

## **New Approach to Estimation of the Core Inflation\***

Jong Won Lee<sup>\*\*</sup> Sang Don Lee<sup>\*\*\*</sup> Ki-Ho Kim<sup>\*\*\*\*</sup>

Recently, the Inflation Targeting System (ITS) has emerged as a major monetary policy scheme in countries like England, Canada, and Australia. Such transition toward the ITS was initiated mainly by the desire to achieve economic stability by using more extensive information variables than a simple traditional money supply variable. The success of the ITS is believed to depend on which variables are utilized as tools, and which are used as the target variable. Variables like monetary aggregates, interest rate, exchange rate and so forth have been extensively used as information variables, while the so-called core inflation has been utilized as a target variable.

The key issue of the ITS thus comes down to how to define and estimate the core inflation, the target variable. So far, the core inflation has been derived as a quasi-trend after arbitrarily truncating extreme fluctuations. This process obviously causes a serious loss of information. In addition, correlation between the headline inflation and the core inflation becomes rather low. Consequently, even though the monetary authority tries to stabilize the headline inflation by controlling a target variable, i.e., core inflation, leverage will be weakened due to low correlation between the two inflation rates.

The main objective of this study is to derive an alternative core inflation indicator, which has a strong correlation to the headline CPI.

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\*\* Professor of Economics, Sungkyunkwan University, 3-ka 53, Myungryun-dong, Jongno-gu, Seoul, Korea, Tel.: +82-2-760-0427, Fax: +82-2-763-4941, E-mail: jwlee@skku.edu

\*\*\* Associate Research Fellow, Korea Research Institute for Vocational Education & Training, 15-1, Chongdam-dong, Gangnam-gu, Seoul, Korea, Tel.: +82-2-3485-5025, Fax: +82-2-3485-5059, E-mail: sdlee@krivet.re.kr

\*\*\*\* Doctoral Candidate, Sungkyunkwan University, 3-ka 53, Myungryun-dong, Jongno-gu, Seoul, Korea, Tel.: +82-2-760-0427, Fax: +82-2-3485-5059, E-mail: cometdad98@yahoo.co.kr

By doing so, we hope to find a more reliable target variable (a new core inflation) to stabilize the headline inflation. To this end, this paper will derive an unobserved but estimatable core inflation indicator which is cointegrated with the headline CPI. In addition, this study will perform policy simulations to prove that the new inflation variable has an edge over the old one in predicting future headline inflation rates. Further, in order to prove the usefulness of the new inflation variable, this paper will provide empirical evidence that it has a stronger correlation with the headline inflation than the old one has.

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## 1. INTRODUCTION

In 1998 Korea changed the framework of its monetary policy to the Inflation Targeting System (ITS). Following the adoption of the ITS, inflation pressure in Korea has been alleviated, although this fact does not necessarily imply that ITS has worked successfully in Korea. Controversies over the success of ITS in Korea are ongoing, and exact evaluations on the performance of ITS in Korea require further study.

The Inflation Targeting System can be briefly summarized as a system of operating monetary policy in which the central bank sets up an inflation target within a pre-designed time horizon and makes use of the available policy instruments. In ITS, headline CPI or core inflation is used as a target variable. However, headline CPI is not appropriate to ITS because headline CPI includes noises such as seasonal factors, change of relative price, etc. In fact, many ITS countries adopted core inflation as the target variable. Headline inflation had been used in Korea as the target. Since 2000, however, the target variable has been changed to core inflation.

It is necessary to note that the core inflation concept cannot be clearly defined by nature and, furthermore, as of yet, there is no consensus on the definition of core inflation. Several estimation techniques for core inflation

are suggested notwithstanding. The most commonly used methods are the method of exclusion, which excludes some items from the basket of CPI. However, this method may suffer information loss due to the exclusion of some informative items, and there is little theoretical rationale for such exclusion. On the other hand, the so-called 'model approach' such as SVAR,  $P^*$ , IIP (independent inflation rate) model and Normal-Normal Mixture model has more theoretical rationales than the exclusion method, and utilizes diverse information.

The primary reason why diverse rationales and estimation methods have been sought for or suggested for core inflation is that core inflation is an inherently unobserved variable. Consequently, the job of estimating the core inflation comes down to how to find unobserved components.

Some time-series-based necessary conditions which core inflation should have were suggested by Marques *et al.* (2002). The conditions are in fact based on the assumption that the inflation variable is  $I(1)$  variable. Marques stated (i) if inflation is  $I(1)$ ,<sup>1)</sup> then core inflation should be cointegrated with inflation; (ii) there should be an error correction mechanism; and (iii) core inflation is strongly exogenous to the parameters of the error correction equation. The first condition implies that discrepancy between inflation and core inflation is an  $I(0)$  process and reflects temporary disturbance, which is caused by weather, demand and supply of goods, etc. The second condition may be interpreted in such a way that in the long run, inflation should converge to core inflation. That is, core inflation is an attractor. The third condition will be necessary for the path of core inflation not to be influenced by past inflation.

The inflation variable in Korea, however, has turned out to be a  $I(0)$  variable, so that the Marques conditions can no longer be directly applicable to the Korean inflation variable. However, no cointegrated relationship between level variables (CPI and core inflation indicator) implies that the two level variables will diverge in the long run, and this divergence between two variables eventually means that the inflation rates which is the growth

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<sup>1)</sup> In case of Korea, headline CPI inflation rate is  $I(0)$  variable, that is, CPI is  $I(1)$  variable.

rates of diverging level variables could not carry useful information. According to this reason, we can consider cointegration relationships between the two level variables which is  $I(1)$  in spite of stationary inflation variables. That is, we may apply the above conditions to CPI (level variable) which is  $I(1)$  variable. This implies that it is desirable for the core inflation indicator to have a common trend with headline CPI (level variable), and have a cointegrated relationship with headline CPI.

The conditions that Marques *et al.* (2002) suggested, however, is a posterior criterion to test that core inflation has desirable time-series based properties. That is, they suggested those conditions for the purpose of the posterior tests. In this paper, we would divert those conditions as ex-ante conditions to estimate core inflation indicator, so that those conditions are imposed as restrictions on the parameters in the model.

On the other hand, those conditions, especially the third condition, bring about the structural conditional error correction model. However, it is impossible to implement a general regression model to estimate the core inflation indicator because the core inflation indicator is inherently unobservable. In this study, we will propose a new estimation technique for the core inflation indicator, which has cointegrated relationships with headline CPI and is imposed to satisfy the above restrictions. To this end we suggest a state space model to estimate the unobserved component core inflation indicator.

In section 2, we will briefly survey definitions and various estimation techniques of core inflation. We will suggest an alternative estimation method of core inflation in section 3. The model needs the state space model to estimate core inflation. The empirical support for our estimation model will be sought for in section 4, and major findings, evidences and concluding remarks will be summarized in section 5.

## 2. DEFINITIONS AND ESTIMATION TECHNIQUES OF CORE INFLATION

### 2.1. Definitions of Core Inflation

Diverse definitions of core inflation have been suggested. The most meaningful ones are as follows. The first one that deserves attention is the one made by Okun (1970) and Flemming (1976). According to their definition, observed inflation ( $\mathbf{p}_t$ ) can be decomposed into two components. One ( $\mathbf{p}_t^{CO}$ ) represents general price change, and the other ( $\mathbf{e}_t$ ) represents relative price change reflecting supply side shocks. Core inflation can thus be defined as

$$\mathbf{p}_t = \mathbf{p}_t^{CO} + \mathbf{e} \quad \text{or} \quad \mathbf{p}_t^{CO} = \mathbf{p}_t - \mathbf{e}. \quad (1)$$

Since  $\mathbf{p}_t^{CO}$  is understood to be related to monetary expansion, core inflation can be thought of as the general price change which is reflected by monetary policy.

On the other hand, Eckstein (1981), and Quah and Vahey (1995) defined core inflation as a persistent component of headline inflation. Eckstein (1981), for example, defined core inflation as a trend of production factor cost, and understood that core inflation would reflect long-run inflation expectations in the private sector, while Quah and Vahey (1995) defined core inflation as inflation which does not affect production in the long run. In other words, their definitions of core inflation focus on cyclical movements in inflation which are related to excess demand. This line of definition for the core inflation can be represented as follows.

$$\mathbf{p}_t = \mathbf{p}_t^{CO} + \mathbf{h} \quad (2)$$

$$\mathbf{p}_t^{CO} = \mathbf{p}_t^{LONG-RUN} + h(z_{t-1}), \quad (2)'$$

where  $\mathbf{p}_t^{LONG-RUN}$  is the long run inflation rate,  $z_{t-1}$  is the cyclical

movement at time  $t - 1$ , and  $h_t$  is temporary inflation.

The core inflation concept of our estimation model will be based on the first definition because we focus on the long run behavior of inflation, which is reflected by monetary policy. That is, we will estimate core inflation, which reflects the general price changes, so that discrepancy between inflation and core inflation will represent relative price change reflecting supply side shocks.

## 2.2. Core Inflation Estimation Models

Various core inflation estimation models have been suggested. They can be safely classified into two groups. One of them uses adjustment techniques like exclusion or trimming to calculate core inflation. The other uses economic models to estimate core inflation. The latter is called 'the model approach'. Models such as SVAR (Structural VAR model), IIR (Independent Inflation Rate) model,  $P^*$  model and Normal-Normal Mixture Model belong to this category.

### 2.2.1. Exclusion or Trimming Methods

These methods are the most popular and easily understandable, since they adopt easy calculation processes. In other words, they simply exclude temporary non-monetary change of prices, so that the inflation component, which reflects non-monetary change of prices, can be eliminated. That is, these methods exclude temporary and transitory factors from the CPI to derive the underlying trend of prices.

The first method of this kind will identify items which are highly volatile among items in the basket of the CPI, and then exclude these items from the basket. The first one is called the 'specific adjustment or adjustment by exclusion (or replacement) method'. The second one suggests to exclude both the largest and smallest fluctuations. The second one is the 'trimmed mean method'. The third one suggests to rank fluctuations of items in the CPI basket, and then utilizes their weighted median as the core inflation.

And the last one is called the 'weighted median method'.

Despite their advantage in ease of calculation and popularity, these methods have a defect in that they lose information included in the excluded items. Oh (1999) examined the usefulness of the Korean core inflation by using these methods.

### 2.2.2. Model Approach

These methods use SVAR, IIR (Independent Inflation Rate),  $P^*$  model, or Normal-Normal Mixture model approach.

Quah and Vahey (1995) used a two-variable SVAR model to estimate core inflation. Quah and Vahey used the identification condition that the long-run Phillips curve is vertical, assuming that core shock eventually does not affect growth rate. Bjornland (2000), also used a three-variable SVAR model. For example, he suggested the SVAR model with oil price, GDP, and CPI inflation as follows.

$$\begin{pmatrix} X \\ Y \\ P \end{pmatrix} = \begin{pmatrix} c_{11}(1) & 0 & 0 \\ c_{21}(1) & c_{22}(1) & 0 \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{pmatrix} \begin{pmatrix} \mathbf{e}_X \\ \mathbf{e}_{NC} \\ \mathbf{e}_C \end{pmatrix}, \quad (3)$$

where  $X$ ,  $Y$ , and  $P$  represent oil price, GDP, and CPI respectively, while  $\mathbf{e}_X$ ,  $\mathbf{e}_{NC}$ , and  $\mathbf{e}_C$  represent oil price shock, non-core shock, and core shock respectively.

The identification condition  $c_{23}(1) = 0$  means core shock does not affect growth rate in the long run, and  $c_{12}(1) = 0$ ,  $c_{13}(1) = 0$  means that oil price is influenced only by oil price shock.

In this model, core inflation is defined as an infinite sum of core shocks, and headline inflation is an infinite sum of all structural shocks. Blix (1995), Claus (1997), and Fase and Folkertsman (1996) have suggested similar SVAR models. Kim and Yoo (2001) used this method to estimate the core inflation of Korea.

On the other hand,  $P^*$  model was developed by FRB in 1989, as another

major model approach to estimating core inflation. This model defines core inflation as a change of potential price level derived from the well known Fisher's equation. The potential price level, which is the long-run equilibrium price level, can be calculated under the condition that production level matches potential GNP.

Fisher's equation is

$$P^* = \frac{MV^*}{Y^*} \quad (4)$$

or

$$\dot{P}^* = \dot{M} + \dot{V}^* - \dot{Y}^*, \quad (4)'$$

where  $P^*$ ,  $M$ ,  $V^*$ ,  $Y^*$  represent potential price level, money, trend of velocity of money, and potential GNP.

The advantage of this model is that it has a firm theoretical basis for the core inflation concept in comparison with the exclusion methods. Hallman, Porter and Small (1989), Armour (1996), and Attah-Mensah (1996) used this model to estimate core inflation. Lee and Kwon (1998) used this method to estimate the core inflation of Korea.<sup>2)</sup>

Further, there is the Independent Inflation Rate (IIR) model recently developed by Arrazola and Hevia (2002). The motivation of this model is to resolve problems that occur when headline inflation is affected by the change of relative price. In other words, this model estimates inflation variation independent from relative price change.

On the other hand, Park (2000) suggested a 'Normal-Normal Mixture Model' to estimate the core inflation. This method is based on the non-normality of distribution of inflation and the intuition that inflation caused by demand-side components should show different distributional properties compared with inflation caused by supply-side components. This means that the distribution of the observed inflation is a mixture of two different

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<sup>2)</sup> They also Exclusion or Trimming methods.



kinds of distributions.

This model starts with the extended version of the price-setting model of Blanchard and Kiyotaki (1987). From the optimal solution of this model, the Normal-Normal Mixture model can be derived by going through the process of simplification.<sup>3)</sup>

### 3. ESTIMATION MODEL

In the previous section, brief reviews of various core inflation estimation methods revealed that core inflation is regarded as an inflation in which temporary shock is deleted. With this notion in mind, we try to develop a new core inflation estimation method, which does not exclude demand-side components, thus has no information loss, but excludes supply-side components. Furthermore, the above approaches do not consider the time-series-based conditions mentioned above. That is, these approaches are unconcerned with the cointegration relationships between core inflation (or core inflation indicator) and inflation (or CPI).

What we intend to propose is a core inflation indicator which has a cointegrated relationship with CPI.<sup>4)</sup> We will consider the conditional error correction model to this end. In order to provide a theoretical rationale for our approach, let us briefly review the conditional error correction model in the first place.

#### 3.1. Conditional ECM

Consider VAR ( $p$ ) with a  $n$  dimensional vector.

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<sup>3)</sup> Notice that this method estimates core inflation itself.

<sup>4)</sup> If the core inflation indicator does not have a cointegrated relationship with CPI, then the core inflation indicator will eventually diverge from CPI in the long run. In that case, core inflation does not give any useful information on CPI. The government-announced official Core inflation indicator in Korea (CPI\_fe) does not have a cointegrated relationship with CPI. For details, see section IV.

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \dots + \Pi_p X_{t-p} + \mathbf{e}_t. \quad (5)$$

ECM can be derived from VAR( $p$ ) by reparameterization as follows.

$$\begin{aligned} \Delta X_t &= \Pi^* X_{t-1} + \Gamma^*_1 \Delta X_{t-1} + \Gamma^*_2 \Delta X_{t-2} + \dots + \Gamma^*_p \Delta X_{t-p+1} + \mathbf{e}_t \\ &= -\mathbf{a}\mathbf{b}'X_{t-1} + \Gamma^*_1 \Delta X_{t-1} + \Gamma^*_2 \Delta X_{t-2} + \dots + \Gamma^*_p \Delta X_{t-p+1} + \mathbf{e}_t. \end{aligned} \quad (6)$$

In equation (6), matrix  $\Pi^* = -\mathbf{a}\mathbf{b}'$  reflects a cointegration relationship. That is,  $\mathbf{b}'X_{t-1}$  is the cointegrating vector, while  $\mathbf{a}$  is speed of the adjustment vector, where,  $\mathbf{a}$  and  $\mathbf{b}$  are  $(n \times r)$  dimensional vector.

Now, let  $X_t$  be decomposed into  $Y_t$  and  $Z_t$ . Then the error correction model can be decomposed into the marginal model, which is equation (7) and the conditional model, which is conditioned by  $Z_t$ . In this case, the marginal model is

$$\Delta Z_t = \mathbf{a}_z \mathbf{b}'_z X_{t-1} + \Gamma_{z1} \Delta X_{t-1} + \dots + \Gamma_{z(p-1)} \Delta X_{t-p+1} + \mathbf{e}_{zt}, \quad (7)$$

and the conditional model is

$$\begin{aligned} \Delta Y_t &= \mathbf{w}\Delta Z_t + (\mathbf{a}_y - \mathbf{w}\mathbf{a}_{1z})\mathbf{b}'X_{t-1} + (\Gamma_{y1} - \mathbf{w}\Gamma_{z1})\Delta X_{t-1} + \dots \\ &+ (\Gamma_{y(p-1)} - \mathbf{w}\Gamma_{z(p-1)})\Delta X_{t-p+1} + \mathbf{e}_{yt} + \mathbf{w}\mathbf{e}_{zt}, \end{aligned} \quad (8)$$

where  $\mathbf{w} = \Omega_{yz} \Omega_{yx}^{-1}$  and  $\Omega$  matrix is variance covariance matrix for equation (6).

When some variables are weakly exogenous for the cointegrating vectors, the error correction model can be estimated via only the conditional model, and this causes no information loss.<sup>5)</sup> The necessary condition for weak

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<sup>5)</sup> The exogeneity of variables for the interested parameters means that the data generating process (DGP) of the exogenous variables are no longer necessary to estimate the conditional model, and this ignorance of the DGP of the exogenous variables causes no

exogeneity of  $Z_t$  is  $\mathbf{a}_z = 0$ , that is, the rows of  $\mathbf{a}$  corresponding to  $Z_t$  are 0. Given that weak exogeneity of  $Z_t$  is valid, the marginal model can be represented without an error correction term.

$$\Delta Z_t = \Gamma_{z1} \Delta X_{t-1} + \dots + \Gamma_{z(p-1)} \Delta X_{t-p+1} + \mathbf{e}_{zt}. \quad (9)$$

Furthermore, if weak exogenous variable  $Z_t$  does not Granger cause  $Y_t$ , equation (9) can be represented by equation (10).

$$\Delta Z_t = \Gamma_{z1} \Delta Z_{t-1} + \dots + \Gamma_{z(p-1)} \Delta Z_{t-p+1} + \mathbf{e}_{zt}. \quad (10)$$

### 3.2. State Space Representation of ECM

Let us briefly review the State Space Model and Kalman filtering.<sup>6)</sup> The State Space Model is used to represent the various unobserved components such as reservation wage (Engle and Watson, 1981), expected inflation (Burmeister and Wall, 1982), ex-ante real interest rates (Antoncic, 1986) etc. The State Space Model is composed of a transition equation and an observation equation. The transition equation represents the law of motion of state variables and the observation equation relates the state variables to observed variables. Equation (11) is a transition equation and equation (12) is an observation equation.

$$\mathbf{x}_{t+1} = T\mathbf{x}_t + \mathbf{u}_{t+1}, \quad (11)$$

$$y_t = A'x_t + H'\mathbf{x}_t + \mathbf{v}_t, \quad (12)$$

where  $\mathbf{x}_t$  is the state variables,  $y_t$  is observed variables,  $x_t$  is exogenous variables, and  $T$  is transition matrix,  $H$  is observation matrix.

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information loss. Refer to Engle, Hendry, and Richard (1983) for the concept of exogeneity, and to Johansen (1992) for its application to the VECM.

<sup>6)</sup> For detailed discussion on the State Space Model and Kalman filtering, refer to Hamilton (1994), Harvey (1989), or Kim and Nelson(1999).

Given the transition equation and the observation equation, the Kalman filter can be used for the estimation of the State Space Model. The Kalman filter can be summarized as a recursive procedure that calculates minimum mean square error (MSE) estimate of state variables by using the available information. The Kalman filter uses the prediction process and the update process each time.

Now let us turn our discussion to the State Space representation of the VECM. In general the VAR( $p$ ) model can be transformed into VAR(1) representation as follows:

$$\begin{pmatrix} X_t \\ X_{t-1} \\ X_{t-2} \\ \vdots \\ X_{t-p+1} \\ X_{t-p} \end{pmatrix} = \begin{pmatrix} \Pi_1 & \Pi_2 & \Pi_3 & \cdots & \Pi_p & 0 \\ I_n & 0 & 0 & \cdots & 0 & 0 \\ 0 & I_n & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & I_n & 0 \end{pmatrix} \begin{pmatrix} X_{t-1} \\ X_{t-2} \\ X_{t-3} \\ \vdots \\ X_{t-p} \\ X_{t-p-1} \end{pmatrix} + \begin{pmatrix} \mathbf{e}_t \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \end{pmatrix}. \quad (13)$$

We can show easily that equation (13) can be transformed into equation (14) by reparametrization as mentioned in section 1 of this chapter.

$$\begin{pmatrix} \mathbf{b}X_{t-1} \\ \Delta X_t \\ \Delta X_{t-1} \\ \vdots \\ \Delta X_{t-p+2} \\ \Delta X_{t-p+1} \end{pmatrix} = \begin{pmatrix} I_r & \mathbf{b}' & 0 & \cdots & 0 & 0 \\ -\mathbf{a} & (-\mathbf{a}\mathbf{b}' + \Gamma_2^*) & \Gamma_2^* & \cdots & \Gamma_{p-2}^* & \Gamma_{p-1}^* \\ 0 & I_n & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & I_n & 0 \end{pmatrix} \begin{pmatrix} \mathbf{b}X_{t-2} \\ \Delta X_{t-1} \\ \Delta X_{t-2} \\ \vdots \\ \Delta X_{t-p+1} \\ \Delta X_{t-p} \end{pmatrix} + \begin{pmatrix} \mathbf{e}_t \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \end{pmatrix}. \quad (14)$$

Now, the VECM in equation (14) can be transformed into a state space model. To represent the state space model, it is necessary to set up the state

vector ( $\mathbf{x}_t$ ), transition equation and observation equation. Let the state vector be

$$\mathbf{x}_t = ((\mathbf{b}'X_{t-1})', \Delta X_t', \Delta X_{t-1}', \dots, \Delta X_{t-p+1}')'$$

Then the corresponding transition matrix  $T$  can be depicted as follows:

$$T = \begin{pmatrix} I_r & \mathbf{b}' & 0 & \dots & 0 & 0 \\ -\mathbf{a} & (-\mathbf{a}\mathbf{b}' + \Gamma_2^*) & \Gamma_2^* & \dots & \Gamma_{p-2}^* & \Gamma_{p-1}^* \\ 0 & I_n & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \dots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & I_n & 0 \end{pmatrix}, \quad (15)$$

where  $I_r$  is a  $r$  dimensional identity matrix,  $r$  is a cointegration rank, and  $\Gamma_i$ s are  $(n \times n)$  coefficient matrices. Of course, when the weak (or strong) exogeneity of variables is valid, the corresponding restriction on coefficients should be imposed on the transition matrix. The observation matrix is as follows:

$$H = (0_r, I_n, 0_n, \dots, 0_n). \quad (16)$$

A detailed matrix will be given at the end of section 4 of this chapter.

### 3.3. Assumptions on the State Vector

Cointegration relationship between non-stationary variables implies that there exists a stationary linear relationship between non-stationary variables. Such a linear combination of non-stationary variables has properties of  $I(0)$  stationarity. Consequently, the state space model needs some assumptions on the state vector. For example, the assumption that all state variables should be a  $I(1)$  variable is needed. In our model, we are going to find a

linear combination of core inflation, which is a non-stationary unobserved state variable, and headline CPI, which is a non-stationary observed variable. The condition that core inflation is a non-stationary  $I(1)$  variable is an essential assumption to the ECM model.

In addition to the non-stationarity assumption, the weak exogeneity of some state variables is needed. That is, according to Marques *et al.* (2002), the core inflation has to be strongly weak-exogenous to the cointegrating vectors. This means that the core inflation indicator, the state variable, should be strongly weak-exogenous in our case. And also we assume that there exists the only cointegrating vector between headline CPI and core inflation indicator. According to the condition of Marques *et al.*, e.g., in the 2 variable case, the cointegrating vector is  $(\mathbf{b}_{\text{inf}}, \mathbf{b}_{\text{core}})' = (1, -1)$ , and other variables except inflation and core inflation are not included in the cointegrating vector.

### 3.4. Model Specification and Data

#### 3.4.1. Model Specification

In our model, the observed variable is headline CPI( $C_t$ ) and GDP( $G_t$ ), while the unobserved state variable is the core inflation indicator ( $C_t^{\text{CO}}$ ). Let optimal lag length of VAR( $p$ ) be, for example,  $p = 2$ , and let the cointegration rank be 1, that is  $r = 1$ . The state space representation of ECM then can be depicted as follows:

To be specific, let the state vector  $\mathbf{x}_t = ((\mathbf{b}'X_{t-1})', \Delta X_t)'$  and the corresponding  $(6 \times 6)$  transition matrix  $T$  be

$$T = \begin{pmatrix} I_r & \mathbf{b}' \\ -\mathbf{a} & (-\mathbf{a}\mathbf{b}' + \Gamma_1^*) \end{pmatrix}. \quad (17)$$

Then the state vector  $\mathbf{x}_t = ((\mathbf{b}'X_{t-1})', \Delta X_t)'$  will be

$$\mathbf{x}_t = (\mathbf{b}_1 C_{t-1}, \mathbf{b}_2 G_{t-1}, \mathbf{b}_3 C_{t-1}^{CO}, \Delta C_t, \Delta G_t, \Delta C_t^{CO}) \quad (18)$$

and the corresponding  $(6 \times 6)$  transition matrix becomes as follows:

In equation (17), GDP is not included in the cointegrating vector, so that  $\mathbf{b}_2 = 0$ , and this means  $-\mathbf{a}_i \mathbf{b}_2 (i=1, 2)$  term should be equal to 0. Furthermore, the necessary condition for the strong exogeneity of core inflation to the cointegrating vector requires  $\mathbf{a}_3 = 0$ , and non Granger causality of core inflation means  $\Gamma_1^{3i*} = 0 (i=1, 2)$ .

According to those restrictions to the transition matrix, equation (19) can be used for the estimation state space model.

$$T = \begin{pmatrix} 1 & 0 & 0 & \mathbf{b}_1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -\mathbf{b}_1 \\ -\mathbf{a}_1 & -\mathbf{a}_1 & -\mathbf{a}_1 & -(\mathbf{a}_1 \mathbf{b}_1) + \Gamma_1^{11*} & \Gamma_1^{12*} & -(\mathbf{a}_1 \mathbf{b}_3) + \Gamma_1^{13*} \\ 0 & 0 & 0 & \Gamma_1^{21*} & \Gamma_1^{22*} & \Gamma_1^{23*} \\ 0 & 0 & 0 & 0 & 0 & \Gamma_1^{33*} \end{pmatrix}, \quad (19)$$

where

$$\mathbf{x}_t = (\mathbf{b}_1 C_{t-1}, \mathbf{b}_2 G_{t-1}, \mathbf{b}_3 C_{t-1}^{CO}, \Delta C_t, \Delta G_t, \Delta C_t^{CO}). \quad (20)$$

The observed variables are headline CPI and GDP, and the corresponding observation matrix would be

$$H = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}. \quad (21)$$

Based on the above matrices, the corresponding transition equation and observation equation can be represented as follows:

Transition equation:

$$\begin{pmatrix} \mathbf{b}_1 C_{t-1} \\ \mathbf{b}_2 G_{t-1} \\ \mathbf{b}_3 C_{t-1}^{CO} \\ \Delta C_t \\ \Delta G_t \\ \Delta C_t^{CO} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & \mathbf{b}_1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -\mathbf{b}_1 \\ -\mathbf{a}_1 & -\mathbf{a}_1 & -\mathbf{a}_1 & -(\mathbf{a}_1 \mathbf{b}_1) + \Gamma_1^{11*} & \Gamma_1^{12*} & -(\mathbf{a}_1 \mathbf{b}_3) + \Gamma_1^{13*} \\ 0 & 0 & 0 & \Gamma_1^{21*} & \Gamma_1^{22*} & \Gamma_1^{23*} \\ 0 & 0 & 0 & 0 & 0 & \Gamma_1^{33*} \end{pmatrix} \begin{pmatrix} \mathbf{b}_1 C_{t-2} \\ \mathbf{b}_2 G_{t-2} \\ \mathbf{b}_3 C_{t-2}^{CO} \\ \Delta C_{t-1} \\ \Delta G_{t-1} \\ \Delta C_{t-1}^{CO} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ \mathbf{e}_{1t} \\ \mathbf{e}_{2t} \\ \mathbf{e}_{3t} \end{pmatrix}.$$

Observation equation:

$$\begin{pmatrix} \Delta C_t \\ \Delta G_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} \mathbf{b}_1 C_{t-1} \\ \mathbf{b}_2 G_{t-1} \\ \mathbf{b}_3 C_{t-1}^{CO} \\ \Delta C_t \\ \Delta G_t \\ \Delta C_t^{CO} \end{pmatrix}.$$

### 3.4.2. Data

One of the practical issues in the measurement of core inflation is to find the appropriate periodicity of the data for policy purposes. For timeliness of policy, monthly-based core inflation would be favorable. However, monthly CPI has noises due to the process of surveying and constructing a consumer price index. For example, the information of property taxes is used to calculate monthly CPI, however, property taxes are reported only once a year. In this regard, such low frequency yearly data do not provide timely information for the policy purposes. For this reason we used quarterly data for the estimation of core inflation.<sup>7)</sup>

In ITS, the monetary authority has to manage inflation and is only

<sup>7)</sup> Besides, we used quarterly data because of the fact that GDP, the information variable used in this model, is announced only once a quarter.



**Table 1 ADF Unit Root Test Results**

Lag \ Variable	CPI	GDP	CPI_fe
1	1.200	0.891	0.307
2	0.813	0.695	0.332
3	0.553	0.661	0.441
4	0.274	0.831	0.557
5	0.400	0.709	0.592
6	0.309	0.557	0.610

Note: Constant term is included in ADF unit root test model.

responsible for inflation by law, however it is also the case that almost all monetary authorities still watch the target variables like employment and growth rate with deep concern. In this regard, we include a target variable, GDP, in the model.

Quarterly data,<sup>8)</sup> e.g., CPI and GDP for 1970. 1Q - 2001. 4Q are used to estimate the state space model. ADF unit root test statistics for those variables are represented in Table 1. Table 1 proves that these variables are all  $I(1)$  variables.<sup>9)</sup>

#### 4. EMPIRICAL RESULTS

To select optimal lag length we utilized a LR (Likelihood Ratio) test. The model that was finally selected has an optimal lag of 3 (see Table 2).

Then we need to test whether calculated core inflation is useful for monetary policy. For this purpose, we compared the derived core inflation (core inflation indicator) with government-announced official core inflation in Korea (CPI\_fe).

<sup>8)</sup> CPI\_fe data will be used for the comparison between CPI\_fe and our suggested core inflation indicator. CPI\_fe is calculated by an exclusion method which excludes supply-side components such as prices of agricultural and marine products, and energy.

<sup>9)</sup> We implemented an ADF unit root test which includes both constant and trend terms. The test results for this case also revealed the non-stationarity of those variables. And the ADF unit root test for the non-stationarity of inflation variable showed that inflation is  $I(1)$  variable.

**Table 2 Model Selection and Likelihood Ratio**

Lag	Likelihood	<i>p</i> -value of LR Test Statistics
1	-117.89	-
2	-120.49	1.00
3	-109.54	0.003
4	139.95	1.00
5	-193.78	1.00

Note:  $H_0$ : lag =  $j$ ,  $H_1$ : lag =  $j-1$ .

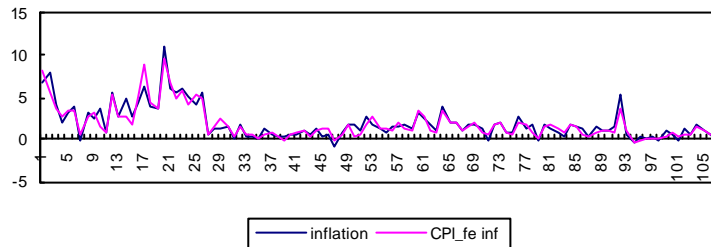
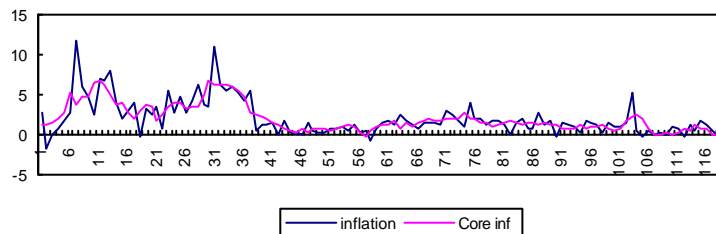
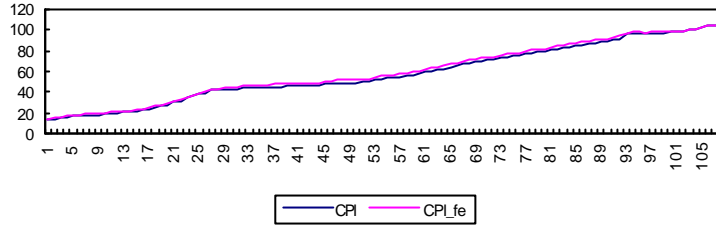
**Figure 1 CPI Inflation and CPI\_fe Inflation****Figure 2 CPI Inflation and Core Inflation**

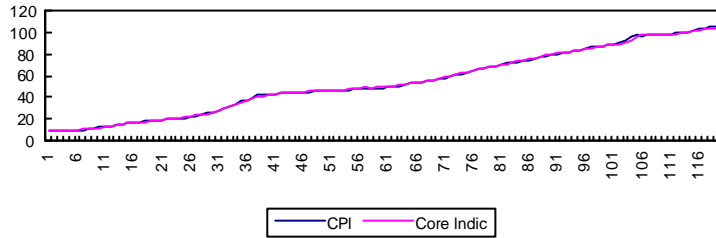
Figure 1 shows CPI inflation and CPI\_fe inflation (present definition of core inflation in Korea), while Figure 2 shows CPI inflation and core inflation. First of all, we can see that suggested core inflation is much less volatile than headline CPI inflation. The superiority of our core inflation is easily visualized by simple comparison of these two diagrams.<sup>10)</sup> On the

<sup>10)</sup> Standard deviations are compared. The volatility of the core inflation was found to be the smallest among all. To be specific, standard deviation of the core inflation was 0.465, while those of CPI and CPI\_fe were 0.539 and 0.593 respectively.

**Figure 3 CPI and CPI\_fe**



**Figure 4 CPI Inflation and Core Inflation**



other hand, Figure 3 and figure 4 show the graphs of level variables.

**4.1. Cointegration between CPI and Core Inflation Indicator**

In order to prove the usefulness of the new method we need to check whether CPI and core inflation indicators have a cointegrated relationship. To this end, it is necessary to check that the suggested core inflation indicator has unit root as mentioned above. ADF test results are given in Table 3. Table 3 shows that our core inflation indicator is a  $I(1)$  variable. From the test results, we can see that CPI\_fe is a  $I(1)$  variable.

**Table 3 ADF Unit Root Test Results for Core Inflation Indicators**

Lag	1	2	3	4	5	6
CPI_fe	0.307	0.322	0.441	0.557	0.592	0.610
Core Indicator	0.526	0.324	0.133	0.355	0.361	0.473

Note: Constant term is included in ADF unit root test model.

**Table 4-1 ADF Unit Root Test for Cointegration: ADF Statistic**

Lag	1	2	3	4	5	6
CPI_fe	-1.945 (-1050.5)	-2.034 (-1042.5)	-1.321 (-1032.7)	-1.762 (-1024.9)	-1.141 (-1013.9)	-0.966 (-997.4)
Core	-4.180 (-950.7)	-3.160 (-943.7)	-2.723 (-931.2)	-3.340 (-922.5)	-2.894 (-907.0)	-3.279 (-895.8)

Note: Numbers in parentheses denote value of SIC.

**Table 4-2 Results of Johansen Cointegration Test:  $I_{trace}$  and  $I_{max}$** 

Lag		1	2	3	4	5	6	
CPI_fe	$r = 0$	$I_{trace}$	16.86	13.45	5.48	8.06	8.18	10.87
		$I_{max}$	13.78	10.96	4.87	6.15	7.57	10.42
	$r = 1$	$I_{trace}$	3.07	2.49	0.59	1.91	0.61	0.45
		$I_{max}$	3.07	2.49	0.59	1.91	0.61	0.45
Core Indicator	$r = 0$	$I_{trace}$	35.75	26.76	26.46	30.05	26.48	31.19
		$I_{max}$	33.76	21.29	19.40	23.20	16.07	20.26
	$r = 1$	$I_{trace}$	1.99	5.47	8.05	6.84	8.41	8.92
		$I_{max}$	1.99	5.47	8.05	6.84	8.41	8.92

The previous unit root tests reveal that CPI\_fe and suggested core inflation indicator is  $I(1)$  variable, so that cointegration analysis can be implemented. We used the residual based method and Johansen's procedure to test a cointegrated relationship between CPI and core inflation. The cointegration tests between CPI and CPI\_fe, and between CPI and the core inflation indicator in our model are presented in Table 4-1 and Table 4-2.

The tests results show that there is no cointegrated relationship between CPI and CPI\_fe, while there is a strong cointegrated relationship between CPI and our core inflation indicator. We used Pesaran *et al.* (2000) as the critical value for the Johansen cointegration test.

## 4.2. Properties of Excluded Components

True core inflation is supposed to exclude all of the components that come from the supply side, so that the resulting difference between headline

inflation and core inflation reflect temporary movements in inflation.

If the suggested core inflation successfully excluded supply-side components, the core inflation and excluded components would be independent. Thus we need to check whether the core inflation and the excluded component are independent.

Before getting into the independence test, we need to find out whether the excluded component is an unbiased predictor of the temporary component of inflation. In order to test whether the excluded component over(under)-predicts the temporary component of the CPI inflation, we utilized a variation of the Cogley(1998) test.

Test procedure is as follows.

First, regress the following equation.

$$(\mathbf{p}_{t+k} - \mathbf{p}_t) = \mathbf{a} + \mathbf{b}(\mathbf{p}_t^{core} - \mathbf{p}_t) + u_t, \quad (22)$$

where  $\mathbf{p}$  represents headline inflation,

Second, test the null hypothesis  $H_0 : \mathbf{a} = 0$  and  $\mathbf{b} = 1$ . If, by chance,  $\mathbf{b} > (<)1$ , then it over-estimates(under-estimates) the transitory movement. We cannot then accept that the excluded component is an unbiased predictor of the temporary component of inflation.

Table 5 presents regression results over the whole sample period, that is, from 1970. 2Q to 2001. 4Q. Regression results show that null hypotheses are not rejected in all  $k$ . This implies that our core inflation excludes temporary components successfully. In case of CPI\_fe, the null hypothesis is rejected at  $k = 2$  and  $k = 6$ . However, it was found to exclude supply-side components as well.

Tests in other model approaches (e.g., SVAR model) for Korean core inflation were, however, not successful.

**Table 5 Results of Estimation for Cogley Equation (22)**

a. Core Inflation				
$k$	$\mathbf{a}$	$\mathbf{b}$	$\bar{R}^2$	Wald Test Statistic $H_0 : \mathbf{a}=0$ and $\mathbf{b}=1$
1	-0.007	1.186	0.684	0.069
2	-0.015	0.844	0.378	0.320
3	-0.022	0.762	0.289	0.119
4	-0.030	0.603	0.186	0.005
5	-0.035	1.028	0.359	0.745
6	-0.050	0.696	0.190	0.067

b. CPI_fe Inflation				
$k$	$\mathbf{a}$	$\mathbf{b}$	$\bar{R}^2$	Wald Test Statistic $H_0 : \mathbf{a}=0$ and $\mathbf{b}=1$
1	0.018	0.859	0.105	0.757
2	-0.008	0.089	0.010	0.001
3	0.007	1.136	0.200	0.830
4	-0.011	0.659	0.066	0.367
5	-0.008	0.905	0.082	0.944
6	-0.041	0.091	0.011	0.007

### 4.3. Predictability for Future Trends of Inflation

Now let us turn our attention to the predictive power of core inflation. To this end, we can utilize the correlation between core inflation and headline inflation. The results reveal that our suggested core inflation has definitely higher correlation than CPI\_fe (see Table 6).

N. Rowe and J. Yetman (2000) pointed out that low correlation does not, however, necessarily mean that core inflation does not predict future inflation well, since successful inflation targeting monetary policies has a tendency to

**Table 6 Correlation between Inflation and Core Inflation**

	CPI_fe	Core Indicator
1	0.661	0.803
2	0.609	0.786
3	0.677	0.754
4	0.659	0.687
5	0.537	0.633
6	0.485	0.558

**Table 7 Regression Results:  $\bar{R}^2$** 

Core Inflation	$a$	$b_1$	$b_2$	$\bar{R}^2$
CPI	0.888 (11.536)	0.037 (0.722)	-	0.759
CPI_fe	0.319 (0.743)	0.592 (1.350)	0.039 (0.758)	0.761
Core indicator	0.048 (0.122)	0.900 (2.147)	0.013 (0.255)	0.768

Note: Numbers in parentheses denote  $t$ -value.

**Table 8 Forecast Error: RMSE**

	CPI	CPI_fe	Core Indicator
1	0.281	0.291	0.007
2	0.317	0.298	0.043
3	0.321	0.298	0.130
4	0.394	0.381	0.141
5	0.395	0.384	0.150
6	0.437	0.434	0.156
7	0.470	0.460	0.215
8	0.474	0.467	0.301

derive correlation to zero.

For this reason, we need to adopt another method to check the predictive power of core inflation. To this end, we employed the following form of equations:

$$p_t = a + b_1 \frac{\sum_{i=1}^4 p_{t-i}}{4} + b_2 \frac{\sum_{i=1}^4 p_{t-i}^{CO}}{4} + u_t. \quad (23)$$

Table 7 shows that the suggested core inflation has better ability to predict future inflation trends in ex-post forecast simulations (see  $\bar{R}^2$  values in estimation equations).

We made a similar test, using an ex-ante forecast this time. Calculated RMSE for each regression model is presented in Table 8. As can be seen from Table 8, the suggested core inflation indicator has the lowest RMSE. This also reflects that the suggested core inflation predicts future inflation trends better.

#### 4.4. Relations to Monetary Policy

In ITS countries, it is core inflation rather than CPI inflation that is used as an intermediate target. Thus, in order to prove its usefulness as a target variable we need to check Granger-causalities between core inflation and monetary aggregates, and between interest rates (call rates) and core inflation. If change of monetary aggregates (or call rates) causes future core inflation it will be highly likely to control core inflation with monetary aggregates (or call rates). On the other hand, we expect that core inflation does not cause direct changes in monetary aggregates (or call rates).

First, in order to check that the change rate of monetary aggregates (or call rates) significantly influences future core inflation, we estimated the following equation.

$$\frac{1}{J} \sum_j \mathbf{p}^*_{t+j} = \mathbf{a} + \sum_i^n \mathbf{b}_i \left( \frac{M_{t-i+1} - M_{t-i}}{M_{t-i}} \right) + \mathbf{e}_t, \quad (24)$$

where  $\mathbf{p}^*$  is a core inflation, and  $n = 4$ .

Equation (24) is constructed in such a way that change in annual money supply can affect the first J quarter future core inflation rates. Table 9 proves that M3 and call rates best fit the suggested core inflation among all.

Second, we tested Granger-causality between monetary aggregates (and call rates). The Granger causality test is made by employing the following

**Table 9 Regression Results ( $\bar{R}^2$ ) for Equation (24)**

$J$	CPI	CPI_fe	Core Indicator
M3	5	0.454	0.534
	6	0.456	0.541
	7	0.457	0.543
	8	0.459	0.552
Call	5	0.905	0.918
	6	0.910	0.922
	7	0.914	0.926
	8	0.919	0.931



equation.

$$X_t = \mathbf{a} + \sum_i^n \mathbf{b}_i X_{t-i} + \sum_i^n \mathbf{g}_i Y_{t-i} + \mathbf{u}_t. \tag{25}$$

Test statistics for the null hypothesis ( $H_0 : \mathbf{g}_1 = \dots = \mathbf{g}_n = 0$ ) are presented in Table 10. Results reveal that Granger-causality from monetary

**Table 10 Granger-causality test results: Wald test (p-value)**

a. Core Indicator

<i>i</i>	M3		Call rates	
	<i>M3</i> → <i>p</i>	<i>p</i> → <i>M3</i>	<i>r</i> ⇒ <i>p</i>	<i>p</i> ⇒ <i>r</i>
1	0.003	0.492	0.016	0.291
2	0.051	0.611	0.004	0.237
3	0.344	0.634	0.026	0.274
4	0.778	0.065	0.080	0.219
5	0.906	0.141	0.137	0.200
6	0.357	0.114	0.150	0.245

b. CPI\_fe

<i>i</i>	M3		Call rates	
	<i>MB</i> → <i>p</i>	<i>p</i> → <i>MB</i>	<i>r</i> ⇒ <i>p</i>	<i>p</i> ⇒ <i>r</i>
1	0.000	0.000	0.025	0.004
2	0.000	0.000	0.057	0.042
3	0.004	0.009	0.209	0.920
4	0.138	0.006	0.362	0.504
5	0.138	0.003	0.500	0.602
6	0.173	0.208	0.348	0.499

c. CPI

<i>i</i>	M3		Call rates	
	<i>M3</i> → <i>p</i>	<i>p</i> → <i>M3</i>	<i>r</i> ⇒ <i>p</i>	<i>p</i> ⇒ <i>r</i>
1	0.002	0.000	0.029	0.000
2	0.023	0.001	0.099	0.493
3	0.257	0.014	0.350	0.440
4	0.778	0.004	0.560	0.257
5	0.804	0.001	0.672	0.344
6	0.461	0.019	0.765	0.459

aggregates to the suggested core inflation is proved to be statistically significant at  $i=1$  and  $i=2$ , while the reverse turned out to be insignificant. Granger-causality from call rates to the suggested core inflation is proved to be statistically significant at  $i=1$  to  $i=3$ , while the reverse turned out to be insignificant. On the other hand, causalities from both directions were proved significant or insignificant, when CPI<sub>fe</sub> was used.

## 5. CONCLUDING REMARKS

Recently, the Inflation Targeting System (ITS) has emerged as a major monetary policy scheme in countries like England, Canada, and Australia. However, the success of the ITS is believed to depend on which variables are utilized as tools, and which are used as the target variable. The key issue of the ITS thus comes down to how to define and estimate core inflation, the target variable.

So far, core inflation has been derived as a quasi-trend after arbitrarily truncating extreme fluctuations. This process obviously causes a serious loss of information. In addition, correlation between the headline inflation and the core inflation becomes rather low.

The main objective of this study is to derive an alternative core inflation indicator which has a strong correlation to the headline CPI. This needs the error correction model, and some additional conditions on the exogeneity lead our model toward the conditional error correction model. To this end, we suggested a state space model designed to estimate an unobserved hidden core inflation indicator which is cointegrated with the headline CPI.

The suggested model does not suffer from the information loss problem, which is a main defect of the old definition of core inflation. In addition, we performed policy simulations to prove that the new core inflation has an edge over the old one in predicting future headline inflation rates. Further, in order to prove the usefulness of the new core inflation, this paper sought

for empirical evidences to have a stronger correlation with the headline inflation than the old one has.

Policy simulation results to prove the usefulness of suggested core inflation show that our core inflation has an edge over the old one in various aspects and has good performance.

## REFERENCES

- Antonic, M., "High and Volatile Real Interest Rates: Where Does the Fed Fit in?" *Journal of Money, Credit, and Banking*, 18, 1986, pp. 18-27.
- Arrazola, Maria and Jose de Hevia, "An Alternative Measure of Core Inflation," *Economics Letters*, 75, 2002, pp. 69-73.
- Attah-Mensah, J., "A Modified P\* Model of Inflation Based on M1," *Bank of Canada Working Paper*, No. 96-15, 1996.
- Bjornland, H. C., "Identifying Domestic and Imported Core Inflation," *IMF Working Paper* No. 00/4, 2000.
- Blanchard, O. and N. Kiyotaki, "Monopolistic Competition and the Effects of Aggregate Demand," *American Economic Review*, 77(4), 1987, pp. 647-666.
- Blix, M., "Underlying Inflation - A Common Trends Approach," *Sveriges RiskBank Working Paper* No. 23, 1995.
- Boswijk, H. Peter, "Efficient Inference on Cointegration Parameters in Structural Error Correction Models," *Journal of Econometrics*, 69, 1995, pp. 133-158.
- Burmeister, E. and K. D. Wall, "Kalman filtering Estimation of Unobserved Rational Expectations with an Application to German Hyperinflation," *Journal of Econometrics*, 20, 1982, pp. 255-284.
- Claus, I., "A Measure of Underlying Inflation in the United States," *Bank of Canada Working Paper*, No. 97-20, 1997.
- Cogley, Timothy, "A Simple Adaptive Measure of Core Inflation," *Journal of Money, Credit and Banking*, 34(1), 2002, pp. 94-113.

- Engle, Robert F. and M. W. Watson, "A One-Factor Multivariate Time Series Model of Metropolitan Wage Rates," *Journal of the American Statistical Association*, 76, 1981, pp. 774-781.
- Engle, Robert F., David F. Hendry, and Jean-francois Richard, "Exogeneity," *Econometrica*, 51(2), 1983, pp. 273-304.
- Ericsson, Neil R., "Conditional and Structural Error Correction Models," *Journal of Econometrics*, 69, 1995, pp. 159-172.
- Fase, M. and C. Folkertsman, "Measuring Inflation: An Amount to Operationalize Carl Menger's Concept of the Inner Value of Money," *De Nederlandsche Bank Working Paper*, 1996.
- Flemming, J., *Inflation*, Oxford University Press, 1976.
- Freeman, Donald G., "Do Core Inflation Measures Help Forecast Inflation," *Economics Letters*, 58, 1998, pp. 143-147.
- Hallman, J. J., R. D. Porter, and D. H. Small, "M2 per Unit of Potential GNP as an Anchor for the Price Level," *Board of Governors of the Federal Reserve System Staff Paper*, 157, 1989.
- Hamilton, James D., *Time Series Analysis*, Princeton University Press, 1994.
- Harvey, Andrew C., *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press, 1989.
- Johansen, Soren, "Testing Weak Exogeneity and the Order of Cointegration in U.K. Money Demand Data," *Journal of Policy Modeling*, 14, 1992, pp. 313-334.
- Kim, Bong-Han and Byung Cheol Yoo, "Estimation of Core Inflation and Its Usefulness as A Indicator for Inflation Targeting System," paper presented at the Korea International Economic Association 2001 Winter Seminar, 2001(in Korean).
- Kim, C. J. and C. R. Nelson, *State Space Models with Regime Switching: Classical and Gibbs-Sampling Approaches with Applications*, MIT Press, 1999.
- Kim, Ki-Ho, "New Approach to Estimation of the Core Inflation and Analysis for Its Usefulness," mimeo, 2003 (in Korean).
- Lee, Jong Gun and Sung Hyuk Kwon, "Estimation of the Korean Core

- Inflation," *Monthly Bulletin*, Bank of Korea, 1998. 3 (in Korean).
- Marques, C. R., P. D. Neves, and A. G. da Silva, "Why Should Central Banks Avoid the Use of the Underlying Inflation Indicators?" *Economics Letters*, 75, 2002, pp. 17-23.
- Marques, C. R., P. D. Neves, and L. M. Sarmento, "Evaluating Core Inflation Indicators," mimeo, 2001.
- Oh, Junggun, "Is Core Inflation Useful As an Indicator for the Inflation Targeting?" *Kyoung Jae Bun Seok*, 5(3), Bank of Korea, 1999 (in Korean).
- Park, Jong Kyu, "Estimation of Core Inflation By Using A Normal-Normal Mixture Model," Korea Institute of Public Finance, Research Report, 2000 (in Korean).
- Pesaran. H. H., Yongcheol Shin and Richard J. Smith, "Structural Analysis of Vector Error Correction Models with Exogenous I(1) Variables," *Journal of Econometrics*, 97, 2000, pp. 293-343.
- Quah, D. and S. P. Vahey, "Measuring Core Inflation," *The Economic Journal*, 105, 1995, pp. 1130-1140.
- Rowe, N. and J. Yetman, "Identifying Policy-makers' Objectives: An Application to the Bank of Canada," *Bank of Canada Working Paper*, No. 2000-11, 2000.