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The Cointegrating VAR Modelling Approach to the Korean Macroeconomy in the Presence of Structural Breaks

Yongcheol Shin*

Abstracts

Garratt et al. (2006) provides a practical modelling strategy that incorporates long-run structural relationships, suggested by economic theory, in an otherwise unrestricted VAR model. We apply this strategy to construct a small quarterly macroeconometric model of Korea and estimate the benchmark model over 1982q3-2006q2 in nine variables: domestic and foreign outputs, prices and interest rates, oil prices, the nominal effective exchange rate, and real money balances. In particular, we explicitly allow for the presence of structural breaks in the model, highlighting the significant impact of the 1997 Asian currency crisis on the macroeconomic performance of Korea during and after the crisis period. Overall estimation results are sensible in terms of identifying the long-run cointegrating relationships weakly consistent with the underlying theory and further dynamic counterfactual analyses in the context of both structural impulse response functions and the probability forecasting of in.ation and output growth.

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Ⅰ. Introduction

Over the past decades, there has been a growing interest in developing macroeconomic models with transparent theoretical foundations and flexible dynamics that fit the historical time series data reasonably well, e.g. Sims (1980), Kydland and Prescott (1982), King et al. (1991), Murphy (1992), Fair (1994), Kim and Pagan (1995), Barrel et al. (2001), Smets and Wouters (2003, 2007) and Botman et al. (2007).

Recently, Garratt et al. (2006, GLPS henceforth) have published a monograph entitled *A Structural Cointegrating Macroeconomic Model of the UK*. It provides a detailed description of the structural cointegrating VAR approach to macroeconometric modelling and takes a full account of the long-run theory used to model an open economy. The econometric methods then describe a construction of the core model and provide the uses of the model, emphasising the importance of the model in the production of impulse response analysis and probability forecasting.

This paper aims to construct a quarterly long-run structural cointegrating VAR model of the Korean core macroeconomy with the following objectives: *Firstly,* we develop a theory and data consistent small core quarterly macro model of Korea. Based on the cointegrating VAR modeling approach advanced by GLPS, we test the validity of the over-identifying restrictions on the long run relationships and analyse further short run dynamic properties of the model. *Secondly,* in order to explicitly examine the significant impact of the 1997 Asian currency crisis on the macroeconomic performance of Korea during and after the crisis period, we extend the basic model and take into account of the presence of structural breaks in the model. This is expected to improve estimation and forecasting results, especially for those countries like Korea most severely hit by the 1997 currency crisis. *Thirdly*, we undertake some policy evaluation exercises. We first investigate the sources of shocks, such as the oil price and monetary policy shocks, which generate fluctuations in real and nominal variables and the mechanisms by which the

effects of different shocks are propagated across different variables and over time. We also provide the probability forecasting for output growth and inflation, which may complement the activities currently undertaken by the Bank of Korea. Hence, we aim to develop a model consistent with both data and theoretically coherent foundation and to provide further insights on the Korean macroeconomy, which should be useful in understanding both the functioning of the economy and the conduct of its macroeconomic policy.

We estimate the benchmark model over 1982q3-2006q4 in nine variables: domestic and foreign outputs, prices and interest rates, oil prices, the nominal effective exchange rate, and real money balances. The dynamic properties of the model are discussed using impulse responses for the effects of an oil price shock and domestic and foreign monetary policy shocks on the long-run relations and the endogenous variables. This paper also argues that probability forecasts convey information on the uncertainties that surround macro-economic forecasts in a straightforward manner which is preferable to confidence intervals. Out of sample probability forecasts of inflation and output growth are also provided, and their implications discussed in relation to the Bank of Korea's inflation target and the need to avoid low growth regimes, both separately and jointly.

This model provides sensible estimation results in terms of identifying the five longrun cointegrating relationships weakly consistent with the underlying theory. Combining these estimated

VECM's with the marginal VAR(2) model for weakly exogenous foreign variables we also provide further dynamic counterfactual analyses in the context of both structural impulse response functions and the probability forecasting of inflation and output growth. Impulse responses of an oil price, foreign equity price and domestic and foreign monetary policy shocks on the endogenous variables provide mostly plausible policy directions. Out of sample probability forecasts of inflation and output growth predict relatively stable growth and inflation prospects over the short-term period, but these forecasts are subject to a high degree of uncertainty, as the forecast horizon increases. In particular, the benchmark model with structural breaks provides somewhat smaller forecasts of output growth and higher forecasts of inflation than those obtained from the model without structural breaks.

The plan of the paper is as follows. Section 2 outlines the main econometric methodology in the context of the structural vector error correction model with structural breaks. Section 3 discusses the detailed steps involved in the construction of the cointegrating VAR model of a Korean Macroeconomy. It also reports the preliminary data analysis and discusses the empirical results obtained from testing the long-run properties of the core model. Section 4 reports the dynamic properties of the estimated impulse response functions for the oil price and domestic and foreign monetary policy shocks. Section 5 presents the results for probability forecasts of macroeconomic events of interest. This section also provides a brief account of inflation targeting in Korea, and presents single and joint event probability forecasts involving output growth and inflation objectives at different forecast horizons. Section 6 provides some concluding remarks.

Ⅱ. A Cointegrating VAR Model with Structural Breaks

We consider the two different data generating processes (DGP) for an m-vector random process, $\{z_t\}_{t=1}^{\infty}$ subject to the observed structural breaks. The first is the intercept-shift vector autoregressive model of order p (IS-VAR(p)):

$$\Phi(L)[z_t - \mu - \gamma t - \mu_* d_t] = e_t,\ t = 1,2,\ldots, \qquad (2.1)$$

where L is the lag operator, μ, μ_* and γ are m-vectors of unknown coefficients, the (m,m) matrix lag polynomial of order p, $\Phi(L) \equiv I_m - \Sigma_{i=1}^{p} \Phi_i L^i$, comprises the unknown (m,m) coefficient matrices $\{\Phi_i\}_{i=1}^{p}$,

$$d_t = \left\{ \begin{matrix} 1 & if\ t > [T\pi] \\ 0 & otherwise \end{matrix} \right\}, \qquad (2.2)$$

is the intercept shift dummy, π is the fraction of break time, and $[T\pi]$ stands for the largest integer value of $T\pi$. The error process $\{e_t\}_{t=-\infty}^{\infty}$ is assumed to be $IN(0,\Omega)$ with Ω being positive-definite and the analysis is conducted given the initial values $Z_0 \equiv (z_{-p+1},\ldots,z_0)$.

It is convenient to express the lag polynomial $\Phi(L)$ in a form which arises in the vector error correction model,

$$\Phi(L) \equiv -\Pi L + \Gamma(L)(1-L), \qquad (2.3)$$

where Π is the long-run multiplier matrix defined by

$$\Pi \equiv -\left(I_m - \sum_{i=1}^{p} \Phi_i\right) \tag{2.4}$$

and the short-run response matrix lag polynomial is given by

$$\Gamma(L) \equiv I_m - \sum_{i=1}^{p-1} \Gamma_i L^i,\ \Gamma_i = -\sum_{j=i+1}^{p} \Phi_j,\ i = 1, \ldots, p-1. \tag{2.5}$$

Using (2.3), we have

$$\Phi(L)\mu = \{-\Pi L + \Gamma(L)(1-L)\}\mu = -\Pi\mu, \tag{2.6}$$

$$\begin{aligned}\Phi(L)\gamma t &= \{-\Pi L + \Gamma(L)(1-L)\}\gamma t = -\Pi\gamma(t-1) + \Gamma\gamma \\ &= -\Pi\gamma t + (\Pi + \Gamma)\gamma,\end{aligned} \tag{2.7}$$

$$\begin{aligned}\Phi(L)\mu_* d_t &= \{-\Pi L + \Gamma(L)(1-L)\}\mu_* d_t \\ &= -\Pi\mu_* d_{t-1} + \Gamma(L)\mu_* \Delta d_t = -\Pi\mu_* d_{t-1} + \sum_{j=0}^{p-1} \delta_t^* \Delta d_{t-j} \\ &= -\Pi\mu_* d_t + \sum_{j=0}^{p-1} \delta_t \Delta d_{t-j},\end{aligned} \tag{2.8}$$

where $\delta_0^* = \mu_*$, $\delta_0 = (\Pi + I_m)\mu_*$, $\delta_j = \delta_j^* = -\Gamma_j \mu_*$ for $j = 1, \ldots, p-1$, and

$$\Gamma \equiv I_m - \sum_{i=1}^{p-1} \Gamma_i = -\Pi + \sum_{i=1}^{p} i\Phi_i. \tag{2.9}$$

Hence, using (2.6)-(2.8), the IS-VAR(p) model, (2.1) can be written as:

$$\Phi(L)z_t = a_0 + a_1 t + b_0 d_{t-1} + \delta(L)\Delta d_i + e_t, t = 1, 2, \ldots, \tag{2.10}$$

where

$$a_0 \equiv -\Pi\mu + (\Gamma + \Pi)\gamma;\ a_1 \equiv -\Pi\gamma;\ b_0 \equiv -\Pi\mu_*; \tag{2.11}$$

$$\delta(L)=\sum_{i=0}^{p-1}\delta_i L^i=\left\{I_m-\sum_{i=0}^{p-1}\Gamma_i L^i\right\}\mu_*. \quad (2.12)$$

We now partition the m-vector, z_t into the n-vector of endogenous $I(1)$ variables, y_t and the k-vector of endogenous $I(1)$ variables, x_t; namely, $z_t=(y_t^{'},x_t^{'})^{'}$ with $k\equiv m-n$. Using (2.3), we write (2.10) as VECM:

$$\Delta z_t=a_0+a_1t+b_0d_{t-1}+\sum_{i=0}^{p-1}\delta_i\Delta d_{t-i}$$
$$+\sum_{i=1}^{p-1}\Gamma_i\Delta z_{t-i}+\Pi z_{t-1}+e_t. \quad (2.13)$$

By partitioning $e_t=(e_{yt}^{'},e_{xt}^{'})^{'}$ conformably with $z_t=(y_t^{'},x_t^{'})^{'}$ and its variance matrix as

$$\Omega=\begin{pmatrix}\Omega_{yy} & \Omega_{yx}\\ \Omega_{xy} & \Omega_{xx}\end{pmatrix},$$

we can express e_{yt} conditionally in terms of e_{xt} as

$$e_{yt}=\Omega_{yx}\Omega_{xx}^{-1}e_{xt}+u_t, \quad (2.14)$$

where $u_t\sim IN(0,\Omega_{uu})$, $\Omega_{uu}\equiv\Omega_{yy}-\Omega_{yx}\Omega_{xx}^{-1}\Omega_{xy}$ and u_t is independent of e_{xt} by construction. A similar partitioning of the parameter vectors and matrices now provides:

$$a_0=(a_{y0}^{'},a_{x0}^{'})^{'};\ a_1=(a_{y1}^{'},a_{x1}^{'})^{'};\ b_0=(b_{y0}^{'},b_{x0}^{'})^{'};$$
$$\delta_i=(\delta_{yi}^{'},\delta_{xi}^{'})^{'},\ i=1,\ldots,p-1;\ \Gamma_i=(\Gamma_{yi}^{'},\Gamma_{xi}^{'})^{'},\ i=1,\ldots,p-1,$$
$$\Gamma=(\Gamma_y^{'},\Gamma_x^{'})^{'};\ \Pi=(\Pi_y^{'},\Pi_x^{'})^{'}.$$

Following Pesaran et al. (2000), we assume that the process $\{x_t\}_{t=1}^{\infty}$ is weakly exogenous with respect to the matrix of long-run multiplier parameters Π; *viz.* $\Pi_x = 0$. Then, substitution of (2.14) into (2.13) provides a conditional IS-VECM(p) model for Δy_t:

$$\Delta y_t = c_0 + c_1 t + c_0^* d_{t-1} + \sum_{i=0}^{p-1} \delta_i^* \Delta d_{t-i} + \Lambda \Delta x_t + \sum_{i=0}^{p-1} \Psi_i \Delta z_{t-i} + \Pi_y z_{t-1} + u_t, \tag{2.15}$$

where

$$c_0 \equiv a_{y0} - \Omega_{yx}\Omega_{xx}^{-1}a_{x0};\ c_1 \equiv a_{y1} - \Omega_{yx}\Omega_{xx}^{-1}a_{x1};$$
$$c_0^* \equiv b_{y0} - \Omega_{yx}\Omega_{xx}^{-1}b_{x0};$$
$$\delta_i^* \equiv \delta_{yi} - \Omega_{yx}\Omega_{xx}^{-1}\delta_{xi},\ i = 1, \ldots, p-1;$$
$$\Psi_i \equiv \Gamma_{yi} - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_{xi},\ i = 1, \ldots, p-1;$$
$$\Lambda \equiv \Omega_{yx}\Omega_{xx}^{-1};\ \Pi_{yy \cdot x} \equiv \Pi_y - \Omega_{yx}\Omega_{xx}^{-1}\Pi_x = \Pi_y.$$

We also have the marginal IS-VAR(p) model for the weak exogenous x_t as:

$$\Delta x_t = a_{x0} + \sum_{i=0}^{p-1} \delta_{xi} \Delta d_{t-i} + \sum_{i=1}^{p-1} \Gamma_{xi} \Delta z_{t-i} + e_{xt}, \tag{2.16}$$

where $c_1 \equiv a_{y1}$ and $c_{0*} \equiv b_{y0*}$ because $a_{x1} = b_{x0} = 0$.[1] Thus, the relations (2.11) and (2.12) are modified to

1) Notice that $a_{x1} = 0$ implies that there are no quadratic trends in the data generating process for the weakly exogenous $I(1)$ variables in x_t (see GLPS) whilst $b_{x0} = 0$ indicates that the foreign variables are not subject to the structural breaks, which is a reasonably maintained assumption.

$$c_0 \equiv -\Pi_y\mu + (\Gamma_y - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_x + \Pi_y)\gamma;\ c_1 = -\Pi_y\gamma;$$
$$c_{0*} = -\Pi_y\mu_*. \tag{2.17}$$

The cointegration rank hypothesis in the conditional IS-VECM(p) model for Δy_t, (2.15) is written as

$$H_r : Rank[\Pi_y] = r,\ r = 0, \ldots, n, \tag{2.18}$$

under which Π_y may be expressed as

$$\Pi_y = \alpha_y \beta', \tag{2.19}$$

where the (n, r) loadings matrix α_y and the (m, r) matrix of cointegrating vectors β are each full column rank and identified up to an arbitrary (r, r) non-singular matrix.

Using (2.17) and (2.19), we rewrite (2.15) as

$$\begin{aligned} \Delta y_t &= c_0 + \sum_{i=0}^{p-1} \delta_i^* \Delta d_{t-i} + \Lambda \Delta x_t \\ &\quad + \sum_{i=1}^{p-1} \Psi_i \Delta z_{t-i} + \Pi_{y^*} z_{t-1}^* + u_t, \end{aligned} \tag{2.20}$$

where $z_{t-1}^* = (t, d_{t-1}, z_{t-1}')'$, and $\Pi_{y^*} = \Pi_y(-\gamma, -\mu_*, I_m)$. Note that $Rank[\Pi_{y^*}] = Rank[\Pi_y]$ and, thus, from (2.19)

$$\Pi_{y^*} = \alpha_y \beta_*', \tag{2.21}$$

where $\beta_* = (-\gamma, -\mu_*, I_m)'\beta$. Consequently, we may therefore restate the cointegration rank hypothesis (2.18) as

$$H_r : Rank[\Pi_{y^*}] = r, \ \ r = 0, \dots, n. \tag{2.22}$$

Next, we consider the trend-shift VAR (TS-VAR) model:

$$\Phi(L)[z_t - \mu - \gamma t - \mu_* d_t - \gamma_* b_t] = e_t, \ \ t = 1, 2, \dots, \tag{2.23}$$

where

$$d_t = \left\{ \begin{matrix} t & if\, t > [T\pi] \\ 0 & otherwise \end{matrix} \right\}. \tag{2.24}$$

Using (2.3), we have

$$\begin{aligned} \Phi(L)\gamma_* b_t &= \{-\Pi L + \Gamma(L)(1-L)\}\gamma_* b_t \\ &= -\Pi \gamma_* b_{t-1} + \Gamma(L)\gamma_* \Delta b_t = -\Pi \gamma_* b_{t-1} + \sum_{j=0}^{p-1} \pi_j^* d_{t-j} \\ &= -\Pi \gamma_* b_t + \sum_{j=0}^{p-1} \pi_j d_{t-j}, \end{aligned} \tag{2.25}$$

where $\pi_0^* = \gamma_*$, $\pi_0 = (\Pi + I_m)\gamma_*$, $\pi_j = \pi_j^* = -\Gamma_j \gamma_*$, $j = 1, \dots, p-1$, Using (2.6), (2.7), (2.8) and (2.25), (2.23) can be written as

$$\begin{aligned} \Phi(L) z_t &= a_0^* + a_1(t-1) + b_1 b_{t-1} + \pi^*(L) d_t \\ &\quad + b_0 b_t + \delta(L)\Delta d_t + e_t \\ &= a_0^* + a_1(t-1) + b_1 b_{t-1} + b_0^* d_t + \varphi(L)\Delta d_t + e_t, \end{aligned} \tag{2.26}$$

where

$$\begin{aligned} & a_0^* \equiv -\Pi\mu + \Gamma\gamma; \ a_1 \equiv -\Pi\gamma; \ b_0 \equiv -\Pi\mu_*; \\ & b_1 \equiv -\Pi\gamma_*; \ b_0^* \equiv \Gamma\gamma_* - \Pi\mu_*; \\ & \varphi(L) = \sum_{i=0}^{p-1} \varphi_i L^i, \end{aligned} \tag{2.27}$$

$$\varphi_i = \left\{ \begin{matrix} (\Pi + I_m)\mu_* + (\Sigma_{i=1}^{p-1}\Gamma_i)\gamma_* & \text{for } j = 0 \\ -\Gamma_j \mu_* + (\Sigma_{i=j+1}^{p-1}\Gamma_i)\gamma_* & \text{for } j = 1, \dots, p-2 \\ -\Gamma_j \mu_* & \text{for } j = p-1 \end{matrix} \right\} \tag{2.28}$$

or alternatively

$$\Phi(L)z_t = a_0 + a_1 t + b_1 b_t + b_0^* d_{t-1} + \varphi(L)\Delta d_t + e_t. \qquad (2.29)$$

Thus, the TS-VAR(p) model of (2.26) can be written as VECM:

$$\Delta z_t = a_0 + a_1 t + b_1 b_{t-1} + b_0^* d_t + \sum_{i=0}^{p-1} \varphi_i \Delta d_{t-1}$$
$$+ \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-1} + \Pi z_{t-1} + e_t. \qquad (2.30)$$

Substitution of (2.14) into (2.30) together with a similar partitioning of the parameter vectors and matrices, provides a conditional model for Δy_t:[2)]

$$\Delta y_t = c_0 + c_1 t + c_1^* b_{t-1} + c_0^{**} d_t + \Lambda \Delta x_t$$
$$+ \sum_{i=1}^{p-1} \Psi_i \Delta z_{t-i} + \Pi_y z_{t-1} + u_t. \qquad (2.31)$$

where $c_0 \equiv a_{y0} - \Omega_{yx}\Omega_{xx}^{-1} a_{x0}$, $c_1 \equiv a_{y1} - \Omega_{yx}\Omega_{xx}^{-1} a_{x1}$, $c_1^* \equiv b_{y1} - \Omega_{yx} \Omega_{xx}^{-1} b_{x1}$, $c_0^{**} \equiv b_{y0}^* - \Omega_{yx}\Omega_{xx}^{-1} b_{x0}^*$, $\Psi_i \equiv \Gamma_{yi} - \Omega_{yx}\Omega_{xx}^{-1} b_{xi}$, $i = 1, \ldots, p-1$, and $\Pi_{yy \cdot x} \equiv \Pi_y - \Omega_{yx}\Omega_{xx}^{-1}\Pi_x = \Pi_y$. We also have the marginal TS-VAR(p) model for the weak exogenous $\{x_t\}_{t=1}^{\infty}$:

$$\Delta x_t = a_{x0} + b_{x0}^* d_t + \sum_{i=1}^{p-1} \Gamma_{xi} \Delta z_{t-i} + e_{xt},\ t = 1, 2, \ldots, \qquad (2.32)$$

where we use $a_{x1} = b_{x1} = 0$, $b_{x0}^* \equiv \Gamma_x \gamma_*$. Noticing that $c_1 \equiv a_{y1}$ and $c_1^* \equiv b_{y1}$, the restrictions are modified to

2) Now, we also have $b_1 = (b_{y1}', b_{x1}')'$, $b_0^* = (b_{y0}^{*\prime}, b_{x0}^{*\prime})'$, $\varphi_i = (\varphi_{yi}', \varphi_{xi}')'$.

$$c_0 \equiv -\Pi_y\mu + (\Gamma_y - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_x + \Pi_y)\gamma;\ c_1 = -\Pi_y\gamma;$$
$$c_1^* = -\Pi_y\gamma_*;\ c_0^{**} \equiv (\Gamma_y - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_x + \Pi_y)\gamma_*; \tag{2.33}$$

Therefore, the TSVAR model (2.15) can be written as

$$\Delta y_t = c_0 + c_0^{**}d_t + \Lambda\Delta x_t$$
$$+ \sum_{i=1}^{p-1}\Psi_i\Delta z_{t-i} + \Pi_y^{**}z_{t-1}^{**} + u_t, \tag{2.34}$$

where $z_{t-1}^{**} = (t, b_{t-1}, z_{t-1}')'$, and $\Pi_{y**} = \Pi_y(-\gamma, -\gamma_*, I_m)$. Note that $Rank[\Pi_y^{**}] = Rank[\Pi_y]$ and, thus, from (2.19)

$$\Pi_y^{**} = \alpha_y\beta_{**}', \tag{2.35}$$

where $\beta_{**} = (-\gamma, -\gamma_*, I_m)'\beta$. Consequently, we restate the cointegration rank hypothesis (2.18) as

$$H_r : Rank[\Pi_{y**}] = r,\ r = 0, \ldots, n. \tag{2.36}$$

We may adapt the reduced rank techniques of Johansen (1995) and Johansen et al. (2000) and the long-run structural modelling of Pesaran and Shin (2002) to estimate the revised system (2.20) or (2.34). See also Garratt et al. (2003a, 2003b) and GLPS for further details on the estimation theory of both long-run cointegrating relationships, their associated VECM and further dynamic analyses including the impulse response functions and probability forecasting.

2.1. Computation of Critical Values

The asymptotic critical values of the two log-likelihood ratio statistics, namely, $\lambda_{\max}$ and λ_{trace}, are evaluated as follows: For a given cointegrating rank hypothesis H_r defined by (2.18), we generate $m-r$ independent random walk processes:

$$z_t = z_{t-1} + e_t, \; t = 1,2,\ldots,T,$$

with $z_0 = 0$ and $e_t \sim IN(0, I_m)$. We then partition $z_t = (y_t^{'}, x_t^{'})$ where y_t and x_t are respectively $(n-r)$- and k-vectors of random walk variables and $e_t = (w_t^{'}, v_t^{'})^{'}$ is partitioned conformably with $z_t = (y_t^{'}, x_t^{'})$, $t = 1,2,\ldots,T$,. We then compute the following:

$$\sum_{t=1}^{T} w_t f_t^{'} \left(\sum_{t=1}^{T} f_t f_t^{'} \right)^{-1} \sum_{t=1}^{T} f_t w_t^{'}, \tag{2.37}$$

where

$$f_t = \left\{ \begin{array}{l} \hat{z}_{t-1}^{*} \text{ for } IS-VAR \\ \hat{z}_{t-1}^{**'} \text{ for } TS-VAR \end{array} \right\},$$

where $\hat{z}_{t-1}^{*}$ is the OLS residual vector from the regression of $z_{t-1}^{*} = (t, d_{t-1}, z_{t-1}^{'})^{'}$ on 1, and $\hat{z}_{t-1}^{**}$ is the OLS residual from the regression of $z_{t-1}^{**} = (t, b_{t-1}, z_{t-1}^{'})^{'}$ on $(1, d_t)$, $t = 1,2,\ldots,T$. The $\lambda_{\max}$ and λ_{trace} statistics are then obtained as the maximum eigenvalue and the trace of the matrix (2.37).

Table 1 tabulates the asymptotic critical values at 5 percent and 10 percent of the $\lambda_{\max}$ and λ_{trace} statistics for $m-r = 1,2,\ldots 12$, and $k = 0,\ldots,7$, when the fraction of break time is 0.5.[3]

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3) The critical values have been tabulated using T=500 and 10,000 replications. To save space we only report for the case with π=0.5. The results for other values of π will be available upon request. Since the critical values obtained when the break happens in the middle of the sample are largest, we argue that this will provide most conservative inference.

【Table 1】 Critical Values of Cointegration Test for CVAR with Exogenous Variables and Intercept Shift Dummy

(a) = 0:05

$\alpha = 0{:}05$	λ_{TRACE}						λ_{MAX}					
(n-r)/k	0	1	2	3	4	5	0	1	2	3	4	5
12	388.8473	412.7178	436.9608	460.4564	483.5919	506.6835	81.3380	84.5593	87.6330	90.5400	93.2149	96.2194
11	335.3652	357.1404	379.3615	401.2378	423.2359	445.4942	76.0396	78.9812	82.1968	85.2173	88.0638	91.0248
10	287.8021	307.6279	327.6062	348.4947	368.2546	388.2087	70.5661	73.5257	76.4897	79.6033	82.6340	85.3321
9	242.8858	261.3967	279.7725	297.5309	315.8947	334.0047	64.5778	67.4220	70.3108	73.1555	76.3010	79.3914
8	201.0733	217.7032	234.0007	250.2652	266.8141	283.0706	58.9249	62.2250	65.1616	68.1921	71.0017	74.0079
7	162.9997	177.2333	191.8870	206.7185	221.2052	235.7242	52.6794	55.8611	58.8461	61.6979	64.8655	67.6991
6	128.6271	141.9141	154.8195	167.1899	179.8923	192.1504	47.0392	50.1493	52.9060	55.9514	58.8158	61.5506
5	99.0213	109.6630	120.6980	131.3444	141.4565	152.2417	40.9034	44.0373	47.0702	49.8225	52.6414	55.2989
4	72.5566	81.5511	90.5563	98.9628	107.7769	116.2609	34.9062	37.8854	40.9744	44.0592	46.8831	49.4809
3	49.2867	56.5279	63.8390	70.5546	76.8062	83.4066	28.4275	31.5930	34.7642	37.3036	40.1174	42.7871
2	30.7021	35.6260	40.4428	45.0147	49.7082	54.1048	22.3804	25.3301	28.1906	30.8745	33.5649	35.9513
1	15.4356	18.2853	20.8704	23.4784	26.0842	28.6132	15.4356	18.2853	20.8704	23.4784	26.0842	28.6132

(b) = 0:10

$\alpha = 0{:}10$	λ_{TRACE}						λ_{MAX}					
(n-r)/k	0	1	2	3	4	5	0	1	2	3	4	5
12	379.6756	403.7482	427.0347	450.2567	473.9474	496.6485	77.9495	80.8507	84.0427	86.9418	89.8325	92.5554
11	327.2660	349.1183	370.9067	392.3374	413.7969	435.2010	72.6523	75.6708	78.5743	81.4721	84.5729	87.2535
10	279.7142	299.5398	319.0719	338.8095	358.8596	378.6984	67.1851	70.1180	73.2111	76.0188	78.9220	81.6214
9	235.6999	253.6353	271.8610	289.6441	307.4576	325.1834	61.3837	64.0881	67.0099	69.9586	72.6647	75.5524
8	194.2930	210.7427	226.8446	242.9741	259.3092	275.1519	55.6631	58.8251	61.7349	64.6448	67.5974	70.5434
7	157.3845	171.5007	185.6566	200.0391	214.3392	228.1780	49.8582	52.7439	55.6362	58.6302	61.4241	64.3954
6	123.7185	136.4048	148.4453	160.8870	172.9692	185.4530	44.1453	47.1829	50.0612	52.8739	55.5427	58.3086
5	94.2496	104.6577	115.2229	125.7010	135.8299	146.1524	38.3116	41.1484	43.9542	46.8737	49.5586	52.3641
4	68.3915	76.8758	85.6194	94.2691	102.8368	110.9423	32.4234	35.2297	38.0814	40.9753	43.8726	46.4677
3	45.8817	52.8041	59.5903	66.0628	72.5084	78.9052	26.2036	29.0002	31.9454	34.6110	37.1719	39.8638
2	27.9225	32.7088	37.3205	41.7117	45.9853	50.5741	19.9493	22.8481	25.5389	28.1259	30.7292	33.1451
1	13.3659	16.1182	18.5627	21.0125	23.4727	25.8273	13.3659	16.1182	18.5627	21.0125	23.4727	25.8273

* The breakpoint threshold = 0:5 of the sample. n is the number of endogenous variables. k is the number of exogenous variables. and r is the number of cointegrating vectors.

[Table 2] Critical Values of Cointegration Test for CVAR with Exogenous Variables and Trend Shift Dummy

(a) = 0:05

α = 0:05	λ_{TRACE}						λ_{MAX}					
(n-r)/k	0	1	2	3	4	5	0	1	2	3	4	5
12	399.4321	422.3423	445.3340	467.9939	491.2563	514.1984	83.4313	86.3666	89.2566	92.2413	95.2876	98.0752
11	346.0180	367.4876	389.5921	410.3297	431.3780	452.1106	77.3883	80.4785	83.4603	86.4626	89.2586	92.2966
10	297.6255	317.7232	336.8586	355.9802	375.1819	393.7412	72.0188	75.2463	78.0489	81.0752	83.8169	86.7355
9	251.2610	268.9065	286.6239	304.4265	321.9740	339.1444	66.2339	69.3018	71.8794	74.7067	77.8632	81.0805
8	209.8867	226.0506	241.9566	256.8333	271.8790	287.5437	60.6134	63.6527	66.6318	69.4382	71.9958	74.8421
7	172.1088	186.2439	199.8148	213.7171	227.8983	241.5106	54.6823	57.5309	60.2621	63.3982	66.0844	68.6154
6	138.0187	149.9250	162.0243	174.2957	186.4906	198.0103	48.9878	51.6948	54.7080	57.5288	60.3725	63.2275
5	106.8249	117.0935	126.8166	137.0618	146.7681	157.0056	43.0682	45.8627	48.6994	51.4749	54.2863	56.8791
4	79.5604	87.7815	96.0944	104.3763	112.8025	120.9870	37.1386	39.9755	42.7777	45.5298	48.5775	51.3777
3	55.4220	62.2263	68.5667	74.8958	81.0236	87.7522	30.6319	33.4122	36.3390	39.2383	41.7005	44.4783
2	35.5288	39.9887	44.3802	48.6898	52.9785	56.8937	24.9056	27.6226	30.1621	32.8580	34.8974	37.4886
1	18.0740	20.4565	22.9491	25.2090	27.3825	29.7689	18.0740	20.4565	22.9491	25.2090	27.3825	29.7689

(b) = 0:10

α = 0:10	λ_{TRACE}						λ_{MAX}					
(n-r)/k	0	1	2	3	4	5	0	1	2	3	4	5
12	389.9147	412.8577	435.4364	457.3913	480.5201	503.2360	79.5817	82.4017	85.5581	88.4930	91.4128	94.1444
11	337.4862	358.0467	379.9824	400.8442	421.4356	442.1073	74.0712	76.9753	79.8339	82.8988	85.8052	88.5119
10	289.8102	308.8042	328.1475	346.9834	366.4160	384.8628	68.6777	71.6158	74.5545	77.5956	80.1280	82.7992
9	244.0409	261.6760	278.5689	296.1055	313.4848	330.6864	62.9417	65.8047	68.4733	71.2892	74.2839	77.1062
8	203.6263	219.0694	234.1773	249.6655	265.1092	280.1390	57.3023	60.2094	63.0049	65.7981	68.6123	71.4937
7	166.5029	180.1355	193.4512	207.1966	220.4422	234.1344	51.6853	54.3856	57.2898	60.0567	62.7621	65.5324
6	132.3972	143.9704	155.9239	167.7107	179.8097	191.2375	45.8793	48.7368	51.5435	54.4109	57.2624	59.9415
5	101.8521	111.6994	121.4426	131.4057	140.9236	151.0216	40.1041	42.9276	45.7541	48.5120	51.0928	53.7029
4	75.3434	83.5171	91.3486	99.4443	107.5018	115.5719	34.5495	37.1226	39.8420	42.6074	45.3302	48.0155
3	51.7763	58.1794	64.1866	70.4123	76.6935	82.7272	28.3251	30.8206	33.5296	36.1481	38.7633	41.3186
2	32.5004	36.7906	41.0797	45.1148	49.2203	53.2601	22.5282	25.0630	27.6266	29.9366	32.3297	34.5801
1	15.8791	18.1344	20.4439	22.6302	24.8867	27.0043	15.8791	18.1344	20.4439	22.6302	24.8867	27.0043

* The breakpoint threshold = 0:5 of the sample. n is the number of endogenous variables. k is the number of exogenous variables, and r is the number of cointegrating vectors.

Ⅲ. A Cointegrating VAR Model of Korean Macroeconomy

We describe the estimation and testing of the core long-run model of the Korean economy. This involves the estimation of a (conditional) VECM of the form:

$$\Delta y_t = a_y + \alpha_y b_0 - \alpha_y \beta' [z_{t-1} - \gamma(t-1) - \mu^* d_{t-1}] + \sum_{i=0}^{p-1} \delta_{yi} \Delta d_{t-i} + \sum_{i=1}^{p-1} \Gamma_{yi} \Delta z_{t-i} + \psi_{yo} \Delta x_t + u_{yt}, \qquad (3.1)$$

where d_t is an intercept shift dummy taking 1 from 1997q4. In this specification, z_t is partitioned as $z_t = (y_t', x_t')'$, where $x_t = (p_t^o, r_t^*, y_t^*)'$, $y_t = (e_t^o, r_t, \Delta \widetilde{p}_t, y_t, p_t - p_t^*, h_t - y_t)'$, a_y is a 6×1 vector of intercepts, α_y is an 6×4 matrix of error-correction coefficients, $\Gamma_{yi}, i = 1, 2, ..., p-1$, are 6×9 matrices of short-run coefficients, ψ_{yo} is an 6×3 vector representing the impact effects of changes in weakly exogenous foreign variables on Δy_t,[4] u_{yt} is an 6×1 vector of disturbances assumed to be $iid(0, \Sigma_y)$, with Σ_y being a

4) To test the weak exogeneity of foreign variables, we combine the conditional VEC model for Δy_t, (2.20) and the marginal VAR model for Δx_t, (2.16), and obtain the full VAR for Δz_t:

$$\Delta z_t = d_0 + \sum_{i=0}^{p-1} \delta_i \Delta d_{t-i} + \sum_{i=1}^{p-1} \Psi_i^* \Delta z_{t-i} + \alpha \beta' (z_{t-1}^* - \mu d_{i,t-1} - \gamma(t-1)) + e_t,$$

where $\alpha_t = (\alpha_y', \alpha_x')'$. The zero restrictions on α_x ensure that the foreign variables are $I(1)$ forcing for the system (Granger and Lin, 1995; Pesaran, Shin and Smith, 2000). Hence, the weak exogeneity of the variables in x_t may be evaluated by the F-statistic testing $\alpha_{x,1} = ... = \alpha_{x,r} = 0$ for the individual equation of each foreign variable, where r is the number of error correction terms. The test statistic follows an asymptotic $F_{(r, T-k)}$ distribution. Using this approach, we .nd that the hypothesis of weak exogeneity of the foreign variables cannot generally be rejected at the 5% level.

positive definite matrix, and by construction uncorrelated with u_{ot} and $\beta'(z_{t-1}-\gamma(t-1)-\mu_* d_{t-1})$ is $r\times 1$ vector of error correction terms, which implies that the cointegrating relationships may contain linear deterministic trends and/or structural breaks.[5)]

3.1. The Preliminary Data Analysis

The theory outlined briefly in (3.1)-(3.5) in subsection 3.4 below motivates our choice of the variables to be included in the core model and suggests the appropriate measurements to be used.[6)] Hence, y_t is measured as the natural logarithm of real per capita GDP; p_t is the logarithm of domestic producer prices; $\tilde{p}_t$ is the logarithm of domestic consumer prices; p_t^* is the logarithm of the producer prices of the OECD countries; e_t is the natural logarithm of the nominal KRW/USD exchange rate (defined as the domestic price of a unit of the U.S. dollar, so that an increase in e_t represents a depreciation of the home currency); r_t is the domestic nominal interest rate, computed as $r_t = 0.25\ln(1+R_t/100)$, where R_t is the Korean 90 day Money Market (Inter-bank) rate per annum; r_t^* is the foreign nominal interest rate, computed as $r_t^* = 0.25\ln(1+R_t^*/100)$, where R_t^* is the U.S.'s 90 day Treasury Bill rate per annum; y_t^* is the logarithm of real per capita GDP of the OECD countries; h_t is the logarithm of the ratio of (end-of-period) real per capita money stock (M1) to real GDP; and

5) We have also considered the cointegrating TS-VAR model containing both intercept and trend shift dummies but the estimation results were generally inferior to those presented herein.

6) For example, to ensure a more satisfactory match between theoretical and empirical concepts, producer price indices are used to construct deviations between the domestic and foreign price levels in the *PPP* relationship, while the consumer price index is used to measure domestic inflation in the Fisher relationship.

p_t^o is the logarithm of oil prices, measured by the average crude oil price.[7)]

The data used are quarterly, seasonally adjusted series covering the period 1982q1-2006q2 (98 observations). Notice that Korea was one of Asian countries that were heavily hit by Asian currency crises in 1997, and this can have a significant effect on an analysis of the macroeconometric cointegrating model used in the paper. To investigate the impacts of the crisis, we split the sample into two sub-periods. Considering that the crisis hit Korea in the late September of 1997, it is plausible that 1997q4 is considered as the break point.[8)] In what follows, we summarise the main statistical characteristics of the series and provide a brief account of their history.

3.1.1. Domestic and Foreign Output

Figures 1a and 1b show the level and first differences of the

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7) The data are collected as follows: y_t, p_t, $\tilde{p}_t$ from Statistics Korea, e_t and $M1$ from Bank of Korea, y_t^* and p_t^* from OECD, Main Economic Indicators, and R_t, R_t^* and p_t^o from IFS. Notice that p_t and $\tilde{p}_t$ are seasonally adjusted using the BOK X-12 ARIMA program.

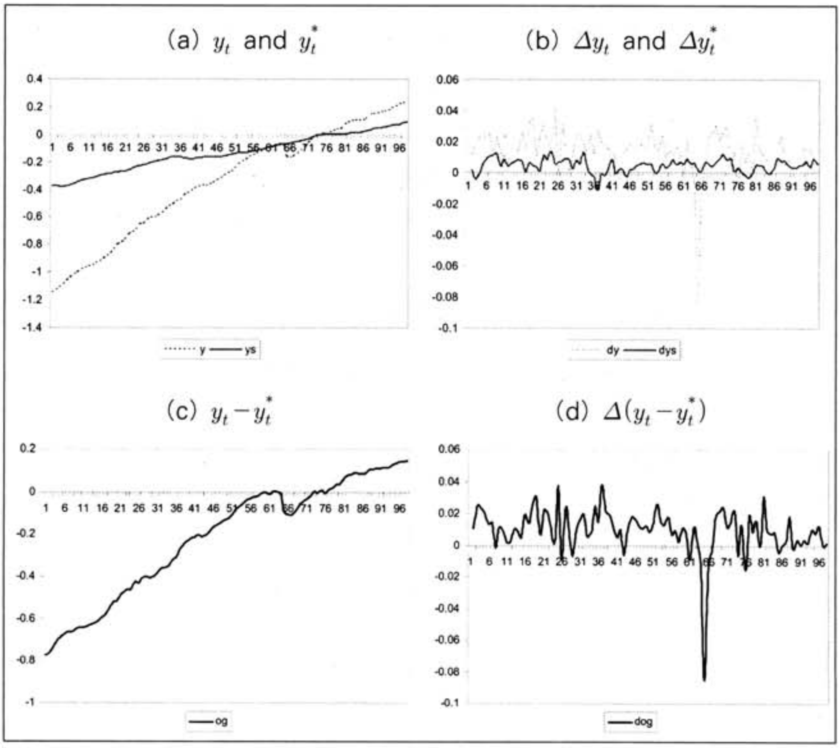
8) Following Greenwood-Nimmo at al. (2009), we follow a simple testing method based on the VECM that does not allow for the presence of intercept shifts:

$$\Delta y_t = c_0 + \Lambda \Delta x_t + \sum_{i=1}^{p-1} \Psi_i \Delta z_{t-i} + \alpha_y \beta' (z_{t-1} - \gamma(t-1)) + u_t.$$

Using this regression, it is straightforward to test for unknown breaks using the recursive-residual-based tests developed by Brown, Durbin and Evans (1975). The principle limitation of this method is that the breaks identified in relation to different endogenous variables will be unlikely to coincide exactly. Furthermore, it is incapable of accommodating multiple breaks or parameter instabilities. In practice, we find it necessary to analyse the raw data in light of the break test results and then define a single 'consensus' break point, taking into account both the statistical evidence and the nature and timing of important macroeconomic events that are likely to have contributed to structural change. The (unreported) CUSUM test results provide a consensus support for the presence of a structural break in 1997q4.

logarithm of domestic output and foreign (OECD) outputs, y_t and y_t^*. Figures 1c and 1d show the output gap between y_t and y_t^* and its first differences.

[Figure 1] Domestic and Foreign Outputs (y_t and y_t^*)



Both variables show clear upward trends and appear stationary in first differences. Over the full sample period, y_t and y_t^* grew at 5.67% and 1.85% per annum, respectively. In general Korean output has grown very rapidly relative to foreign output. But this obscures quite different experiences over sub-periods. The plots of the level and first differences in Figures 1a and 1b clearly show that the crisis had a significantly negative impact on the Korean output. In the period before the crisis Korean growth rate is 6.93%, while it is only 3.61% after the crisis. Foreign output, by way of contrast, achieved relatively stable levels of growth of

1.89% and 1.72% per annum for the periods before and after the crisis, respectively. This relative decline over the second half of the sample period are demonstrated in Figure 1c. When running the simple regression of the output gap, $(y-y^{*})_t$ on constant and time trend, we find that the differential in domestic and foreign growth rates reduces to the half after the crisis. An additional feature, which is apparent in Figure 1b, is the large time-variation in the volatility of output growth. Output growth in Korea is much more volatile than its foreign counterpart and was at its most volatile during Asian Crisis. For details see Table 3 below.

[Table 3] Analysis of Domestic and Foreign Outputs

(a) Domestic and Foreign Output, Output Growths

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
y_t	-0.3397	0.3978	-0.5610	0.3211	0.0562	0.1193
y_t^*	-0.1257	0.1243	-0.2018	0.0842	0.0112	0.0387
$y_t-y_t^*$	-0.2139	0.2765	-0.3592	0.2392	0.0449	0.0819
Δy_t	0.0142	0.0144	0.0173	0.0090	0.0090	0.0199
Δy_t^*	0.0046	0.0042	0.0047	0.0046	0.0043	0.0034
$\Delta(y_t-y_t^*)$	0.0096	0.0146	0.0126	0.0100	0.0047	0.0195

(b) Regression of Output Gap on a Constant and Trend

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
c	-0.6954*	0.0133	-0.789*	0.0045	-0.0933*	0.0082
t	0.0096*	0.0002	0.0132*	0.0001	0.0075*	0.0003

* Signicant at 5% signicance level: (.) Standard Errors.

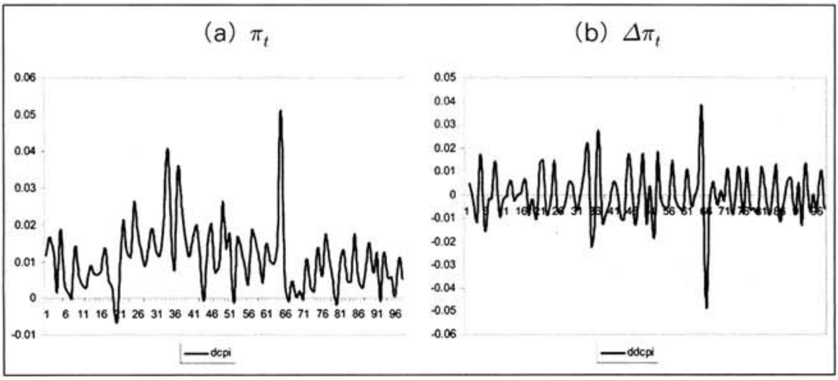
(c) Output Growths (% p.a.)

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Δy_t	5.6772	5.7540	6.9316	3.6056	3.6168	7.9472
Δy_t^*	1.8432	1.6763	1.8967	1.8438	1.7205	1.3592

3.1.2. Domestic and Foreign Prices

Figures 2a-2b plot the time paths of the levels and first differences of domestic consumer price inflation, $\Delta\tilde{p}_t$. A significant part of these price movements is associated with rapidly rising oil prices since the 70's and exchange rate depreciations over the sample period. However, other domestic and global factors were also associated with the high and low inflation periods. Over the whole sample period an average inflation rate is 4.3% per annum. But, the domestic inflation climbed dramatically up to 20% per annum during the Asian crisis, after which it decreased and stayed within a relatively stable band. However, there is somewhat different pattern between consumer price inflation and producer price inflation, Δp_t (Figure 3b). During the whole sample period producer price inflation is on average 1.9% per annum but with much higher volatility as compared with consumer price inflation. In particular, two price inflations have different movements after the crisis. While consumer price inflation decreased from an average of 4.9% before the crisis to 3.2% after the crisis, the producer price inflation increased from 1.4% to 2.5% with its volatility nearly being three times larger than that of consumer price inflation. The decrease of the consumer price inflation can be

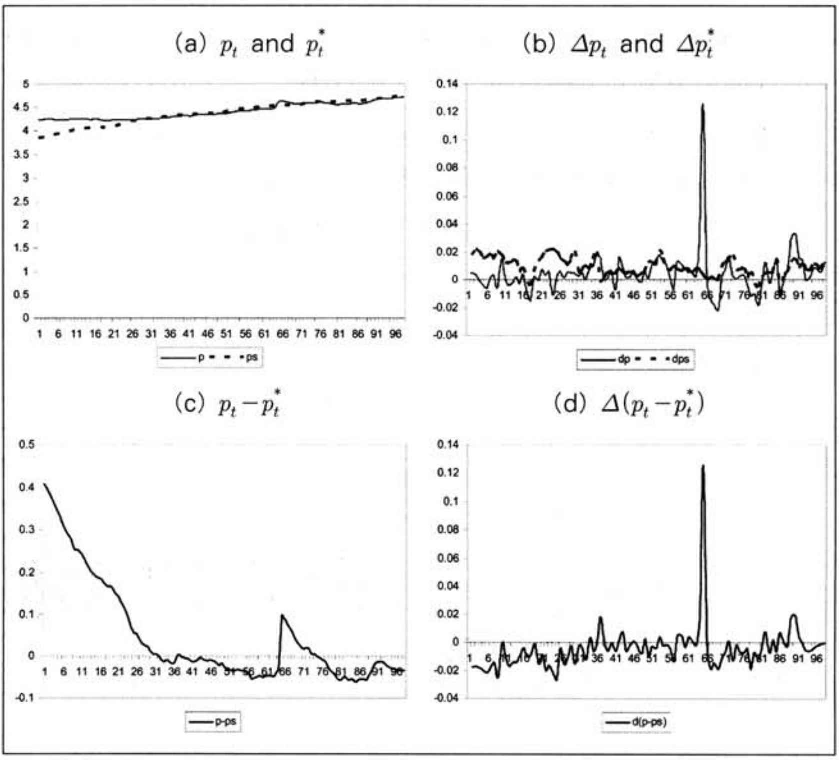
【Figure 2】 Domestic Inflation (π_t)



partially explained by an introduction of the Korean government's inflation-targeting policy in 1998 in the aftermath of the Asian crisis. The complete transition to inflation-targeting in Korea was made in 2001.

Domestic and foreign producer price indices plotted in Figures 3a seem to have a clear upward trend, which might reflects the increasing prices of production inputs over the time (such as oil price). Before the crisis the Korean producer price was more stable and lower than the foreign producer price. However, after the crisis, Korean producer price shifted to a new higher level and became less stable. Thus, the higher producer price inflation could be explained by both the increasing prices of production inputs and the resulting effect of the Asian crisis. Figure 3c shows that

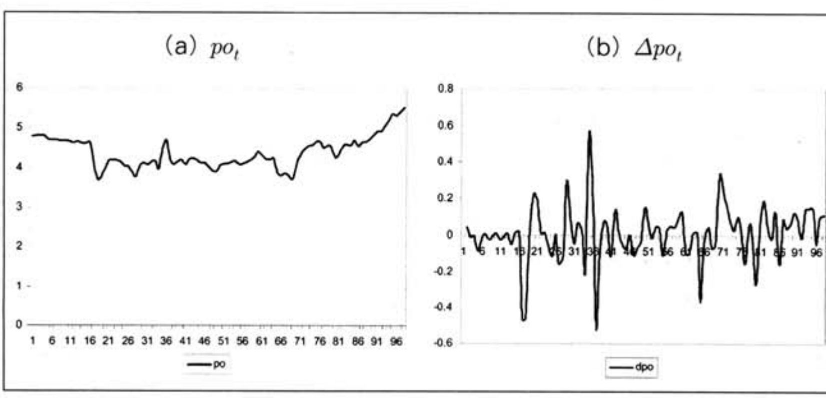
[Figure 3] Domestic and Foreign Producer Prices (p_t and p_t^*)



the relative price decreased rapidly from the early 1980s to 1997, which is due to the rapid increase in the foreign producer price. But, during the crisis there was a sharp increase in the relative price resulting from shock to the Korean producer price, which was then followed by a slow decrease. In particular, during the period before the crisis, the relative price declines at an average rate of 2.95% per annum, while in the later period, the relative price declines at an average rate of 0.09% per annum, i.e. about thirty times slower than previously. Obviously, the pattern of the relative price and the shock to domestic producer price do have a strong implication for the PPP relationship in the core model.

Figures 4a-4b plot the time paths of the level and first differences of the oil prices. Figure 4a shows that at the beginning of the sample the oil price is relatively high and stable. This is the effect of the increase in the oil price in the late 1979, which was brought about largely by the Iranian Revolution in February 1979. In 1986q1, the oil price fell sharply, largely instigated by Saudi Arabia, and there followed a period where the level was considerably lower than previously, but where the volatility was high. Large increases in the oil price were experienced in 1990q3-1990q4 during the Persian Gulf War in the aftermath of the

【Figure 4】 Oil Price (po_t)



invasion of Kuwait by Iraq, but these were reversed in 1991q1. Over the remaining part of our sample, real oil prices fell slightly relative to domestic as well as foreign prices in the period from 1991q2 to 1999q4, then gradually increased.

The summary descriptive statistics for the levels and first differences of the various prices series considered in our model p_t, $\tilde{p}_t$, p_t^*, $p_t - p_t^*$ (plus the second differences of p_t, $\tilde{p}_t$ and p_t^*) are reported in Table 4.

[Table 4] Analysis of Domestic Inflations, Domestic and Foreign Prices, Oil Prices

(a) Inflation, Prices, Price Growths

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
π_t	0.0108	0.0090	0.0123	0.0085	0.0079	0.0094
p_t	4.4228	0.1589	4.3151	0.0753	4.6168	0.0469
p_t^*	4.3804	0.2436	4.2408	0.1905	4.6304	0.0621
$y_t - y_t^*$	0.0424	0.1154	0.0743	0.1308	-0.0135	0.0426
po_t	4.3729	0.3906	4.2577	0.2897	4.5871	0.4647
$\Delta\pi_t$	-0.0001	0.0113	0.0000	0.0104	-0.0003	0.0131
Δp_t	0.0048	0.0156	0.0036	0.0070	0.0063	0.0244
Δp_t^*	0.0094	0.0068	0.0110	0.0066	0.0065	0.0064
$\Delta(p_t - p_t^*)$	-0.0046	0.0160	-0.0074	0.0089	-0.0002	0.0232
Δpo_t	0.0076	0.1505	-0.0091	0.1571	0.0378	0.1373

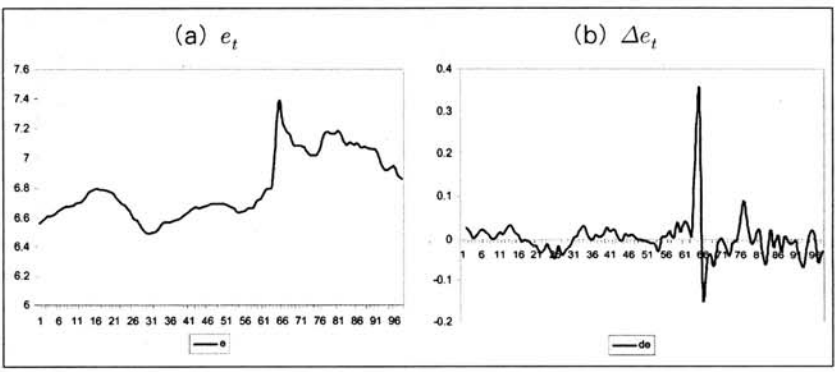
(b) Inflation and Price Growths (% p.a.)

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
π_t	4.3076	3.5894	4.9032	3.4032	3.1778	3.7448
Δp_t	1.9305	6.2380	1.4510	2.7922	2.5188	9.7536
Δp_t^*	3.7593	2.7194	4.4020	2.6250	2.6090	2.5728
$\Delta(p_t - p_t^*)$	-1.8288	6.3868	-2.9512	3.5710	-0.0902	9.2892

3.1.3. Exchange Rates

Figures 5a and 5b plot the level and first differences of the nominal exchange rate, e_t. At the beginning of the sample period, the Korean Won depreciated until the late 1985 and started to appreciate from 1986 to 1989. The exchange rate then depreciated slightly before the Asian crisis hit Korea in 1997. Korean Won was heavily depreciated during the Asian crisis and then sharply appreciated. In particular, before the Asian crisis, Korean Won depreciated at an average rate of 1.5% per annum with an average volatility of 7.5% per annum. After the crisis, Korean Won appreciated at an average rate of 2.2% per annum but with a volatility of 29% per annum, which is about four times higher.

[Figure 5] Exchange Rate (e_t)



Moreover, the shock to the nominal exchange rate caused by the Asian crisis together with the shock to the domestic producer price surely left a significant effect on the real exchange rate, i.e. the PPP relationship. From Table 5, it is observed that in the period before the Asian crisis, the real exchange rate depreciated at an average rate of 4.4% per annum with a volatility of 7.7% per annum. This depreciation might be caused mainly by the constant increase in the foreign producer price. However, after the crisis, the real exchange rate appreciated at an average of 2.1% per annum but with a volatility of about three times higher than that of the period before. The increasing volatility is attributed to the remarkable fluctuations in the nominal exchange rate and domestic producer price.

[Table 5] Analysis of Nominal and Real Exchange Rates

(a) Exchange Rates and Exchange Rate Changes

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
e_t	6.8094	0.2172	6.6623	0.0783	7.0743	0.1052
re_t	6.7633	0.2775	6.5827	0.1504	7.0883	0.0960
Δe_t	0.0030	0.0515	0.0038	0.0189	-0.0055	0.0726
Δre_t	0.0076	0.0429	0.0112	0.0193	-0.0052	0.0558

(b) Exchange Rate Changes (% p.a.)

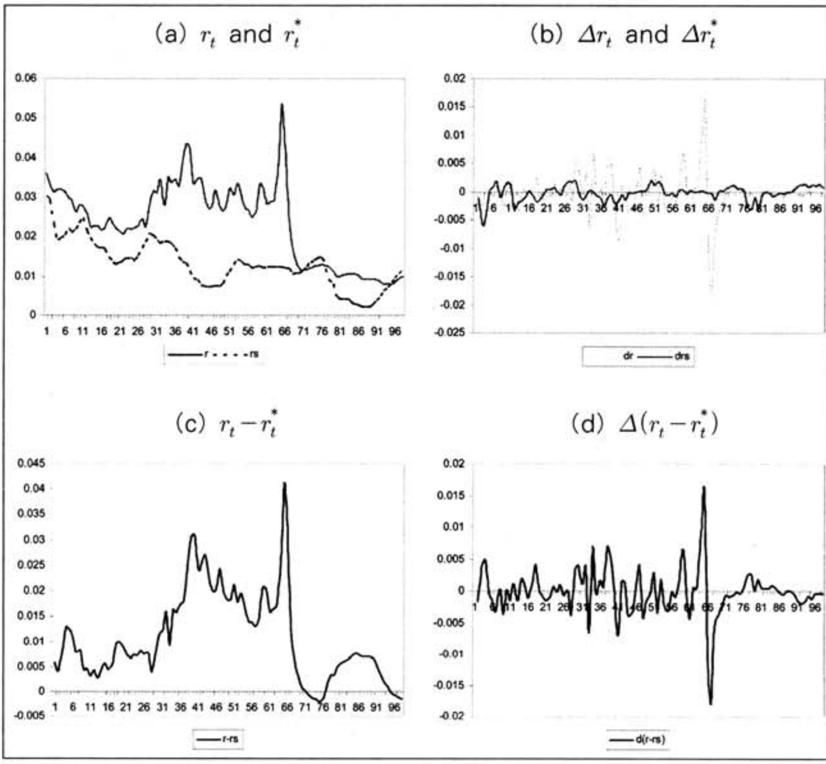
Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Δe_t	1.1994	20.6180	1.5195	7.5788	-2.1874	29.0388
Δre_t	3.0282	17.1640	4.4708	7.7368	-2.0972	22.3020

3.1.4. Domestic and Foreign Interest Rates

Figures 6a - 6d display the time series plots of r_t, r_t^*, $(r_t - r_t^*)$ and their first differences. Our sample period (1982q1-2006q2) is characterised by generally falling foreign nominal interest rates which is the U.S. 90 day Treasury bill rate. The foreign interest rate shows a clear downward trend and their first differences shows very small volatility. Over the two periods from 1982 to 1988 and from 1999 onwards, Korean interest rate seems to share

a similar declining pattern with the foreign interest rate. However, the interesting differential between Korean and foreign interest rates lies in the period of ten years from 1989 to 1998 which has always been considered as one of the main cause of the financial crisis in Korea in 1997. During this period, while the foreign interest rate shows a decreasing trend, Korean interest rate shows ups and downs at a level which is much higher than the international standard.

[Figure 6] Domestic and Foreign Interest Rates (r_t and r_t^*)



Some facts related to the foreign and Korean interest rates during this period did explain the observed patterns and revealed some inferences. In the period, major industrial countries lowered their interest rates in a response to the recession. Japan and the U.S. were two typical cases. While the U.S. lowered its interest rate in an attempt to overcome its debt deflator, the dramatic interest rate cut of Japan was seen as the action from the Japan's government in the response to their failure to recover the economy after the bust of the property and stock market bubbles in 1989-1990. At the time when major industrial countries were experiencing recession, Asian Tigers were experiencing a period of high growth rates and belief in considerable future expansion. These countries were considered by foreign creditors as economies with low risk, high returns and stable exchange rates. Asian Tigers then kept expanding production and domestic firms continuously borrowed under the purpose of expansion. Korean economy was one among those. At that time, it seemed the Korean economy could observe any influx of capital. The increasing demand for capital kept interest rate high, and foreign investors, who could not make reasonable profits at major industrial countries as before due to the lowering interest rates and economic recession, then moved their capital towards Asian tigers, including Korea. However, their purpose was never going to be long-term commitments but to invest in the form of short-term loans either to domestic commercial banks or productive firms in order to make profit from the interest rate differential between Korean and foreign ones. Excessive borrowings with poor management and control along with the wrong use of borrowings (mostly to repay the interests of old debts) made up one of the main cause of a bad crisis in Korea. When the crisis hit Korea in 1997, Korean rate

shot up sharply which might be due to the tightened monetary policy and credit control. After that, Korean rate was decreased sharply to the international standards in order to prevent further arbitrage move to make risk-free profits.

The above facts somehow explained the different patterns between the Korean and foreign interest rates in the period of 1989-1998, which made the relative interest rate $r_t - r_t^*$ seem to be nonstationary and have no clear trend (see Figures 6c-6d). Especially, Table 6 displays that the first differences of $r_t - r_t^*$ show a large volatility, which may suggest a careful analysis in examining the validity of the UIP relationship between Korean and foreign interest rates.

【Table 6】 Analysis of Domestic and Foreign Interest Rates

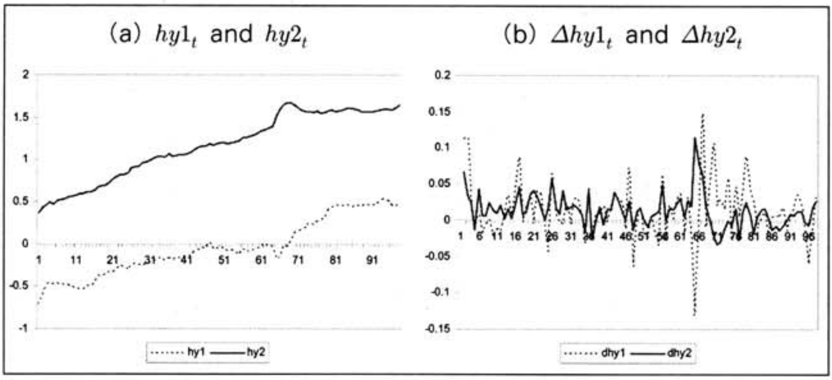
Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
r_t	0.0235	0.0102	0.0288	0.0051	0.0133	0.0095
r_t^*	0.0127	0.0057	0.0152	0.0049	0.0081	0.0042
Δr_t	-0.0003	0.0038	-0.0001	0.0029	-0.0008	0.0048
Δr_t^*	-0.0002	0.0013	-0.0003	0.0014	0.0000	0.0011
$r_t - r_t^*$	0.0107	0.0088	0.0134	0.0073	0.0057	0.0093

(*) Interest Rates and Interest Rate Changes.

3.1.5. Real Money Balances Relative to Income

Figures 7a and 7b show the time series for $h_t - y_t$ and their first difference, one using M1 ($hy1$) and the other using M2 ($hy2$). The variable $h_t - y_t$ measures the inverse of the per capita real narrow money velocity. Both $hy1$ and $hy2$ show clear upward trends. The clear upward trend is consistent with the upward trend of Korean output, which increased the money demand. Before the Asian crisis, $hy1$ grew at an average rate of 4.6% per annum while it was 6.5% for $hy2$. But $hy1$ experienced a decrease during the Asian crisis, whereas $hy2$ showed an increase after the crisis. With regards to $hy1$, during the crisis there was a clear decrease which could be understood as: firstly, the observed decrease in domestic output led to the decrease in money demand and thus the decrease in money supply; secondly, it was due to the tightened monetary policy implemented by Korean government under the recommendation of IMF in order to receive the IMF support package in the aftermath of the Asian crisis. The Asian crisis does not seem to have a noticeable impact on $hy2$. However, after the crisis, there was an increase in $hy2$, which might be credit expansion policy but under tight control implemented by Korean government in an attempt to restore the production of the economy. Notice that the increasing trend of $hy2$ is gradually flattened out after the crisis.

【Figure 7】 Real Money Balances ($hy1_t$ using M1 and $hy2_t$ using M2)



【Table 7】 Analysis of Real Money Balances Relative to Income

(a) Real Money Balances Relative to Income and Its Growths

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
$(h1_t - y_t)$	-0.0445	0.3250	-0.2435	0.1752	0.3181	0.2016
$(h2_t - y_t)$	1.1698	0.3861	0.9349	0.2791	1.5915	0.0341
$\Delta(h1_t - y_t)$	0.0123	0.0391	0.0115	0.0342	0.0150	0.0471
$\Delta(h2_t - y_t)$	0.0132	0.0230	0.0164	0.0180	0.0072	0.0297

(b) Real Money Balances Relative to Income Growths (% p.a.)

Variables	Full sample		Before Asian Crisis		After Asian Crisis	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
$\Delta(h1_t - y_t)$	4.9252	15.6392	4.6040	13.6980	6.0088	18.8304
$\Delta(h2_t - y_t)$	5.2632	9.1884	6.5408	7.1964	2.8747	11.8660

The explanation could be the tightened credit control in the economy. This fact is also confirmed through the growth rates of real money balances. From Table 7 we observe after the crisis that while the average growth rate of $hy1$ increased to 6% per annum, the average growth rate of $hy2$ decreased to 2.8% per annum. Moreover, $hy1$ is more volatile than $hy2$, especially after the crisis hit.

This concludes our overview of the Korean macroeconomic experiences as reflected in the variables to be included in the core macroeconomic model. As expected the 1997 Asian currency crisis did have a significantly strong impact on all the domestic variables. Thus, this fact must be carefully taken into account in the modelling stage, otherwise results might be misleading.

3.2. The Different Stages of Estimation and Testing

We now describe the sequence of steps we follow in our empirical work. We can identify five stages of the estimation procedure. *First*, a sequence of unrestricted VAR(p) models for $p=1,\ldots,4$, are estimated over the same sample period, 1982q1-2006q2. The maximum lag order, 4, is chosen *a priori* bearing in mind the quarterly nature of the observations. The order of VAR model is then selected in the light of the Akaike Information criterion (AIC), the Schwarz Bayesian criterion (SBC) and/or the likelihood-ratio tests.

Second, cointegration tests are carried out using the trace and the maximum eigenvalue statistics. In the case where the test results can be inconclusive, they need to be carefully interpreted in conjunction with the theory's prediction.

Third, having decided that there exist, say, r cointegrating vectors, we are in a position to estimate an exactly-identified set of long-run relations, in which r^2 restrictions are imposed on the cointegrating vectors (r restrictions on each of the r vectors).

The *fourth* step considers the imposition and testing of over-identifying restrictions on the cointegrating vectors, as predicted by economic theory. This analysis is carried out using the restricted ML estimation of the model. The tests of over-identifying restrictions will be in the form of the χ^2 tests with degrees of freedom equal to the number of the over-identifying restrictions.

The *fifth* step concerns the interpretation of the results. The imposition of theory-based long-run restrictions yield error correction terms that can be interpreted as characterizing disequilibria in particular markets, and the associated error correction regressions show the short-run evolution of the variables in response to deviations from disequilibria and to past changes in the variables of the model. The error correction regressions are also subjected to diagnostic tests.

3.3. Unit Root Properties of the Core Variables

In order to incorporate the long-run cointegrating relationships into a suitable model, it is important that the variables used in the empirical analysis can be reasonably argued to be $I(1)$. The results of the Augmented Dickey-Fuller (ADF), computed over the sample period for the levels and first differences of the core variables, are reported in Table 8. Tests provide relatively strong support for the view that y_t, p_t, p_y^*, r_t, r_t^*, e_t, $(h_t - y_t)$ and p_t^o are $I(1)$. There is, however, some ambiguity regarding the order of integration of y_t^* and $\Delta\widetilde{p_t}$. Application of the ADF test to Δp_t, $\Delta\widetilde{p_t}$ and Δp_t^* clearly rejects the hypothesis that there is a unit root in the domestic and foreign inflation rates.

These preliminary results raise interesting issues concerning the use of economic theory and statistical evidence in macroeconometric modelling. For example, the validity of the Fisher equation requires that inflation and interest rates have the same order of

[Table 8] Unit Root Tests

(a) Unit Root Test for Levels

Sample	Lag/Variable	y_t	y_t^*	r_t	r_t^*	e_t	$h1_t - y_t$	$h2_t - y_t$	π_t	p_t	p_t^*	$p_t - p_t^*$	po_t
Full Sample	ADF(0)	-1.3	-2.83	-1.68	-1.42	-1.35	-2.18	-0.73	-7.68	-2.33	-2.52	-2.61	-1.65
	ADF(1)	-1.48*	-3.08	-2.2	-2.23*	-2.06	-2.22	-1.49	-6.15	-2.72*	-2.41*	-2.57*	-2.03
	ADF(2)	-1.61	-3.4	-1.58*	-2.18	-1.65	-2.06	-1.88*	-4.15	-2.54	-2.42	-2.55	-1.2
	ADF(3)	-1.44	-2.92*	-1.41	-2.15	-2.06*	-2.53*	-1.94	-2.78*	-2.41	-2.42	-2.54	-1.65*
	ADF(4)	-1.43	-2.76	-1.32	-2.14	-1.83	-2.48	-1.81	-3.03	-2.24	-2.38	-2.54	-1.23
Before Crisis	ADF(0)	-.87*	-2.36	-2.29*	-1.15	-0.12	-2.03	-1.59*	-5.83	-1.55*	-1.5	-1.80*	-2.72
	ADF(1)	-0.65	-2.39	-2.16	-1.91*	-1.96	-1.62	-1.36	-5.07	-1.6	-2.15	-1.72	-3.25
	ADF(2)	-0.9	-2.63*	-1.86	-1.78	-2.62*	-1.63	-1.33	-3.1	-1.54	-2.09	-1.67	-2.12
	ADF(3)	-1.32	-2.26	-1.66	-1.76	-2.54	-2.22*	-1.68	-1.82*	-1.48	-2.27	-1.63	-2.46
	ADF(4)	-1.27	-2.02	-1.94	-1.79	-2.52	-2.41	-1.78	-2.07	-1.26	-1.92*	-1.57	-1.81*
After Crisis	ADF(0)	-3.61*	-0.96	-4.47	-0.64	-0.79	-2.06*	-2.03	-5.90*	-0.91	-0.62	-1.96	-1.73
	ADF(1)	-3.54	-2.21*	-1.5	-1.40*	-1.65	-2.11	-2.69	-4.02	-1.43*	-1.2	-1.88*	-2.14
	ADF(2)	-3.84	-2.38	-1.61	-1.68	-1.34	-2.06	-2.3	-3.1	-1.16	-1.68*	-1.86	-1.89
	ADF(3)	-3.08	-1.84	-1.63	-1.74	-1.74*	-2.02	-2.52	-2.75	-0.92	-1.69	-1.64	-2.63
	ADF(4)	-3.39	-2.33	-1.74*	-1.29	-1.27	-1.7	-3.42*	-3.12	-0.44	-1.23	-1.35	2.99*

When applied to the levels, the augmented Dickey-Fuller test statistics are computed using ADF regressions with an intercept, a linear time trend and four lagged first-differences of dependent variables, with the exception being r_t and r_t^* where only an intercept was included. The relevant lower 5% critical values for the ADF tests for full sample period, before crisis period, after crisis period are: -3.4581, -3.4875, and -3.5671, respectively. For the case of r_t and r_t^*, the relevant lower 5% critical values for the ADF tests for full ample period, before crisis period, after crisis period are: -2.8925, -2.9118, and-2.9627, respectively. (*) Lag selected by AIC and SBC criteria.

(b) Unit Root Test for First Dierences

Sample	Lag/Variable	Δy_t	Δy_t^*	Δr_t	Δr_t^*	Δe_t	$\Delta h1_t$	$\Delta h2_t$	$\Delta \pi_t$	Δp_t	Δp_t^*	$\Delta(p_t - p_t^*)$	Δpo_t
Full Sample	ADF(0)	-7.25	-5.37	-7.65	-4.89*	-6.97	-9.41	-6.36*	-13.92	-7.33*	-5.02*	-7.12*	-8.08
	ADF(1)	-4.95*	-3.96	-7.92*	-4.4	-6.8	-7.31	-4.55	-12.62	-6.46	-4.04	-5.86	-8.42
	ADF(2)	-4.83	-4.46*	-6.67	-4.06	-4.67*	-4.71*	-4.06	-11.6*	-5.72	-3.5	-4.78	-5.1
	ADF(3)	-4.15	-4.46	-5.73	-3.84	-4.66	-4.33	-4.09	-7.02	-5.53	-3.82	-4.36	-5.16*
	ADF(4)	4.25	-3.41	-5.13	-3.36	-3.91	-4.71	-3.9	-5.77	-4.5	-3.48	-3.62	-5.21
Before Crisis	ADF(0)	-8.02	-4.29	-8.09*	-4.12*	-3.05*	-9.18*	-8.41*	-10.11	-5.71*	-3.60*	-5.01	-6.55
	ADF(1)	-4.63	-3	-6.48	-3.99	-2.3	-5.8	-5.61	-10.63	-4.42	-3.35	-3.39	-7.67
	ADF(2)	-2.92*	-3.30*	-5.49	-3.64	-2.42	-3.45	-3.51	-10.2*	-3.6	-2.6	-2.41*	-4.64
	ADF(3)	-2.7	-3.56	-3.69	-3.2	-2.48	-2.89	-3.07	-5.46	-3.64	-3.13	-2.45	-5.24
	ADF(4)	-2.98	-2.57	-3.29	-2.78	-2.65	-3.25	-2.64	-3.97	-2.99	-2.76	-2.07	-4.77
After Crisis	ADF(0)	-4.63	-2.66*	-5.18	-2.21*	-3.87	-4.07*	-3.19	-9.4	-3.41*	-3.83*	-3.68*	-4.71*
	ADF(1)	-2.76	-2.24	-4.31	-1.71	-4.10*	-3.27	-3.29	-6.6	-3.41	-2.65	-3.00	-4.14
	ADF(2)	-3.11*	-2.76	-3.58	-1.59	-3.23	-2.37	-3.23	-6.87	-3.2	-2.49	-2.98	-2.83
	ADF(3)	-2.76	-1.98	-3.51*	-2.16	-3.08	-2.15	-3.21	-5.53	-3.04	-2.76	-2.46	-2.81
	ADF(4)	-3.2	-1.92	-2.83	-2.15	-2.28	-2.16	-3.79*	-4.86	-2.04	-2.31	-1.9	-3.49

When applied to the first differences, the augmented Dickey-Fuller test statistics are computed using ADF regressions with an intercept and four lagged first differences of dependent variables. The relevant lower 5% critical values for the ADF tests for full sample period, before crisis period, after crisis period are: -2.8929, -2.9127, and -2.9665, respectively. (*) Lag selected by AIC and SBC criteria.

integration. The theoretical literature generally assumes that these series are $I(0)$, but the empirical evidence is mixed with the interest rate behaving as an $I(1)$ variable and the inflation rate being a border line case. Our approach to this dilemma is a pragmatic one, aiming to adequately capture the statistical properties of the data in a modelling framework which is coherent with our underlying analytic account of how the economy operates. For these reasons, we treat r_t, r_t^* and $\Delta\widetilde{p_t}$ as $I(1)$ variables. In the case of the core variables under consideration, we will work with the relative price variables $p_t - p_t^*$ rather than the two price levels p_t and p_t^* separately. As shown in Table 8a, the relative price term is unambiguously $I(1)$.

In summary, then, we can say that it seems appropriate to view all nine variables of $z_t = (p_t^o, r_t^*, y_t^*, e_t, r_t, \Delta\widetilde{p_t}, y_t, p_t - p_t^*, h_t - y_t)'$ as approximately $I(1)$ on the basis of the unit root statistics reported.

3.4. Testing and Estimating of the Long Run Relations

The first stage of our modelling sequence is to select the order of the underlying VAR using AIC and SBC reported in Table 9. Here we find that a VAR of order two appears to be appropriate when using the AIC as the model selection criterion. But not surprisingly that the SBC favours a VAR of order one whereas the LR test suggests an order four.

Hence, we estimate VAR(2)-VAR(4) models, (3.1), with unrestricted intercepts, restricted trend coefficients and restricted intercept shift dummy coefficients, and treating the oil price variable, p_t^o, and foreign interest and output variables, r_t^* and y_t^* as weakly exogenous $I(1)$ variables, and find from Table 10 that both maximal eigenvalue and trace statistics for VAR(2) indicate the presence of three cointegrating relationships at the 10% significance level, while the statistics for VAR(3) and VAR(4) support the presence of four or five cointegrating relationships at the 5% significance level.

[Table 9] Test for VAR Lag Order

Lag Order	LL	ACI	SBC	LR test	Adj. LR test
4	1918.3	1738.3	1509.4	N/A	
3	1879.7	1735.7	1552.6	CHSQ(36)= 77.13[.00]	52.51[.03]
2	1846.2	1738.2	1600.8	CHSQ(72)= 144.16[.00]	98.15[.02]
1	1782.6	1710.6	1619	CHSQ(108)= 271.39[.00]	184.78[.00]
0	1413.5	1377.5	1331.7	CHSQ(144)= 1009.60[.00]	687.35[.00]

* AIC: Akaike Information Criterion; SBC: Schwarz Bayesian Criterion; CHSQ: 2 with (.) degree of freedom; [.] p-value.

[Table 10] Cointegration Test Results

No. of Coin	VAR(2)		VAR(3)		VAR(4)		CV for L_{RTRACE}		CV for LR_{MAX}	
	Trace	Max	Trace	Max	Trace	Max	95%	90%	95%	90%
$r \leq 0$	272.17	102.86	253.21	72.50	333.49	89.38	167.65	161.33	56.09	52.98
$r \leq 1$	169.30	74.93	180.71	58.75	244.11	82.31	131.50	125.29	50.18	46.86
$r \leq 2$	94.38	40.01	121.96	41.93	161.80	68.45	99.26	94.45	43.78	40.95
$r \leq 3$	54.36	26.67	80.02	35.27	93.35	43.11	70.48	66.28	37.72	34.67
$r \leq 4$	27.69	16.91	44.75	23.47	50.24	29.50	44.89	41.78	30.74	28.06
$r \leq 5$	10.78	10.78	21.28	21.28	20.74	20.74	23.36	20.78	23.36	20.78

* Critical Values are for the Breakpoint Threshold = 0:6 sample.

Considering the uncertainty regarding the lag order selection and the rather limited data availability with structural breaks, we proceed with the cointegration analysis using a more parsimonious VAR(2) and initially assume that $r = 5$. We then attempt to estimate the following five theory-consistent long-run relationships:[9]

9) For simplicity, we do not include intercept shift dummy coefficients in the long-run relationships. But, these relationships may exhibit such breaking behavior, which will be investigated empirically.

$$p_t - p_t^* - e_t = b_{10} + b_{11}t + \beta_{17}(y_t - y_t^*) + \xi_{1,t+1}, \tag{3.1}$$

$$r_t - r_t^* = b_{20} + \xi_{2,t+1}, \tag{3.2}$$

$$h_t - y_t = b_{30} + b_{31}t + \beta_{35}t_t + \beta_{37}y_t + \xi_{3,t+1}, \tag{3.3}$$

$$r_t - \Delta\tilde{p}_t = b_{40} + \xi_{4,t+1}, \tag{3.4}$$

$$y_t - y_t^* = b_{50} + b_{51}t + \xi_{5,t+1}. \tag{3.5}$$

The first relationship represents purchasing power parity (PPP) modified to allow for differential productivity growth rates across countries (the so-called Harrod-Ballassa-Samuelson effect, or 'productivity-biased' PPP, e.g. Officer, 1976). The second is a longrun version of the uncovered interest parity (UIP) condition which omits $E_t(\Delta e^*_{i,t+1})$, the expected rate of depreciation of the currency of country i.[10] The third represents the demand for real money balances, which we model as a function of real output and nominal (or real) interest rates. The fourth relationship, the Fisher equation, suggests that the real interest rate is stationary and ergodic.[11] The fifth postulates that the domestic and foreign output are convergent in the long-run.[12]

These five long-run relations can be written more compactly as

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10) We describe this equation as long-run UIP as it is widely acknowledged that $E_t(\Delta e^*_{i,t+1})$, follows a stationary $I(0)$ process and, therefore, does not belong in a long-run (cointegrating) relationship. When the exchange rate follows a random walk, the UIP condition reduces to (3.2).

11) We may allow for the output gap effect so the relationship is modified to be a Taylor relation (Taylor, 1993).

12) Although the neoclassical growth model does not explicitly address the issue of cross-country output convergence, it is argued that, in an interrelated global economy, technological progress (taken to be an unobserved $I(1)$ process) is likely to become increasingly common across countries. This may happen for a number of reasons, most notably innovation and imitation of traded goods such that the downstream economy may appropriate some (or potentially all) of the technological advantage of the innovative exporter. In the case where the output convergence holds the productivity-biased PPP relation reduces to the classical version, $e_t + p_t^* - p_t \sim I(0)$.

$$\xi_t = \beta'_{TH} z_{t-1} - b_0 - b_1(t-1), \tag{3.6}$$

where

$$b_0 = (b_{10}, b_{20}, b_{30}, b_{40}, b_{50})', \ b_1 = (b_{11}, 0, b_{31}, 0, b_{51})',$$

$$\xi_t = (\xi_{1t}, \xi_{2t}, \xi_{3t}, \xi_{4t}, \xi_{5t},)',$$

$$\beta'_{TH} = \begin{pmatrix} 0 & 0 & -\beta_{17} & -1 & 0 & 0 & \beta_{17} & 1 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \beta_{35} & 0 & \beta_{37} & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}. \tag{3.7}$$

The matrix β_{TH} imposes all the restrictions necessary to correspond to the long-run relationships and as such is *over*-identified. We then test the 17 over-identifying restrictions predicted by the long-run theory.13)

Initially, we proceed to report the estimation results for the vector error correction model with five exactly identified cointegrating vectors.14) All the estimated dynamic error correction models (unreported) fit the observation patterns of variables reasonably well, which was not case without explicitly accommodating the structural breaks.

Ⅳ. Impulse Response Analysis

One important use of macroeconometric models is to conduct counterfactual experiments in order to interpret historical episodes

13) In addition, working with a cointegrating VAR with restricted trend coefficients and restricted intercept shift dummy coefficients, there are potentially eight further parameters in the four cointegrating relationships, the validity of which are tested separately or jointly.

14) Currently, there has been a convergence problem computationally when estimating the vector error correction model subject to the full theory-consistent over-identifying restrictions.

and to help with policy analysis. For example, it is important to learn about the impacts of changes in interest rates or oil prices on output and inflation over one or more years into the future. Our understanding of the macroeconomy will be enhanced if we are able to characterise past observations on economic activity as being related to 'trend' growth or as 'cyclical' movements around the trend.

We now report the estimates of impulse response functions of the endogenous variables of the core model with respect to 3 shocks of interest: oil price shock, foreign and domestic interest rate shocks. The first two shocks are exogenous. The foreign interest rate is the U.S. 90 day Treasury bill rate, which is chosen because of the close trading and financial relations between Korea and the U.S. The domestic interest rate shock, which might happen as a government's monetary policy with respect to certain circumstances, will be valuable to see how this shock affects other endogenous variables.

To compute all the impulse response functions analysed, we need to estimate the marginal VAR(2) model for exogenous I(1) variables, namely, p_t^o, r_t^* and y_t^*. For this we base on the unrestricted VAR(1) in first differences in these variables:

$$\Delta x_t = a_{x0} + d_{x0}^* d_t + d_{x1}^* d_{t-1} + \Gamma_x \Delta z_{t-i} + e_{xt}, t = 1,2,..., \quad (4.1)$$

Empirical results in what follow are based on the estimation of the model, (4.1) with the restrictions $d_{x0}^* = d_{x1}^* = 0$ being imposed.[15)]

The analysis of the dynamic response of the macroeconomy to shocks provides important insights with which to interpret recent

15) The unrestricted estimates of these break dummy coefficients in the marginal model for weakly exogenous variables are found to be all insignificant, as expected.

episodes in the Korean economy and with which to consider the potential effects of changes abroad or of moderate changes in policy. Such an analysis illustrates and summarises the complex macrodynamics that can be captured by a cointegrating VAR model. Furthermore, if we wish to identify the effects of the structural shocks such as monetary policy shocks, we require a much more detailed a priori modelling of expectations, production and consumption lags, and the short-run dynamics of the technological process and its diffusion in the economy. This relates to the following structural VECM:

$$A\Delta z_t = \tilde{c} - \tilde{\alpha}\beta_*' z_{t-1}^* + \sum_{i=1}^{p-1} \tilde{\Gamma}_i \Delta z_{t-i} + \epsilon_t \tag{4.2}$$

where A represents the matrix of contemporaneous structural coefficients, $\tilde{c} = Ac$, $\tilde{\alpha} = A\alpha$, $\tilde{\Gamma}_i = A\Gamma_i$ and $\epsilon_t = Ae_t$ are the associated structural shocks which are serially uncorrelated and have zero means and the positive definite variance covariance matrix, $\Omega = A\Sigma A'$.[16] Here we follow GLPS and carry out the structural impulse response analyses with respect to monetary policy shocks (r_t).[17] This requires us to carefully determine the position of the monetary policy variable, r_t. Following GLPS we order $y_t = (e_t, r_t, \Delta\tilde{p}_t, y_t, p_t - p_t^*, h_t - y_t)'$ as employed in (3.1).[18]

16) The restrictions on A that are necessary for identification of these structural effects require a tight description of the decision-rules followed by economic agents, incorporating agents' use of information and the exact timing of the information flows.

17) In passing through the analyses of impulse responses with respect to various shocks considered below, it is worth noting that the Generalized Impulse Responses (Pesaran and Shin, 1998) generally exhibit similar patterns and magnitudes to the Structural Impulse Response counterparts with the only significant difference being the case of domestic interest rate shocks.

18) GLPS (Appendix B) establish that once the position of the monetary policy

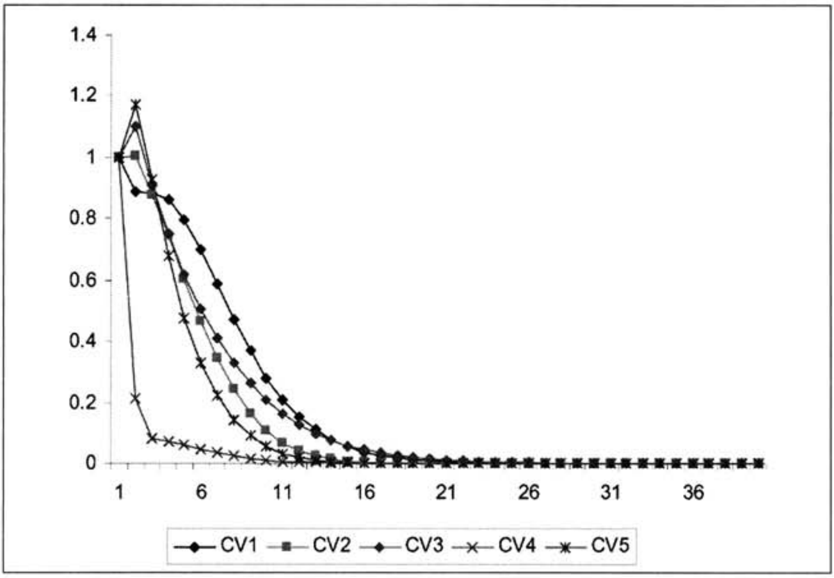
4.1. Persistence Profiles

We shall also be interested in the time profile of the effects of these shocks on the long-run relationships in the model. Despite the integrated properties of the underlying variables, the effects of shocks on the long-run relations can only be temporary and should eventually disappear. However, it will be interesting to see how long such effects are likely to last. These types of impulse response functions are referred to as "persistence profiles" (Pesaran and Shin, 1996) It is now worth looking at the persistence profiles of the five cointegrating relationships in the economy with respect to a system-wide shock, which is provided in Figure 8.[19] It is seen that all the five cointegrations do reverse to the equilibria. However, while the Fisher relationship, the fourth cointegrating vector (CV), nearly dies out in just five quarters, it take about 12 quarters (3 years) for the output gap (fifth CV) and money demand (second CV) relationships to return to equilibria. With regards to the first (UIP) and the third (PPP) cointegrating vectors, the speeds of convergence are relatively slow, about 20 quarters. From this observation, we can see that the relationships in the real side of the economy (OG, PPP, MD) die out with slower speeds than that of the relationship in the financial markets. Moreover, with such a relative slow speed of convergence, UIP seems to hold weakly in the Korean economy. From these initial analyses, we may expect the similar patterns when analysing impulse response functions of these vectors with respect to both endogenous and exogenous shocks.

variable, r_t in z_t is fixed, the (structural) impulse response functions of the monetary policy shocks will be invariant to the re-ordering of the variables before and after r_t in z_t.

19) We also find that the persistence profiles with respect to the individual shocks on the long-run relationships are qualitatively similar and will be available upon request.

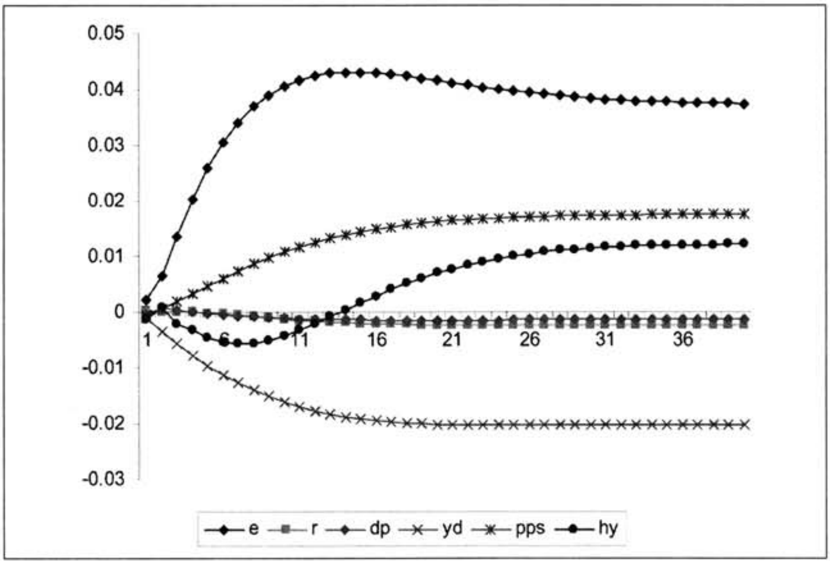
【Figure 8】 Persistence Profiles of Cointegrating Vectors (CVs)



4.2. Effects of an Oil Price Shock

Figure 9 shows the structural impulse responses of the impacts of one standard error shock of oil price on core domestic variables. First, the oil price shock seems to have negligible negative effects on domestic interest rate and consumer price inflation. But, the oil price shock does have significant impacts on the other four domestic variables. It is seen that oil price shock leaves remarkable negative impacts on domestic output. After about fifteen quarters of gradual decrease, output then remains stable but at a lower level than previously. With respect to oil price shock, real money balance initially decreases (negative impact of oil price shock), then gradually goes up before ending up at a long-term positive value. Meanwhile, in the first instance, the oil price shock makes the exchange rate depreciate and increases producer prices, especially the domestic producer prices which can be seen through the increasing relative price. After twenty five quarters, exchange rate and relative price converge to their long-run values. In general, the responses of core domestic variables to the oil price shock seem to be reasonably theory-consistent while the responses of the five cointegrations are as the expected patterns.

【Figure 9】 SIRs of Core Variables to a Positive Oil Price Shock

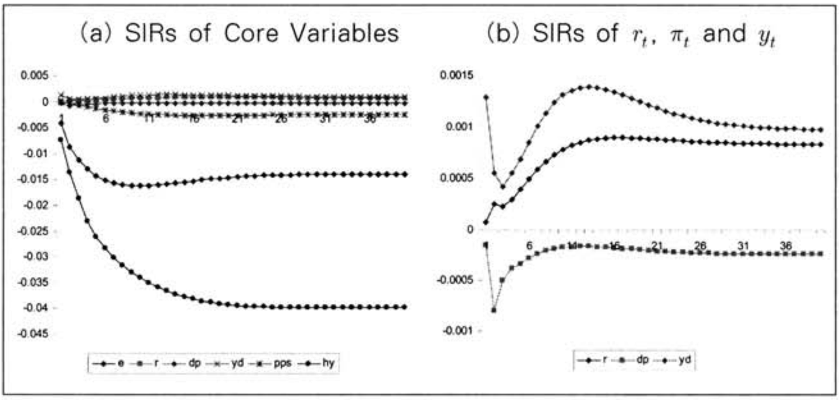


4.3. Effects of a Foreign Monetary Policy Shock

Figures 10a and 10b present the structural impulse responses of the effects of one standard error increase in the foreign interest rate equation on the core endogenous variables. The increase in the foreign interest rate could be seen as the foreign contractionary monetary policy. The foreign monetary shock seems to have very small impacts on domestic interest rate, output, inflation and relative price in comparison with the effects on the nominal exchange rate and domestic real money balance. However, when having a close look at the responses of domestic interest rate, output and inflation through Figure 10b, it is observed that the shock does increase domestic rate and lower the domestic inflation, which is theory-consistent. Meanwhile, the foreign contractionary monetary policy is also reflected through the response of domestic output which suffers a gradual decrease in the first four quarters. Domestic output then increases and stabilizes at a long-run positive value. So this shock has a small impact on domestic output.

Moreover, the domestic real money balance experiences a significant decrease in the first twenty quarters as a result of foreign tighten monetary policy. The negative response of the domestic real money balance to foreign interest rate shock is somewhat predictable, but the response of this magnitude does show how sensitive the domestic monetary variable is with respect to foreign monetary variable (in this case, the U.S. interest rate shock). This also demonstrates the close relation between Korean and the U.S. economies. In terms of the response of nominal exchange rate, this variable shows a gradual appreciation in the first ten quarters then slightly depreciates before reaching an appreciated long-run permanence after twenty quarters (Figure 10a). This pattern of response seems to be reasonable since the foreign interest rate shock increases the domestic rate. Increase in domestic interest rate then results in the observed pattern of nominal exchange rate which is a sequence of periods of appreciation followed by depreciation, as discussed by Eichenbaum and Evans (1995). Furthermore, foreign interest shock results in a decrease in relative price. Thus, the decreases in relative price and domestic real money balance might explain the appreciation of nominal exchange rate. The reaction of nominal exchange rate seems not to be too extreme because the foreign monetary shock is somehow filtered through the domestic monetary policy. This pattern of exchange rate movement will be further demonstrated through the domestic interest rate shock. In general, the reactions of the core domestic variables with respect to foreign monetary shock seem to be as predicted based on theoretical arguments.

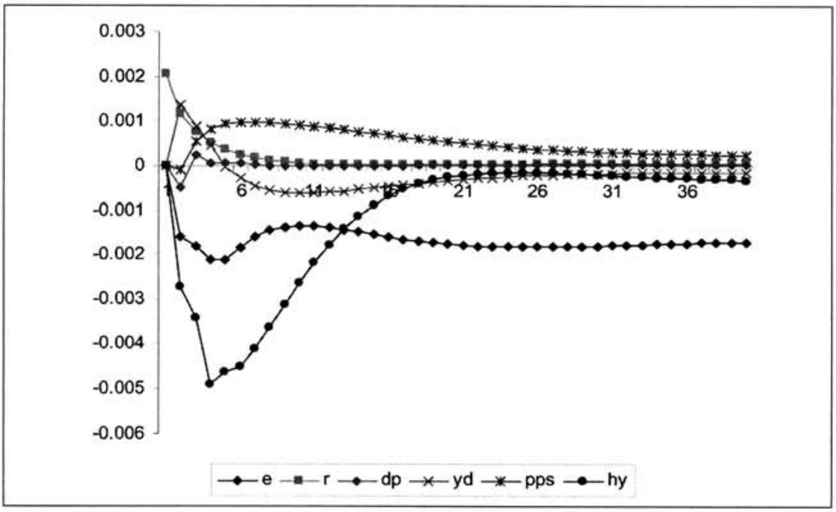
【Figure 10】 SIRs of Core Variables to a Positive Foreign Monetary Shock



4.4. Effects of a Monetary Policy Shock

The structural impulse responses of the core domestic variables with respect to one standard error shock of the domestic interest rate (about 100 base points) are presented in Figure 11. Most of these plots exhibit familiar patterns. After the initial impact, the domestic interest rate declines at a steady rate, settling down after approximately 2 years at an equilibrium value of 0. The impact effect of the monetary policy shock on the nominal exchange rate is zero by construction but the shock causes the exchange rate to appreciate immediately by around 0.3 % in the following quarter. The exchange rate remains roughly constant for the next two quarters and then depreciates rapidly in the following ten quarters. After that the speed of depreciation is rather slow. This pattern seems to be reasonably consistent with the Dornbush (1976) overshooting model which would predict a large initial appreciation in the exchange rate in response to a monetary contraction, followed by subsequent depreciation to its long-run level. Certainly, it matches well the broader view of overshooting in which there might be a sequence of periods of appreciation followed by depreciation because of secondary effects of the shock on risk premia, speculative behaviour and information imperfections relating to the permanence of the shock (e.g. Bernanke et al., 1997). Moreover, this time profile for the exchange rate is observed in a set of responses in which a positive differential of domestic over foreign interest rates is associated with a constant or depreciating exchange rate as suggested by UIP. This accords well with theory and is in contrast to the "exchange rate puzzle" observed by Eichenbaum and Evans (1995) in which the interest rate differential is maintained indefinitely and is associated with a persistently appreciating exchange rate.

【Figure 11】 SIRs of Core Variables to a Positive Domestic Monetary Shock



Meanwhile, the domestic interest rate shock seems to cause somewhat puzzling responses of core variables in the real side of the economy at the beginning of the forecast horizon. After the starting positive value due to the shock, the relative price slowly decreases and reaches a permanent negative value after about thirty quarters. This means that the relative price is lower than it is before the shock. Figure 11 also provides evidence of the well-known "price puzzle" as inflation increases in immediate response to the contractionary monetary shock. Inflation shows a sharp decrease in the first quarter, then bounces back in the following two quarters before settling down around zero value after one year. The impulse response of domestic real money balance starts with an initial puzzling positive (overshooting) value as a result of the domestic contractionary monetary policy, and then falls sharply in the following eight quarters. After that the real money balance remains relatively constant before a steady bouncing-back which ends up at a positive long-run equilibrium.

The series that provide the most puzzling response is domestic output. Due to the domestic (contractionary) monetary shock, domestic output overshoots in the second period by 0.2% when it should react reversely. The series then shows a gradual decrease in the following two years to a small negative value before having a negligible increase in the following quarters. Domestic output then reaches a stable positive equilibrium at the end of the forecast horizon. From these pictures of domestic output and real money balance, it is seen that the contractionary effects of the policy seem to be felt on output and real money balances after one quarter.

The reason that domestic core variables of the real side of the economy have some puzzling responses with respect to the domestic monetary shock might be due to the fact that interest rate was not used properly as an effective tool in the monetary policy in Korea before the crisis. Recalling the movements of Korea interest rate, output, inflation and real money balance before the 1997 crisis (see subsection 3.1.4), it is clearly observed that the movements of the interest rate does not match with those of other variable. For example, while domestic output shows a rapid growth, domestic interest rate maintains at a relatively high level (in comparison with foreign interest rate) when it should express a decreasing trend. Therefore, the impacts of the domestic interest rate shock on most domestic core variables will be misleading without referring to the hard fact of Korea's economic situation before the financial crisis. With the proper use of domestic interest rate as a monetary policy tool after the crisis, the responses of core variables to this kind of shock might be different and theory-consistent. Unfortunately, we have not had a sample period long enough to examine.

V. Probability Event Forecasting

A number of macroeconomic modelling teams in Korea have recently begun to provide further information on the uncertainties surrounding their forecasts of key macroeconomic variables. It is widely acknowledged that it is important to provide this information on the precision of the forecasts in order to enable policy-makers to motivate and justify actions based on the forecasts, and to help a more balanced evaluation of the forecasts by the public. However, it remains rare for forecasters to provide the detailed information on the range of potential outcomes that agents might find useful in decision making and policy analysis. One explanation of this relates to the difficulty in measuring the uncertainties associated with forecasts in the large mainstream macroeconomic models typically employed. A second explanation is the perceived difficulty in conveying the outcomes of complicated macroeconomic models in an easily understood form.

Our compact modelling approach, however, provides a practical framework for probability forecasting. The model is theoretically coherent, fits the Korean historical aggregate time series data reasonably well and yet the model is small enough to allow for a large variety of probability forecasting problems of interest to be analysed without encountering difficult computational problems.[20]

5.1. Probability Forecasts of Inflation and Output Growth

Here we compute out-of-sample probability forecasts of events relating to inflation targeting and output growth which are of particular interest for the analysis of macro-economic policy. The fan charts produced by the Bank of England are an important step towards acknowledging the significance of forecast uncertainties in the decision making process and it is clearly a welcome innovation. However, the approach suffers from two major shortcomings. First, it seems unlikely that the fan charts can be replicated by independent researchers. This is largely due to the subjective manner in which uncertainty is taken into account by the Bank, which may be justified from a real time decision-making perspective but does not readily lend itself to independent analysis. Second, the use of fan charts is limited for the analysis of uncertainty associated with joint events. Currently, the Bank provides separate fan charts for inflation and output growth forecasts. Here, we address both of these issues using the benchmark long-run structural model.

In what follows, we present plots of estimated predictive distribution functions for inflation and output growth at a number

20) The theory-based cointegrating model is clearly one amongst many possible models that could be used to provide probability forecasts. In order to address the issue of model uncertainty we will provide the forecasting results based on the Bayesian Model Averaging (BMA) framework.

of selected forecast horizons. These plots provide us with the necessary information with which to compute probabilities of a variety of events, and demonstrate the usefulness of probability forecasts in conveying the future and parameter uncertainties that surround the point forecasts.[21] But our substantive discussion of the probability forecasts focuses on two central events of interest; namely, keeping the rate of inflation within the announced target range of 1.5 to 3.5 per cent and avoiding a recession and low growth. Following the literature, we define a recession as the occurrence of two successive negative quarterly growth rates.

5.2. In-sample Evaluation and Comparisons of Probability Forecasts

In the evaluation exercise, the model was used to generate probability forecasts for a number of simple events over the period 2004q3-2006q2. This was undertaken in a recursive manner, whereby we first estimated the model over 1982q3-2004q2 and

21) One of the many problems policy-makers face is conveying to the public the degree of uncertainty associated with point forecasts. Policy makers recognise that their announcements can themselves initiate responses which a¤ect the macroeconomic outcome. The Central Bank Governor is reluctant to discuss either pessimistic possibilities, as this might induce recession, or more optimistic possibilities, since this might induce inflationary pressures. There is therefore an incentive for policy makers to seek ways of making clear statements regarding the range of potential macroeconomic outcomes for a given policy, and the likelihood of the occurrence of these outcomes, in a manner which avoids these difficulties. Here we have argued for the use of probability forecasts as a method of characterising the uncertainties that surround forecasts, believing this to be superior to the conventional way of trying to deal with this problem through confidence intervals. A further advantage is the flexibility of probability forecasts, as illustrated by the ease with which the probability of joint events can be computed and analysed. Moreover, in situations where utility or loss functions are non-quadratic and/or the constraints are non-linear, the whole predictive probability distribution function rather than its mean is required for decision making.

computed one-step-ahead probability forecasts for 2004q3, then repeated the process moving forward one quarter at a time, ending with forecasts for 2006q2 based on models estimated over 1982q3-2006q1. The probability forecasts were computed for directional events of interest. In the case of $p_t - p_t^*$, e_t, r_t, r_t^*, and $\Delta \tilde{p}_t$, we computed the probability that these variables rise next period, namely $\Pr[\Delta(p_t - p_t^*) > 0 \mid \Im_{t-1}]$, $\Pr[\Delta e_t > 0 \mid \Im_{t-1}]$, and so on, where $\Im_{t-1}$ is the information available at the end of quarter $t-1$. For the remaining variables, (y_t, y_t^*, $h_t - y_t$ and p_t^o) which are trended, we considered the event that the rate of change of these variables rise from one period to the next, namely $\Pr[\Delta^2 y_t > 0 \mid \Im_{t-1}]$, $\Pr[\Delta^2 y_t^* > 0 \mid \Im_{t-1}])$, and so on. The probability forecasts are computed recursively and then evaluated using a number of different statistical techniques.

To evaluate the probability forecasts, we adopted a statistical approach, using a threshold probability of 0.5, so that an event was forecast to be realized if its probability forecast exceeded 0.5. Formal statistical comparisons of forecasts and realizations were made using Kuipers score (KS), Pesaran and Timmermann (1992) directional statistic and the probability integral transform as proposed by Dawid (1984) and developed further in Diebold et al. (1998). Table 9 reports the incidence of the four possible combinations of our directional forecasts based on the benchmark model. For each variable, nine event forecasts are generated over the period 2004Q3-2006q2 (eight quarters), thus providing 72 forecasts for evaluation purposes. These event forecasts are compared with their realisations and grouped under the headings, 'UU', indicating forecasts and realizations are in the same upward direction, 'UD' indicating an upward forecast with a realized downward movement, and so on. High values for UU and DD indicate an ability of the model to forecast upward and downward movements correctly, while high values of UD and DU suggest poor forecasting ability.

Table 11 shows that for the case of future uncertainty the hit rate is 0.682 versus 0.667 when both parameter uncertainty and future uncertainty are considered. The forecasting performance summarised by the Kuipers score (KS), demonstrate that the probability forecasts taking account of future uncertainty provides the more accurate forecasts.[22] Pesaran and Timmermann (1992) provide a formal statistical test which, as shown in Granger and Pesaran (2000), turns out to be equivalent to a test based on the Kuipers score.[23] For the forecasts based on the model, we obtained PT= 3.187 when only future uncertainty was allowed for, and PT= 2.292 when both future and parameter uncertainties were taken into account. Both of these statistics are statistically significant, suggesting that the benchmark model performs well and highlighting the importance of imposing theory-based long-run restrictions for probability forecasting.

An alternative approach to probability forecast evaluation would be to use the probability integral transforms (e.g. Diebold et al.,

22) KS, defined by $H-F$, where H is the proportion of ups that were correctly forecast to occur, and F is the proportion of downs that were incorrectly forecast. These two proportions are known as the "hit rate" and "false alarm rate" respectively. In the case where the outcome is symmetric, in the sense that we value the ability to forecast ups and downs equally, then the score statistic of zero means no accuracy, whilst high positive and negative values indicate high and low predictive power.

23) The PT statistic is defined by $PT=(\hat{P}-\hat{P}^{*})/\{\hat{V}(\hat{P})-\hat{V}(\hat{P}^{*})\}^{\frac{1}{2}}$, where $\hat{P}$ is the proportions of correctly predicted upward movements, $\hat{P}^{*}$ is the estimate of the probability of correctly predicting the events under the null hypothesis that forecasts and realisations are independently distributed, and $\hat{V}(\hat{P})$ and $\hat{V}(\hat{P}^{*})$ are the consistent estimates of the variances of $\hat{P}$ and $\hat{P}^{*}$ respectively. Under the null hypothesis, the PT statistic has a standard normal distribution.

1998):

$$u(z_t) = \int_{-\infty}^{z_t} p_t(x)dx, \quad t = T+1,\ T+2, \ldots, T+n,$$

where $p_t(x)$ is the forecast probability density function, and z_t, $t = T+1,\ T+2, \ldots, T+n$, the associated realizations. Under the null hypothesis that $p_t(x)$ coincides with the true density function of the underlying process, the probability integral transforms will be distributed as $iid\,U[0,1]$. In our application, we first computed a sequence of one step ahead probability forecasts (with and without allowing for parameter uncertainty) from the over-identified and exactly identified models for the nine simple events set out above over the nine quarters $2004q3, \ldots, 2006q2$, and hence the associated probability integral transforms, $u(z_t)$. To test the hypothesis that these probability integral transforms are random draws from $U[0,1]$, we calculated the Kolmogorov-Smirnov statistic,

$$D_n = \sup_x |F_n(x) - U(x)|,$$

where $F_n(x)$ is the empirical cumulative distribution function (CDF) of the probability integral transforms, and $U(x) = x$, is the CDF of $i.i.d.\,U[0,1]$. Large values of D_n indicate that the sample CDF is not similar to the hypothesized uniform CDF.[24] For our benchmark specification with $r = 5$, we obtained the value of 0.111 for the Kolmogorov-Smirnov statistic when only future uncertainty was allowed for, and the larger value of 0.125 when the underlying probability forecasts took account of both future and parameter uncertainties. All these statistics are well below the 5%

24) For details of the Kolmogorov-Smirnov test see Neave and Worthington (1992).

critical value of Kolmogorov-Smirnov statistic, and the hypothesis that the forecast probability density functions coincide with the true ones cannot be rejected.

Overall results do not reject our benchmark model. With this in mind, we proceed to out-of-sample forecast probabilities of interest using the benchmark model.

【Table 11】 Forecast Evaluation of the Model

Statistics		Future Uncertainty				Future & Parameter Uncertainty			
Variables	Thresholds	UD	DD	DU	UU	UD	DD	DU	UU
po_t	$\Delta^2 po_t > 0$	0	4	2	2	0	4	2	2
r_t^*	$\Delta r_t^* > 0$	0	0	0	8	0	0	0	8
y_t^*	$\Delta^2 y_t^* > 0$	1	3	1	3	1	3	1	3
e_t	$\Delta e_t > 0$	3	3	0	2	3	3	0	2
r_t	$\Delta r_t > 0$	2	2	2	2	2	2	2	2
π_t	$\Delta^2 \pi_t > 0$	4	2	0	2	4	2	0	2
y_t	$\Delta y_t > 0$	2	3	2	1	2	3	2	1
$p_t - p_t^*$	$\Delta(p_t - p_t^*) > 0$	3	1	0	4	3	1	0	4
$h_t - y_t$	$\Delta^2(h_t - y_t) > 0$	1	2	0	5	1	2	1	4
Total		16	20	7	29	16	20	8	28
Hit rate		0.681				0.667			
Kuipers Score		0.385				0.351			
Pesaran & Timmerman Test		3.187				2.921			
Kolmogorov & Smirnov Stat.		0.111				0.125			

5.2.1. Point and Interval Forecasts

Table 12 provides the point forecasts for domestic inflation rates and output growth over the period 2006q3-2008q2 together with their 95% confidence intervals. Meanwhile, Figures 12a and 12b provide the plots for the point estimates of 4-quarter moving averages of inflation and output over the forecast horizon of 40 quarters. The model predicts the average annual rate of inflation to rise above 3% over next two years. Output growth is predicted to be above 4% over the next two years. Therefore, based on these point forecasts, we may be tempted to predict the relatively stable growth prospects over the 2007-2008 period. Notice also that the point estimate forecast results with careful treatment of structural break are lower than those in the model without structural break. Thus, the results in the model which taking into account the structural break might provide more sensible forecast scenarios for inflation and output growth.

[Table 12] Point and Interval Forecasts of Inflation and Output Growth

(a) Forecasts of Inflation

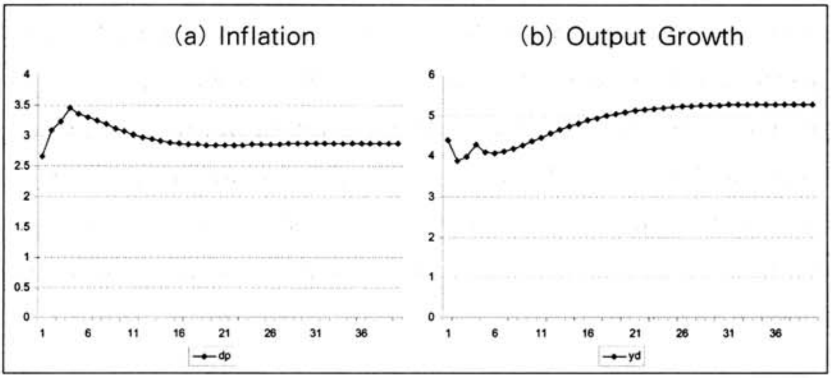
Time	Quarterly Level	h-Step Averages	4-Quarter Moving Averages & 95% CI		
			Point est.	Lower 95%	Upper 95%
2006Q3	3.6763	3.6763	2.6525	1.4271	3.8572
2006Q4	3.4743	3.5753	3.0850	1.5586	4.6084
2007Q1	3.3474	3.4993	3.2263	1.3398	5.0912
2007Q2	3.3374	3.4589	3.4589	1.3066	5.6069
2007Q3	3.2774	3.4226	3.3591	1.1370	5.5750
2007Q4	3.2103	3.3872	3.2931	0.8275	5.7558
2008Q1	3.1475	3.3529	3.2432	0.8264	5.6317
2008Q2	3.0883	3.3199	3.1809	0.6607	5.6975

(b) Forecasts of Output Growth

Time	Quarterly Level	h-Step Averages	4-Quarter Moving Averages & 95% CI		
			Point est.	Lower 95%	Upper 95%
2006Q3	4.8201	4.8201	4.3961	2.6616	6.1065
2006Q4	4.2646	4.5423	3.8684	1.2748	6.4513
2007Q1	4.0016	4.3621	3.9848	0.8637	7.0950
2007Q2	4.0613	4.2869	4.2869	0.4976	7.9438
2007Q3	4.0861	4.2467	4.1034	-0.4015	8.5636
2007Q4	4.1333	4.2278	4.0706	-0.6651	8.7633
2008Q1	4.2182	4.2265	4.1248	-1.0674	9.2887
2008Q2	4.3138	4.2374	4.1879	-0.7727	9.1295

* The historical mean of inflation is 4.32%, the average inflation before crisis is 3.24% and the average inflation after crisis is 4.92%. Meanwhile, the historical mean of output growth rate is 5.68%, the average output growth before crisis is 6.92% and the average output growth after crisis is 3.44%.

[Figure 12] Four Quarter Moving Averages Central Forecasts of Inflation and Output Growth



However, these point forecasts are subject to a high degree of uncertainty, particularly when longer forecast horizons are considered. It is difficult to evaluate the significance of these forecast intervals for policy analysis and a more appropriate approach is to directly focus on probability forecasts as a method of characterising the various uncertainties that are associated with events of interest.

5.2.2. Predictive Distribution Functions

In the case of single events, probability forecasts are best represented by means of probability distribution functions. Figures 13a and 13b give the estimates of these functions for the four-quarter moving averages of inflation and output growth for the 1-quarter, 1, 2 and 6-year-ahead forecast horizons.[25)]

Figure 13a presents the estimated predictive distribution function for inflation for the threshold values ranging from 0% to 6.5% per annum. The function for the one quarter-ahead forecast horizon is quite steep, but it becomes flatter as the forecast horizon is increased. Above the threshold value of 2%, the estimated

25) These estimates are computed using the simulation techniques and take account of future uncertainties only.

probability distribution functions shift to the right as longer forecast horizons are considered, showing that the probability of inflation falling below thresholds greater than 2.0% declines with the forecast horizon. For example, the forecast probability that inflation lies below 3% becomes smaller at longer forecast horizons, falling from about 80% one quarter ahead (2006q3) to 45% eight quarter ahead (2008q2). This means that the uncertainty increases with longer forecast horizons.

[Figure 13] Predictive Distributions of Inflation and Output Growth

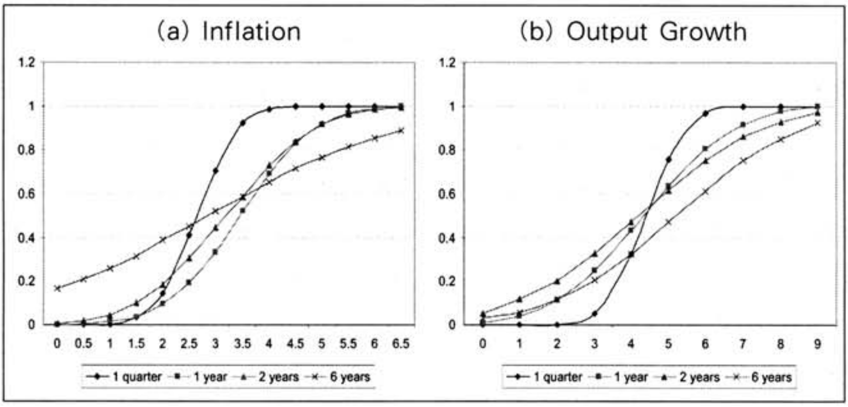


Figure 13b plots the estimated predictive distribution functions for output growth. These functions also become flatter as the forecast horizon is increased, reflecting the greater uncertainty associated with growth outcomes at longer forecast horizons. These plots also suggest a weakening of the growth prospects in 2007-8. For example, the probability of output growth being smaller than 2% one quarter ahead (2006q3) is estimated to be almost zero, but rises to 11% for four quarters ahead (2007q2) and further rising to about 20% after 2 years (2008q2).

5.2.3. Event Probability Forecasts

Here we consider three single events of particular interest:

A : Achievement of inflation target, defined as the four-quarterly moving

average rate of inflation falling within the range 2.5%-3.5%,

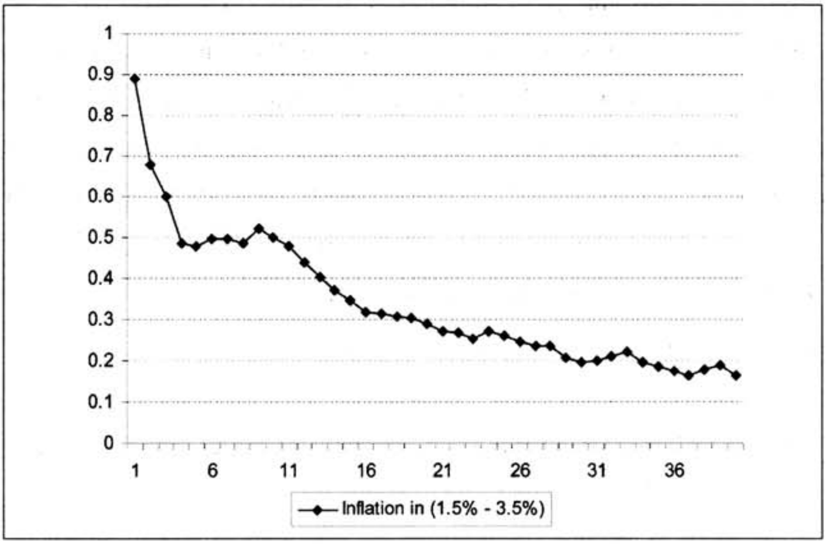
B : Recession, defined as the occurrence of two consecutive quarters of negative output growth,

C : Poor growth prospects, defined to mean that the four-quarterly moving average of output growth is less than 2%,

and the joint events $A \cap \overline{B}$ (Inflation target is met and recession is avoided), and $A \cap \overline{C}$ (Inflation target is met *combined* with reasonable growth prospects), where $\overline{B}$ and $\overline{C}$ are complements of B and C.

Inflation Target Figure 14 shows the forecasts of the single event A (inflation target) probabilities. Conditional on the information available at the end of 2006q2, the probability that the Bank of Korea will be able to achieve the inflation target is estimated to be high in the short run but falls in the longer run, reflecting the considerable uncertainty surrounding the inflation forecasts at longer horizons. Specifically, the probability estimate is high (0.9) in 2006q3, but it falls rapidly to nearer 0.48 by the mid of 2007. This fall in the first quarters of the forecast reflects the increasing likelihood of inflation increasing above the 3.5% upper threshold (since the probability of observing inflation below the 2.5% lower threshold is close to zero through this period). After four or five years, this probability falls to below 0.3. So these figures reflect the relatively high degree of uncertainty associated with inflation forecasts even at moderate forecast horizons. Hence, while the likely inflation outcomes are low by historical standards, there is a reasonable probability of hitting the target range in the short-run and there are also comparable likelihoods of undershooting the inflation target range at longer horizons.

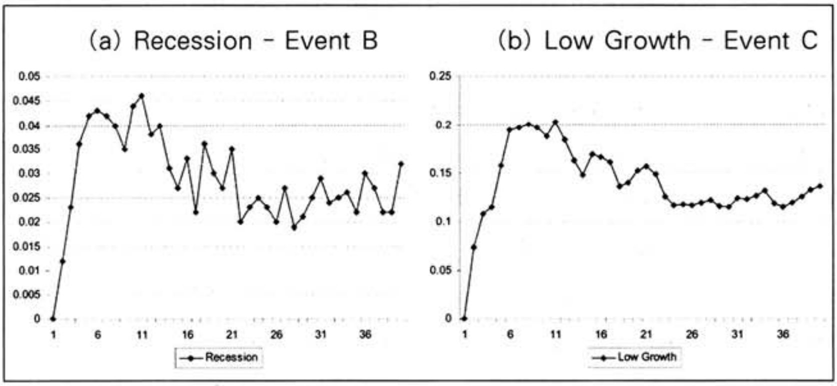
【Figure 14】 Probabilistic Forecasts of Inflation within Target Range (1.5%-3.5%) - Event A



Recession and Growth Prospects The probability estimates suggest a very low probability of a recession and a low (poor) growth. Figure 15a displays that probability of a recession occurring in 2006q3 is estimated to be around zero, gradually increases and reaches a peak of about 0.045 by the end of 2007 whilst Figure 15b shows that the probability of a low growth shares a similar pattern with the probability of a recession; starting around zero and reaching it peak (0.2) by the mid of 2008.

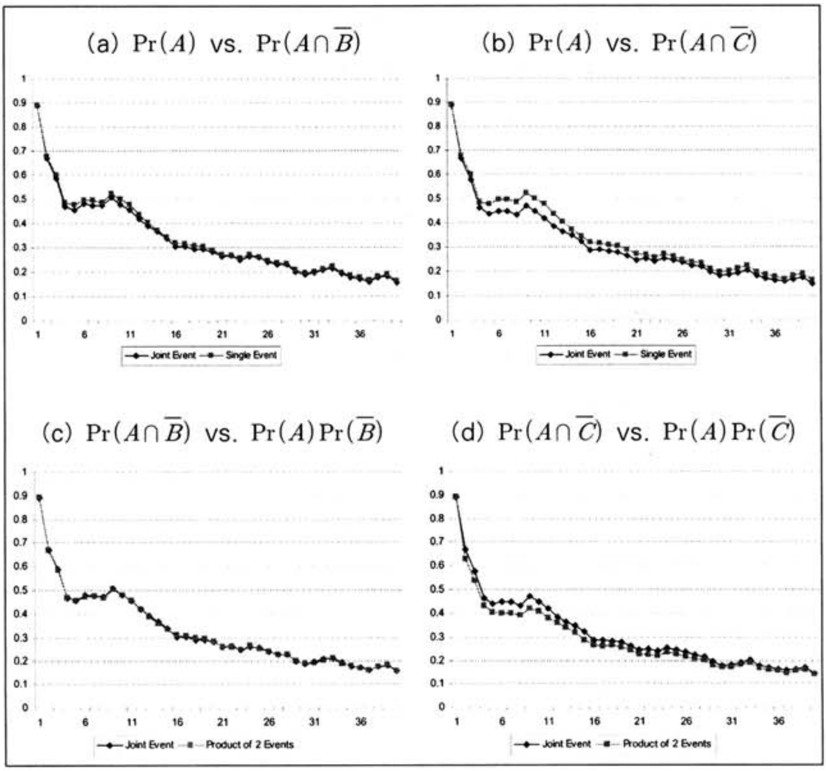
Decision makers are very often concerned with joint events involving, for example, both inflation and output growth outcomes. As examples here, we consider the probability estimates of the two joint events, $A_{T+h} \cap \overline{B}_{T+h}$, and $A_{T+h} \cap \overline{C}_{T+h}$, over the forecast horizons $h = 1, 2, ..., 24$. Both events are of policy interest as they combine the achievement of the inflation target with alternative growth objectives. For the event $A_{T+h} \cap \overline{B}_{T+h}$, the joint probability forecasts are similar in magnitude to those that for $\Pr(A_{T+h} | \Im_T)$ alone at every time horizon. This is not surprising since the probability of a recession is estimated to be small at most forecast horizons and therefore the probability of avoiding recession is close to one. Nevertheless, the differences might be important since even relatively minor differences in probabilities can have an important impact on decisions if there are large, discontinuous differences in the net benefits of different outcomes. The probability forecasts for $A_{T+h} \cap \overline{C}_{T+h}$, are very slightly less than those for $\Pr(A_{T+h} | \Im_T)$ alone.

【Figure 15】 Single-Event Probabilistic Forecasts of Output Growth - Events B and C



Figures 16a and 16d plots the values of the joint event probability over the forecast horizon alongside a plot of the product of the single event probabilities; that is $\Pr(A_{T+h} | \Im_T) \times \Pr(\overline{B}_{T+h} | \Im_T)$, and $\Pr(A_{T+h} | \Im_T) \times \Pr(\overline{C}_{T+h} | \Im_T)$, $h = 1, 2, \ldots, 24$. These comparison provides an indication of the degree of dependence of the two events. As it turns out, the gaps between the two series are almost negligible at most forecast horizons, indicating little dependence between output growth prospects and inflation outcomes. This result is compatible with the long-term neutrality hypothesis that postulates independence of inflation outcomes from output growth outcomes in the long run.

【Figure 16】 Comparisons of Probabilistic Forecasts



Ⅵ. Concluding Remarks

This paper follows a practical long-run structural VAR modelling approach advanced by Garatt et al. (2006) and applies it to the construction of a small quarterly macroeconometric model of Korea. We also extend the model to explicitly allow for the presence of structural breaks, which is shown to be successful in the analysis of the significant impact of the 1997 Asian currency crisis on the macroeconomic performance of Korea during and after the crisis period.

We then provide the detailed preliminary data analysis over the full sample periods and over the two sub-periods before and after the break identified as 1997q4, and estimate the benchmark model over 1982q3-2006q2 in nine variables: domestic and foreign outputs, prices and interest rates, oil prices, the nominal effective exchange rate, and real money balances. The long-run cointegrating VAR analysis with restricted trend coefficients and restricted break dummies suggests that there are five cointegrating relationships. Combining these estimated VECM's with the marginal VAR(2) model for weakly exogenous foreign variables we also provide further dynamic characteristics of the model. Impulse responses of an oil price, foreign equity price and domestic and foreign monetary policy shocks on the endogenous variables provide mostly plausible policy directions. Out of sample probability forecasts of inflation and output growth predict relatively stable growth and inflation prospects over the short-term period, but these forecasts are subject to a high degree of uncertainty, as the forecast horizon increases.

Given the increasing integration and globalisation and of economic and financial markets, there is a growing desire to explicitly model the sources of foreign influences on the domestic economy and the contributions of national economies to conditions overseas. The global vector autoregressive (GVAR) model originated by Pesaran et al. (2004), Dees et al. (2007) and Greenwood-Nimmo et al. (2009) represents an accessible way of combining country-specific models into a global framework without falling victim to the dimensional problems typically associated with such large scale models. The ability to coherently model the global economy and to assess the effects on a sovereign state/economic bloc

both of global shocks and of shocks emanating from specific countries renders GVAR a powerful tool for policy analyses at the national and supra-national levels. In this regard the principal area for ongoing research is to extend the current study into the GVAR modeling framework where the dynamic international linkages of a small open economy such as Korea will be further investigated.

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구조적 변동을 고려한 공적분 VAR 모형을 이용한 한국 거시경제 분석

신 용 철*

논문초록

Garratt et al.(2006)은 VAR 모형에서 장기구조적 균형관계식을 명시적으로 분석할 수 있는 방법을 제시하였다. 본고에서는 특히 1997년 외환위기가 한국 거시경제 전반에 미친 영향을 고려하여, 구조적 변동이 미치는 영향을 공적분 VAR 모형에 명시적으로 도입, 확장된 방법을 적용하여 한국 거시 경제 모형을 개발하였다. 1982년 3분기 - 2006년 2분기 사이의 9 변수 (국내 총생산, 물가지수, 이자율, 명목 환률, 실질통화량, 유가, 해외총생산, 물가지수, 이자율)에 대한 자료를 이용하여 한국 거시 경제 모형에 대한 추정 및 검정결과를 도출하였다. 추정된 장기 균형관계식들은 경제이론의 예상과 적합하였으며, 구조적 충격 반응 함수와 경기성장률 및 물가 변동에 대한 확률 전망을 이용한 동태적 예측 분석은, 이후 전개된 경제현상과 전반적으로 부합하였다. 특히, 구조적 변동을 명시적으로 고려할 경우, 경기성장률은 좀 더 낮게, 물가 변동률은 좀 더 높게 전망되고 있다.

주제분류 : B030104

핵심 주제어 : 공적분 VAR 거시 경제 모형, 구조적 변동, 외환 위기, 충격 반응 함수, 성장률 및 물가 변동에 대한 확률 전망

* 리즈 대학교 경영대학 경제학과.