Measures of core inflation in Korea

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I. Introduction

Most central banks adopting inflation targeting as a monetary policy regime take the headline consumer price index (CPI) as a target index. This is because the CPI broadly mirrors the changes of prices in goods and services and can capture effectively the changes in inflation and welfare that people experience in daily life.

Headline CPI, however, includes various items, the prices of which are critically influenced by temporary shocks such as weather conditions, unexpected surges in international raw material price, or one-off effects stemming from the change in government policies. Thus, headline CPI is sometimes not the most useful index for grasping the underlying trend of inflation in the short run.

Meanwhile, having generally enjoyed low and stable prices since the early 2000s, most of the key economies in the world are now going through the final phase of a boom and bust cycle in asset (housing) prices based upon liquidity expansion, owing to sustained low interest rates and financial market innovations such as derivatives. In this regard, the argument may be put forward that monetary policy may fail to cope properly with increasing pressure on asset prices under an inflation targeting regime using headline CPI as its target index, which does not include asset prices.

In this paper, we examine the possibility that we can fix the problems mentioned above to improve the usefulness of CPI. First, we measure the core inflation indices that reflect cross-sectional information in the Korean CPI series. Second, we calculate the dynamic factor index (DFI), which Bryan et al (2002) have proposed to reflect the trend of asset prices in the CPI, and evaluate its usefulness as an information variable for monetary policy.

II. Measures of core inflation and its usefulness

1. CPI based measures of core inflation[4]

The cross-sectional distribution of the growth rates of the individual CPI components is different from a normal distribution in that it is fat-tailed. Table 1 gives some important statistics on the monthly cross-sectional distribution of the Korean CPI, where the kurtosis measuring the extent of the thickness of tails is 8.8 on a monthly average; greater than the

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[4] This section is based on Seung Yong Lee and Jung Min Park (2008).

3 under a normal distribution. The fat tail, which means that items with high volatility are concentrated at both extremes of the distribution, implies that the rate of increase in the Korean CPI is generally affected by items located at both tails of the cross-sectional distribution.

The skewness is 0.75 on a monthly average, meaning that the distribution is right-skewed and differs significantly from normal distribution, where skewness is zero. Resulting from downward stickiness, this means that the number of items with prices that decrease is smaller than that of those with prices that increase.[5]

Table 1

Statistics on the cross-sectional distribution of the rate of increase in the CPI

	Average	**Standard deviation**	**Skewness**	**Kurtosis**
Whole period (Jan. 1991–Dec. 2007)	4.27	6.74	0.75	8.80
Before currency crisis (Jan. 1991–Nov. 97)	5.77	7.13	0.47	8.07
After currency crisis (Jun. 2000–Dec. 2007)	3.06	5.86	0.91	9.88
Currency crisis period (Dec. 1997–May 2000)	3.78	8.32	1.05	7.55

The characteristic of Korean CPI distribution shows that the growth rate in headline CPI has high volatility, influenced by some items that increased or decreased greatly. Thus, in addition to headline CPI, it is necessary to develop an index that minimises misleading signals such as temporary or one-off factors in order to determine the appropriate stance of short-term monetary policy. For this purpose, we measured core inflation in Korea using a trimmed mean method and an exclusion-based method, which appropriately remove the influence of the items located at both tails of the cross-sectional distribution.

Trimmed mean method

The trimmed mean method obtains the core inflation for a given month by first sorting the individual price changes in ascending order; second, discarding a certain fraction of the tails in the distribution; and finally calculating the weighted average of the remaining components. The fraction to be trimmed is predetermined but the components to be excluded vary with each trim. Since the cross-sectional distribution of consumer price changes for Korea is asymmetric, we also apply a different fraction of extreme observations to each tail.[6]

To apply the different fraction of exclusion to each tail, the percentile that corresponds to the sample mean of the distribution is calculated and is designated the mean percentile. The result indicates that the 57th percentile is the mean percentile for the 1991–2007 period. If we use 10% as the fraction of total exclusion, the 57th percentile gives us 5.7% for the left tail and 4.3% for the right tail.

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5 Comparing the cross-sectional distributions of growth rates in the Korean CPI before and after the 1997–98 currency crisis tells us that the skewness and kurtosis increased, which means that the price movements of some items had greater influence on total CPI after currency crisis than before.

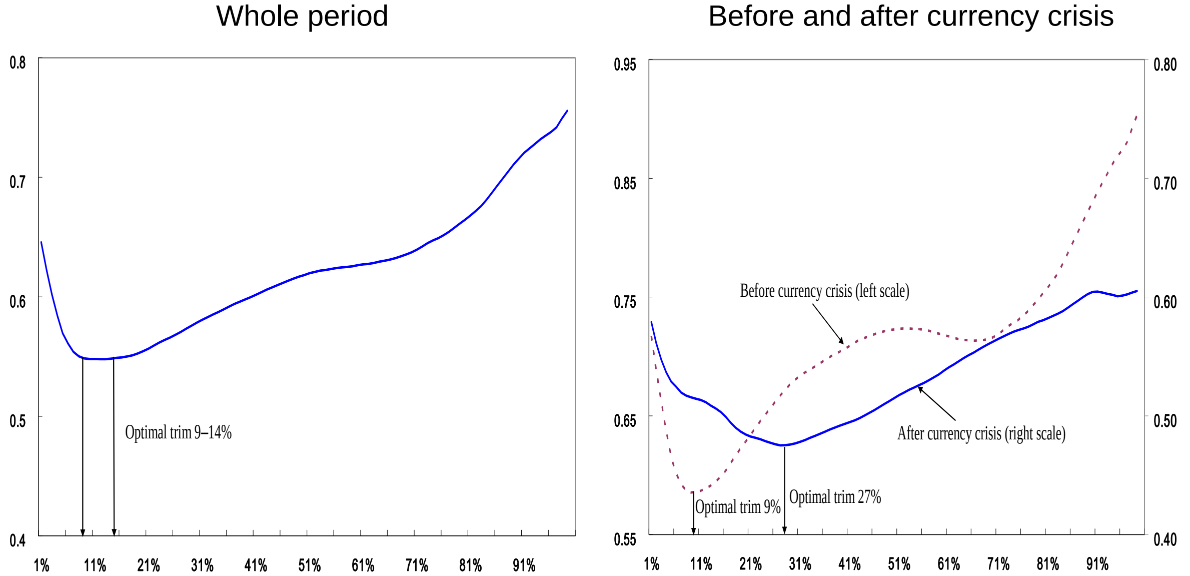
6 If the cross-sectional distribution is symmetric, the same fraction of extreme observations is trimmed from each tail; for asymmetric distribution, a different fraction is applied. This is because if the distribution is asymmetric and the same fraction is trimmed from each tail, the mean will not be an unbiased estimator.

To find the optimal trim, we obtained 99 different trimmed series, from 1% to 99% trimmed series, and calculated the root mean square error (RMSE) of these series versus a measure of trend inflation. The trend or benchmark inflation rate is defined as the centred 24-month moving average of CPI inflation. We found that the smallest RMSE lies in the range of 9% (left tail: 5.13%, right tail: 3.87%) to 14% (left tail: 7.98%, right tail: 6.02%). When we divided the period into two, before and after the currency crisis, the optimal trim was 9% before the crisis and 27% after it (see Figure 1).

We also used other series of the benchmark inflation rates, the 30-month and 36-month moving average series and the HP-filtering series to find the robust optimal trim. For the 30-month and HP-filtering benchmark, 18% was optimal, and for the 36-month benchmark, 20% was optimal during the whole period. For the period after the crisis, the optimal trim was in the range of 26–30%.

Figure 1

Root mean square error and optimal trim



Based on these calculations, we conclude that the optimal trim is 18%[7] for the whole period and 27% for the period after the crisis. But we face the problem of choice between the two candidates. We chose 18% as the optimal trim because the period after the currency crisis is rather short. A long series has been used for the calculation of the optimal trim in most research papers, even though there seems to have been a structural change during the crisis period. This method using the 18% trimmed mean is termed TRIM_82.

Exclusion-based method

The exclusion-based method is a core inflation measure that selects ex ante the items that have been frequently at the extreme of cross-sectional distribution of price changes and excludes these items. This method has the fixed items excluded from the CPI basket. To select the volatile items in the CPI basket, the specific criteria below are applied:

1) Items of which 12-month changes exceed 1.5 times the standard deviation from the average.

[7] For the 24-month and 36-month benchmarks, the 18% trim shows a difference of within 1% from the smallest RMSE, and 30-month and HP-filtering benchmarks obtain the smallest RMSE at the 18% trim.

2) Items that are among the items fulfilling criterion 1 for more than 25% of the observation period.

Table 2 shows 11 items (fruit, vegetables, other agricultural products, salted and dried fish, other livestock products, durables for culture and recreation, other durables, fuel for transport, fuel for heating and cooking, municipal gas, cigarettes) that are frequently located on the tails of a cross-sectional distribution of price changes. However, we do not exclude durables for culture and recreation or other durables from the CPI basket, because their prices have shown a persistently decreasing tendency due to innovation in the information technology industries.[8] Salted and dried fish and other livestock products are not eliminated either, because their weights in the CPI are too small.

Table 2

Highly volatile items in the CPI

	Frequency of elimination (%)	Average	Standard deviation
Fruit (16.7)	72.1	7.8	17.4
Vegetables (14.5)	51.5	8.0	16.2
Other agricultural products (7.1)	25.5	6.3	10.7
Fuel for heating and cooking (6.9)	49.5	10.8	15.3
Fuel for transport (47.0)	27.5	9.5	11.6
Municipal gas (16.1)	31.4	6.0	11.5
Cigarettes (10.8)	30.4	7.2	9.5
Durables for culture and recreation (9.4)	43.1	–6.1	5.5
Other durables (4.3)	39.2	–6.3	7.3
Other livestock products (2.8)	34.8	4.1	13.1
Salted and dried fish (2.1)	24.5	5.4	9.1

1) Figures in parentheses are the weights (%) in the CPI basket

Below, we categorise remaining seven items into agricultural products, petroleum products and cigarettes, and then make the various compositions including public service charges. Public service charges are included because they are affected by the one-off effects of government policies and are mainly adjusted in a specific period (first quarter every year), although their variance does not fulfil the criteria. In addition, we chose a candidate excluding food and energy, which is the most popular core inflation measure in the United States. Table 3 shows six candidates.

8 Durables for culture and recreation and other durables have fulfilled the criteria 88 times (43.1%) and 80 times (39.2%) respectively. However, these two items have almost always been located in the left extreme.

Table 3

Coverage of each case using exclusion-based method

	Excluded items	Weights
Case 1	• Agricultural products excluding cereals	961.7
Case 2	• Petroleum products including municipal gas	930.0
Case 3	• Agricultural products excluding cereals • Petroleum products including municipal gas	891.7
Case 4	• Agricultural products excluding cereals • Petroleum products including municipal gas • Cigarettes	880.9
Case 5	• Agricultural products excluding cereals • Petroleum products including municipal gas • Public service charges	733.9
Case 6	• Food excluding alcoholic beverages • Petroleum products including municipal gas • Electricity charges	668.1

Next, the ability of candidate indicators to track trend inflation is compared by using the centred 24-month moving average of CPI inflation as a benchmark. Table 4 shows various exclusion-based methods compared with benchmark inflation by using the RMSE and the mean absolute deviation (MAD).

Table 4

RMSE[1)] of various exclusion-based methods

in per cent

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Whole period	22.3 (12.4)	0.0 (2.3)	5.1 (0.0)	9.8 (4.8)	36.3 (33.6)	15.5 (10.0)
Before currency crisis	0.0 (0.0)	20.8 (17.2)	17.1 (10.5)	20.0 (12.4)	61.9 (60.4)	17.1 (5.4)
After currency crisis	25.5 (21.8)	11.9 (11.8)	0.0 (0.0)	11.3 (10.4)	41.2 (30.7)	45.4 (40.5)

Notes: 1) [RMSE/minimal RMSE – 1] × 100. 2) Figures in parentheses are MAD.

In the results of the comparison, Case 3 (CPI_X1), which excludes agricultural and petroleum products (including municipal gas) from the CPI, and Case 2 (CPI_X2), which excludes petroleum products (including municipal gas), are evaluated as effectively eliminating the temporary and disturbing factors of inflation. CPI_X1, which is officially calculated by the Korean National Statistical Office, turns out still to be a useful indicator. Also, CPI_X2 can be used as a supplementary indicator when oil prices are on the rise.

The exclusion-based method is easy to measure and we can therefore select the excluded items according to the characteristics of supply shocks. For example, the core measure used in the United States (Case 6, Core_US), which excludes energy and food, is helpful in assessing the trend of underlying inflation when both oil prices and agricultural prices are rising steeply.

Usefulness of CPI-based measures

Core inflation indicators measured by the trimmed mean method and exclusion-based method are evaluated for their usefulness based on a variety of criteria. Trimmed mean core inflation has relative superiority in its ability to track the underlying trend of inflation. In ability to forecast the future direction of headline inflation, there is no meaningful difference between them. Concerning the reversion of headline CPI inflation to core indicators, we find that both indicators show statistically significant reversion over the six-month horizon, which means that headline inflation in Korea has tended to revert more strongly towards core indicators than core indicators have moved towards headline inflation (see Table 5). It should, however, be taken into account that exclusion-based core inflation is comparatively superior in the sense of being a simple indicator whose method is transparent and readily understood by the public. Accordingly, the indicators from both methods seem to have their own particular usefulness.

A single core inflation measure cannot account for all types of shocks and can at times be misleading about what is happening to the underlying rate of overall inflation (Mishkin (2007)). Accordingly, we should consider a collection of underlying inflation indices rather than focus on a single measure. This is what we seem to have seen recently in Korea. From late 2005 to the middle of 2006, the price of cereals fell sharply due to a change in government policy. That move led to marked falls in headline CPI inflation and CPI_X1 core inflation, while TRIM_82 core inflation remained quite stable during this period because this one-off effect had been properly eliminated.

Table 5

Evaluation of the various measures of core inflation

(Sample period: Jan. 1991–Dec. 2007)

		Exclusion-based methods		**Trimmed mean**
		CPI_X1	**Core_US**	**Trim_82**
Deviations of core inflation from trend[1]	RMSE	1.01	1.11	0.90
	MAD	0.72	0.79	0.66
Predictability[2]	6 months	1.57	1.58	1.52
	12 months	2.23	2.06	2.18
Reversion[3),4)]	$\beta_h^{5)}$	–0.90*** (0.23)	–0.73*** (0.19)	–1.41*** (0.28)
	$B_h^{6)}$	0.16 (0.19)	0.15 (0.15)	0.67*** (0.22)

Notes: 1) Statistics between the benchmark inflation (24-month centred moving averages of actual CPI inflation) and each measure of core inflation. 2) Prediction errors (RMSE) for 6-month and 12-month forecasting horizons. 3) ***, **, * represent significance levels of 1%, 5% and 10%, respectively. 4) Figures in brackets are standard errors calculated using the Newey-West method. 5) $\pi_{t+6} - \pi_t = \alpha_h + \beta_h(\pi_t - \pi_t^{core}) + \varepsilon_{t+h}$ 6) $\pi_{t+6}^{core} - \pi_t^{core} = \alpha_h + B_h(\pi_t^{core} - \pi_t) + \varepsilon_{t+h}$

2. Asset price based measure of core inflation[9]

Estimation of the DFI

Considering the defect that the calculation methods of the CPI and variance weighted price indices do not reflect the persistence of goods prices, Cecchetti (1996) and Bryan et al (2002) have presented a method of deriving trend inflation (DFI), where goods prices reflect dynamically changing behaviours. The DFI model, based on the Kalman filter and the state space model presented in these research papers, can be represented as an observation equation and transfer equations that are not observable in the actual time-series data such as trend inflation and the relative price fluctuation of each good. In other words, inflation of individual goods seen in equation (1) can be common to all goods prices containing similar asset prices, but consists of non-observable trend fluctuations (Π_t of core inflation) and peculiar fluctuations of individual goods (relative price fluctuation, $x_{i,t}$). It is assumed that common trends and peculiar fluctuations follow a polynomial lag distribution in equations (2) and (3), respectively.

Observation equation: $\pi_{i,t} = \Pi_t + x_{i,t}$, $i = 1,.....,n$ (1)

Transfer equation: $\Psi(L)\Pi_t = \delta + \xi_t$, $\xi_t \sim N(0,\sigma_\xi^2)$ (2)

Transfer equation: $\Theta(L)x_{i,t} = \eta_{i,t}$, $\eta_{i,t} \sim N(0,\sigma_\eta^2)$ (3)

Let us suppose that common trends and peculiar fluctuations are mutually independent in all lags for identifying the model. Each parameter and the common trends (Π_t) are estimated by maximum likelihood estimation employing the Kalman filter.

Following this methodology, we set up the DFI model for Korea, which consists of 14 variables: 12 commodity groups of the CPI such as food and non-alcoholic beverages, housing prices, and stock prices. We estimated 31 parameters in the state space model composed of observation and transfer equations employing the maximum likelihood estimation and then derived trend inflation and the relative price fluctuation of the commodity index (refer to Appendix). The variance (σ_ξ^2) of trend inflation is fixed as 1 in Bryan et al (2002) and, for reflecting the dynamic volatility, the estimation is performed by setting up the AR (2) model. Under the same condition in Korea, however, the statistical significance of the estimated model is not high. That based upon the AR (1)[10] model shows the highest statistical significance; accordingly, we verify the model's stability by estimating and comparing the model that is directly estimated without fixing σ_ξ^2 as 1 (baseline model), the model where σ_ξ^2 is fixed as 1 (model 2), and the model where only housing prices are regarded as asset prices (model 3).

According to the analysis, it can be seen that each value of the coefficients is estimated as comparatively consistent, showing a similar value regardless of the estimation method. In the case of estimated trend inflation, its constant terms and AR (1) coefficients are statistically significant, and the long-term inflation level calculated at an annual rate has also values within 3.7%. Stock prices, however, have almost no effect on trend inflation. Figure 2 shows

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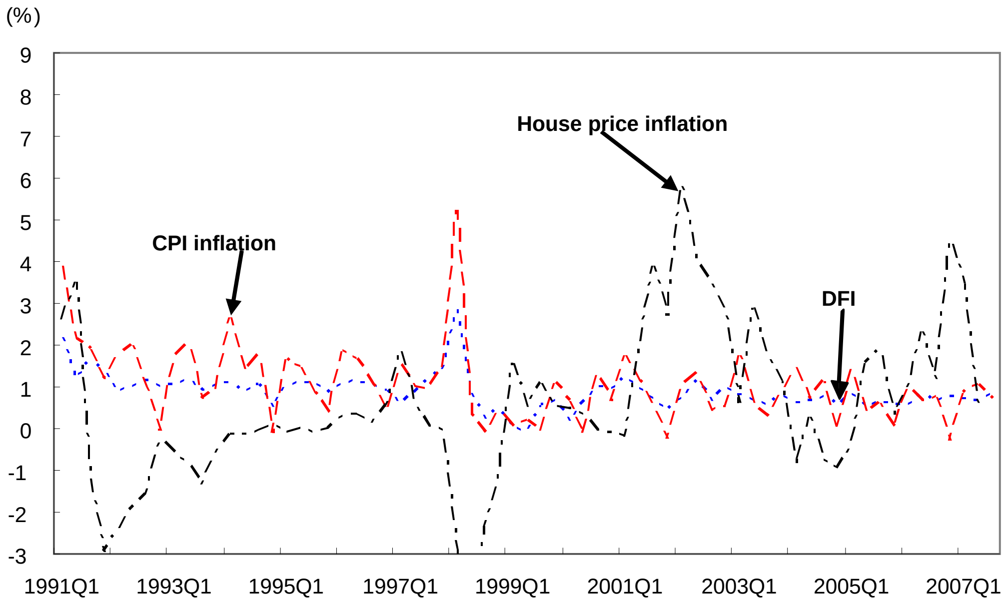
[9] This section is based on Yang Woo Kim and Joon Myoung Woo (2008).

[10] According to the estimation result of the AR(2) model, both trend inflation and most of the second lag coefficient of the index by item are not statistically significant.

the comparison between CPI inflation and the estimation result of model 3 using the data in which housing prices are regarded as the only asset prices. In the estimation result of the model, the DFI growth rate remains at stable levels of 0.8–1.2% (based on the previous quarter), and fluctuations in the CPI growth rate centre on the DFI growth rate. The DFI growth rate was below the CPI inflation level in the 1990s when housing prices remained stable with a downward tendency for a long period. The growth rate was also relatively low right after the currency crisis when CPI inflation surged.

Figure 2

Trends of DFI and CPI inflation (from the previous quarter)

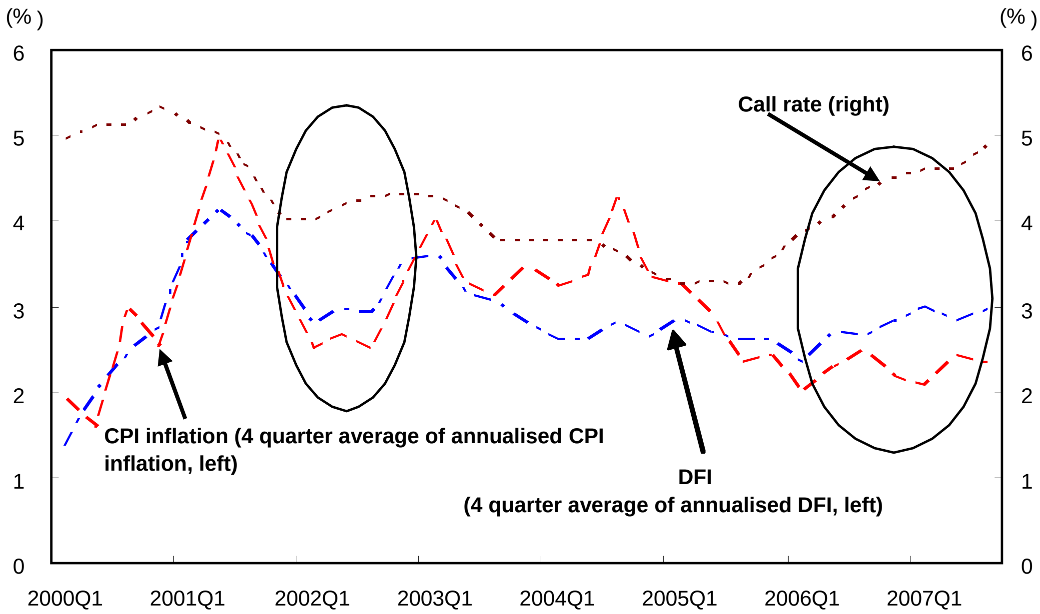


To compare the DFI and the CPI year by year, Figure 3 displays the annualised growth rates over the previous quarter. During periods of a sharp rise in housing prices, the DFI growth rate generally records higher levels than CPI inflation. The DFI – unlike the CPI – is considered sensitively to reflect purchasing power fluctuations caused by housing price fluctuations. That is, when the DFI showed 3.1% and 3.0% growth rates in 2002 and 2007 when the housing inflation rate was high, CPI inflation increased by 2.8% and 2.5%, respectively, which was lower than the DFI growth rates.[11] During 2004 and 2005, by contrast, the DFI growth rate was 2.7%, which was lower than the CPI growth rate (3.6% and 2.8%, respectively).

[11] In 2003, despite an exceptional hike in housing prices, the CPI growth rate was higher than the DFI growth rate. A base effect, caused by the markedly low CPI growth rate of the previous year, seems to have been at work to a certain extent.

Figure 3

Trends of DFI and CPI inflation



Usefulness of the DFI

An analysis is conducted to investigate whether it is possible to use the DFI as an information variable for CPI inflation, which is an indicator of price stability. The result shows that the DFI not only contains useful information in predicting CPI inflation, but also itself plays a role on the long-term trend of CPI inflation.

The analysis based on equation (4) demonstrates that, in predicting future CPI inflation, the lagged dependent variable of the DFI shows slightly better inflation-forecasting power than that of the CPI, having lower prediction errors for long- and short-term inflation.

$$\pi_{t+i} = a + \beta_0 A_t + \beta_1 \Delta ULC_t + \beta_2 GAP_t + \beta_3 \Delta MPI_t \quad (4)$$

i : forecasting horizon, ΔULC : growth rate of unit labour cost,

GAP : GDP gap ratio, ΔMPI : growth rate of import prices, A_t : CPI or DFI inflation

Table 6

(RMSE) prediction error by forecasting horizon

Forecasting horizon		**2002Q1–2006Q4**	**2004Q1–2006Q4**	**2006Q1–2006Q4**
A_t : CPI inflation	i= 4	0.714	0.608	0.595
	i= 8	0.667	0.577	0.574
	i=12	0.597	0.572	0.623
A_t : DFI	i= 4	0.691	0.565	0.580
	i= 8	0.656	0.566	0.566
	i=12	0.573	0.564	0.576

We conduct a variance decomposition of prediction error using a three-variable VAR model consisting of GDP growth rate, DFI and CPI inflation. The result indicates that the degree of DFI's contribution to CPI inflation volatility reaches 55%, which is higher than the degree of CPI inflation's contribution, 21%.[12] This is because housing prices containing substantial information on future inflation are taken into account in the DFI.

Table 7

Variance decomposition result

Period	DFI		CPI	
	DFI	CPI	DFI	CPI
1	82.10	0.00	58.67	29.01
2	82.60	0.67	60.53	27.89
3	82.05	0.64	60.27	26.36
4	78.17	0.73	59.36	23.98
5	75.50	0.71	57.99	22.07
6	73.40	0.75	56.84	21.88
7	72.26	0.92	56.25	21.38
8	71.49	0.94	55.84	21.01
9	70.97	0.99	55.55	20.77
10	70.62	1.03	55.37	20.60

Given that the DFI eliminates the part of relative fluctuations caused by temporary disturbing factors from the price fluctuations of many commodities and extracts trend fluctuation, it can be also interpreted as a kind of core inflation index. If the DFI has the characteristics of trend inflation, it is expected to be effectively used to predict consumer prices in the future. If the current CPI growth rate is lower than that of the DFI, which shows inflationary pressure arising from temporary factors, inflation will increase above its current level and is highly likely to converge on the trend level in the future.

In order to examine this likelihood, we estimate an error correction model, which can analyse the long-run equilibrium relationship between DFI and CPI inflation. According to the analysis, even if we change the lag value of the error correction model, the error correction coefficient (γ) appears significant. Even though there appears a disparity between CPI inflation and DFI inflation in the short run, the DFI containing housing price information can be used as a long-term trend for CPI inflation, which is underpinned by the finding that the CPI inflation converges with DFI inflation in the long run.

$$\Delta\pi_t = \sum_{i=1}^{k} \alpha_j \Delta\pi_{t-i} + \sum_{i=1}^{k} \zeta_j \Delta DFI_{t-i} + \gamma(\pi_{t-1} - DFI_{t-1}) + \varepsilon_t \qquad (5)$$

[12] The lag of the VAR model is set as 3 according to the AIC criterion. Therefore, even if the lag is changed, the result will not differ substantially.

Table 8

Estimation result of error correction coefficient (γ)

LAG (k)	Estimate	Standard error	LAG (k)	Estimate	Standard error
1	–0.931**	0.300	2	–0.869**	0.282
3	–1.093**	0.340	4	–1.064**	0.383

III. Conclusion

The Bank of Korea changed the target indicator for its inflation targeting system from core inflation to headline CPI in 2007, and this has encouraged a variety of studies on the measurement of core inflation. This paper is a summary of two recent research papers.

The first subject deals with the measurement of core inflation by the trimmed mean method and the exclusion-based method, reflecting the characteristics of cross-sectional distribution of Korea's consumer price increases. The trimmed mean method excludes both extremes of the cross-sectional distribution asymmetrically, taking into account the fact that the distribution is fat-tailed and right-skewed. Findings on the exclusion-based method show that official indicators announced by the Korean National Statistical Office are still useful, and that the excluded items were very often located at the both extremes of the cross-sectional distribution. The second subject considers the computation of a dynamic factor index (DFI) containing asset prices, in which housing prices are added into the CPI in Korea as an eclectic method that can take into account price stability and asset price fluctuations at the same time.

Measures of core inflation by the trimmed mean method and exclusion-based method can be evaluated to determine their usefulness from the criteria of deviations from the trend and predictive ability. The evaluation shows that trimmed mean core inflation has relative superiority in ability to track the underlying trend of inflation over exclusion-based core inflation. In predictability, there are no meaningful differences. It should, however, be taken into account that exclusion-based core inflation is comparatively superior in the sense of being readily understood by economic agents and possessing transparency. According to the above analysis, the indicators from each method seem to have their own particular usefulness.

As for the DFI, the study reveals that it can be used as an information variable. This is because it not only contains useful information for predicting CPI inflation, but also itself plays the role of a long-term trend of CPI inflation. Recent researchers suggest that central banks should adopt policies that are adaptable to the specific market conditions of each country because the effectiveness of monetary policy's response to asset price fluctuations could depend on the characteristics of macroeconomic conditions and the housing and financial markets country by country.[13] With regard to the response of monetary policy to

[13] The IMF pointed out in its World Economic Outlook (April 2008) that the monetary policy measures taken in response to rapid change in housing prices should be carried out depending on the degree of the development of the mortgage market. This is because, in the case of a country like the US where the mortgage market is well developed, the effects of monetary policy on housing prices and of housing prices on the business cycle are becoming greater.

asset price fluctuations, therefore, there is no clear consensus as yet. Since the experiences of policy effects differ from country to country and from model to model, it is essential to conduct a close examination and in-depth research of this continuously.

Appendix:
MLE estimation result of the DFI model

	Baseline model (includes housing and stock prices)	Model 2 (variance of trend = 1, includes housing and stock prices)	Model 3 (includes housing prices only)
Trend inflation (DFI)	$\pi_t = 0.4904 + 0.4724\pi_{t-1} + n_t$ (0.01422) (0.1396) $\sigma_n^2 = 0.4277$ (0.0444)	$\pi_t = 0.5505 + 0.4593\pi_{t-1} + n_t$ (0.2106) (0.1844) $\sigma_n^2 = 1(\mathit{fixed})$	$\pi_t = 0.4814 + 0.4812\pi_{t-1} + n_t$ (0.1406) (0.1379) $\sigma_n^2 = 0.4278$ (0.0444)
Long-run level (annual rate)	**0.93% (3.72%)**	**0.93% (3.74%)**	**0.93% (3.71%)**
		DFI configuration by item	
Food and non-alcoholic beverages	$x_{1,t} = 0.2232x_{1,t-1} + \xi_{1,t}$ (0.1100) $\sigma_{\xi 1}^2 = 1.4528$ (0.1143)	$x_{1,t} = 0.2180x_{1,t-1} + \xi_{1,t}$ (0.1105) $\sigma_{\xi 1}^2 = 1.4475$ (0.1145)	$x_{1,t} = 0.2233x_{1,t-1} + \xi_{1,t}$ (0.1101) $\sigma_{\xi 1}^2 = 1.4530$ (0.1144)
Alcoholic beverage and cigarettes	$x_{2,t} = -0.0275x_{2,t-1} + \xi_{2,t}$ (0.1070) $\sigma_{\xi 2}^2 = 2.1667$ (0.1685)	$x_{2,t} = -0.0153x_{2,t-1} + \xi_{2,t}$ (0.0000) $\sigma_{\xi 2}^2 = 2.1826$ (0.1700)	$x_{2,t} = -0.0268x_{2,t-1} + \xi_{2,t}$ (0.1142) $\sigma_{\xi 2}^2 = 2.1676$ (0.1686)
Clothing and footwear	$x_{3,t} = 0.5598x_{3,t-1} + \xi_{3,t}$ (0.0998) $\sigma_{\xi 3}^2 = 0.6995$ (0.0600)	$x_{3,t} = 0.5147x_{3,t-1} + \xi_{3,t}$ (0.1061) $\sigma_{\xi 3}^2 = 0.7382$ (0.0637)	$x_{3,t} = 0.5603x_{3,t-1} + \xi_{3,t}$ (0.0997) $\sigma_{\xi 3}^2 = 0.6996$ (0.0600)
Housing, water and fuels	$x_{4,t} = 0.1586x_{4,t-1} + \xi_{4,t}$ (0.1215) $\sigma_{\xi 4}^2 = 0.9028$ (0.0759)	$x_{4,t} = 0.1216x_{4,t-1} + \xi_{4,t}$ (0.1286) $\sigma_{\xi 4}^2 = 0.8562$ (0.0736)	$x_{4,t} = 0.1535x_{4,t-1} + \xi_{4,t}$ (0.1225) $\sigma_{\xi 4}^2 = 0.9019$ (0.0753)
Furnishings and household equipment	$x_{5,t} = 0.3118x_{5,t-1} + \xi_{5,t}$ (0.1254) $\sigma_{\xi 5}^2 = 0.7047$ (0.0606)	$x_{5,t} = 0.2961x_{5,t-1} + \xi_{5,t}$ (0.1350) $\sigma_{\xi 5}^2 = 0.7025$ (0.0620)	$x_{5,t} = 0.3120x_{5,t-1} + \xi_{5,t}$ (0.1255) $\sigma_{\xi 5}^2 = 0.7043$ (0.0605)
Healthcare	$x_{6,t} = 0.2735x_{6,t-1} + \xi_{6,t}$ (0.1085) $\sigma_{\xi 6}^2 = 1.1771$ (0.0933)	$x_{6,t} = 0.2653x_{6,t-1} + \xi_{6,t}$ (0.1095) $\sigma_{\xi 6}^2 = 1.1965$ (0.0958)	$x_{6,t} = 0.2736x_{6,t-1} + \xi_{6,t}$ (0.1085) $\sigma_{\xi 6}^2 = 1.1764$ (0.0937)
Transport	$x_{7,t} = 0.2030x_{7,t-1} + \xi_{7,t}$ (0.1116) $\sigma_{\xi 7}^2 = 1.6141$ (0.1270)	$x_{7,t} = 0.2032x_{7,t-1} + \xi_{7,t}$ (0.1131) $\sigma_{\xi 7}^2 = 1.5778$ (0.1248)	$x_{7,t} = 0.2018x_{7,t-1} + \xi_{7,t}$ (0.1118) $\sigma_{\xi 7}^2 = 1.6141$ (0.1270)

Notes:1) Figures in parentheses are standard deviations. 2) The long-run level is calculated by substituting L=1 into $\Pi = \frac{\delta}{(1-\Psi L)}$ and then multiplying by 4.

MLE estimation result of the DFI model (continued)

Item	Baseline model	Variance of trend = 1	Includes housing prices only
Communications	$x_{8,t} = 0.3532 x_{8,t-1} + \xi_{8,t}$ (0.1071) $\sigma^2_{\xi 8} = 2.2431$ (0.1741)	$x_{8,t} = 0.3629 x_{8,t-1} + \xi_{8,t}$ (0.1067) $\sigma^2_{\xi 8} = 2.2515$ (0.1749)	$x_{8,t} = 0.3532 x_{8,t-1} + \xi_{8,t}$ (0.1072) $\sigma^2_{\xi 8} = 2.2433$ (0.1741)
Culture and recreation	$x_{9,t} = 0.7754 x_{9,t-1} + \xi_{9,t}$ (0.0838) $\sigma^2_{\xi 9} = 0.4657$ (0.0490)	$x_{9,t} = 0.7678 x_{9,t-1} + \xi_{9,t}$ (0.0883) $\sigma^2_{\xi 9} = 0.4788$ (0.0563)	$x_{9,t} = 0.7743 x_{9,t-1} + \xi_{9,t}$ (0.0838) $\sigma^2_{\xi 9} = 0.4659$ (0.0489)
Education	$x_{10,t} = 0.7511 x_{10,t-1} + \xi_{10,t}$ (0.0741) $\sigma^2_{\xi 10} = 0.8139$ (0.0686)	$x_{10,t} = 0.7481 x_{10,t-1} + \xi_{10,t}$ (0.0754) $\sigma^2_{\xi 10} = 0.8157$ (0.0699)	$x_{10,t} = 0.7512 x_{10,t-1} + \xi_{10,t}$ (0.0741) $\sigma^2_{\xi 10} = 0.8141$ (0.0687)
Eating out and accommodation	$x_{11,t} = 0.6928 x_{11,t-1} + \xi_{11,t}$ (0.0824) $\sigma^2_{\xi 11} = 0.8822$ (0.0736)	$x_{11,t} = 0.6858 x_{11,t-1} + \xi_{11,t}$ (0.0849) $\sigma^2_{\xi 11} = 0.8495$ (0.0745)	$x_{11,t} = 0.6915 x_{11,t-1} + \xi_{11,t}$ (0.0826) $\sigma^2_{\xi 11} = 0.8828$ (0.0740)
Miscellaneous goods and services	$x_{12,t} = 0.1134 x_{12,t-1} + \xi_{12,t}$ (0.1175) $\sigma^2_{\xi 12} = 0.9551$ (0.0812)	$x_{12,t} = 0.1498 x_{12,t-1} + \xi_{12,t}$ (0.1215) $\sigma^2_{\xi 12} = 0.9202$ (0.0776)	$x_{12,t} = 0.1110 x_{12,t-1} + \xi_{12,t}$ (0.1179) $\sigma^2_{\xi 12} = 0.9549$ (0.0784)
Stock price	$x_{13,t} = 0.4428 x_{13,t-1} + \xi_{13,t}$ (0.1006) $\sigma^2_{\xi 13} = 12.1934$ (0.9356)	$x_{13,t} = 0.4477 x_{13,t-1} + \xi_{13,t}$ (0.1003) $\sigma^2_{\xi 13} = 12.1935$ (0.9356)	na
Housing price	$x_{14,t} = 0.6687 x_{14,t-1} + \xi_{14,t}$ (0.0784) $\sigma^2_{\xi 14} = 1.6568$ (0.1295)	$x_{14,t} = 0.6607 x_{14,t-1} + \xi_{14,t}$ (0.0794) $\sigma^2_{\xi 14} = 1.6844$ (0.1320)	$x_{14,t} = 0.6890 x_{14,t-1} + \xi_{14,t}$ (0.0784) $\sigma^2_{\xi 14} = 1.6569$ (0.1295)

Notes: 1) Figures in parentheses are standard deviations. 2) The time series (housing prices, stock indices, and CPI index by item) used in the analysis are data from 1986Q1–2007Q2, and are used after being seasonally adjusted.

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