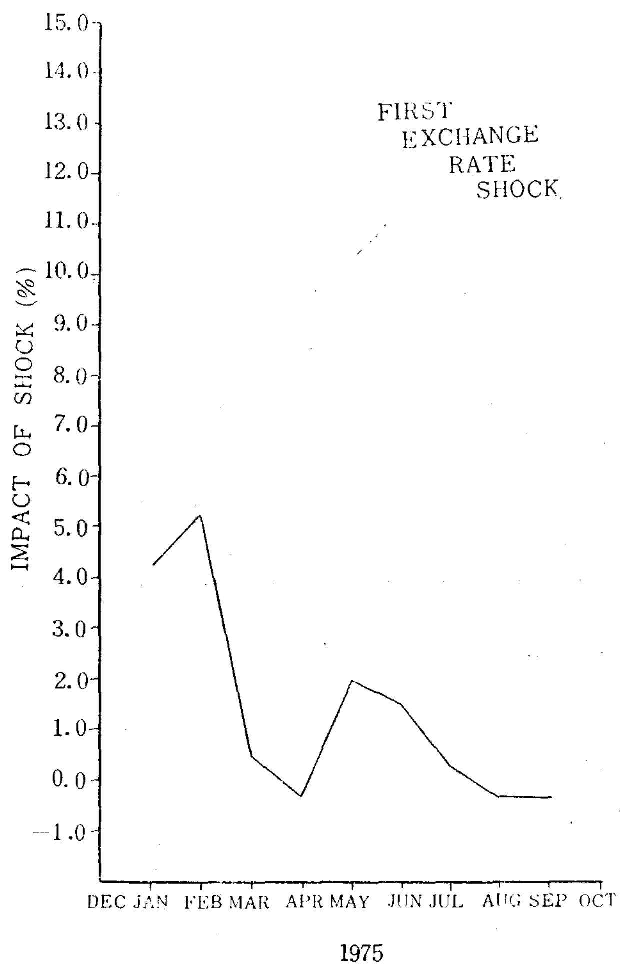

Figure 6. Effects of the First Foreign Exchange Shock

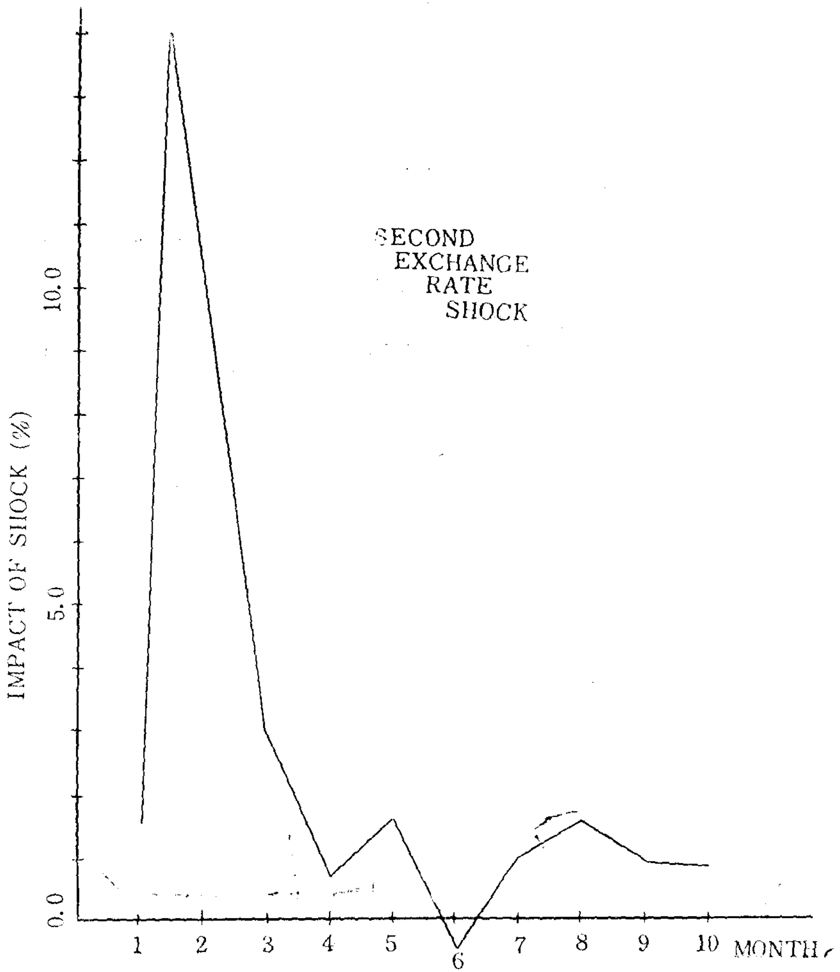

Figure 8. Effects of the Second Exchange Rate Shock

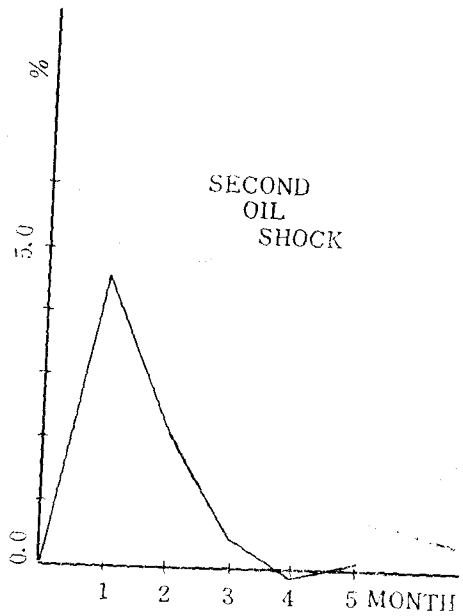

Figure 7. Effects of the Second Oil Shock

The change in the foreign exchange rate in January 1980 had a great effect on the price level. The magnitude of the effect can be compared to that of the first oil shock as shown in Figures 6 and 8. The effects of the second foreign exchange shock is similar to those of the first oil shock. In fact, the second foreign exchange shock was an institutional change, *i.e.*, a new exchange rate system was implemented in January 1980. The sudden increase in the price change rate can be interpreted as a result of the expectations due to these institutional change.

(6) Impacts on Price

The effects of the shocks are shown in Table 2, where impacts were calculated by differences between forecasts and actual values. As oil price rose by 1%, the WPI rose by about 0.13% to 0.18%. As the foreign exchange rate increased by 1%, the WPI was affected by 0.63% from the first change in the foreign exchange rate. The WPI increased by 0.95% as the foreign exchange rate rose by 1% from January to May 1980. Other environmental factors such as political disturbances may also affect the general price level during this period.

TABLE 2 Impacts on Price

Month	WPI of Petro. & Related Products		Exchange Rate		Cumulative Impacts(%)
	(%)	Change Rate	Won	Change Rate	
1973. 11	28.5	0			4.2318
12	36.7	28.77			8.61328
1974. 1	38.9	32.49			23.62026
2	70.4	147.02			26.44745
3	70.6	147.72			30.90345
4	78.5	175.44			
1974. 12. 6			397.50	0	
7			484.00	21.76	4.1529
1975. 1					9.65081
2					10.16945
3					9.86145
4					12.06263
5					13.76755
1979. 6	124.5	0			4.5717
7	190.9	53.33			6.94254
8	194.5	56.22			7.52366
9	194.5	56.22			
1980. 1. 11			484.00		
12			580.00	19.83	1.3523
2			580.70	19.98	15.6454
3			586.10	21.10	19.24231
4			590.50	22.00	20.077
5			596.20	23.20	22.00

5. Conclusion

This paper is concerned with the Intervention Analysis and its application to the wholesale price index of Korea. The effects of four major shocks during the 1970's were investigated.

The monthly change rate of the WPI was 0.71% on the average during the prior-intervention period, *i.e.*, from January 1965 to December 1973. Four big shocks could be clearly observed on the WPI during the last two decades, *i.e.*, the first oil shock in December 1973, change in the foreign exchange rate in December 1974, the second oil shock in July 1979, and change in the foreign exchange system in January 1980. The effects of the first oil shock in December 1973 and the change in the foreign exchange rate in January 1980 were remarkably large in magnitude and their features were alike. The first foreign exchange shock had an oscillating effect on the WPI with a second tide of effects lagged by three months.

Analysis of the past effects of the shocks can be explained by the intervention analysis. For forecasting purposes, however, learning effects or change in the effects of the shocks should be explored.

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