Measures of trend inflation in Hong Kong

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I. Introduction

The search for an appropriate measure of inflation has been an important task for central banks around the world, particularly those with an inflation targeting framework. Given that the principal monetary policy objective of the Hong Kong Monetary Authority (HKMA) is to maintain exchange rate stability under the Linked Exchange Rate system, there is little room for conducting discretionary monetary policy in Hong Kong. Nevertheless, any significant changes in the trend movement in general prices have significant policy implications for Hong Kong, which should be closely monitored by policymakers. In particular, the trend price indicator provides useful information about the extent of macroeconomic and financial imbalances, which are important for guiding prudential supervisory policies.

Various measures have been used to gauge underlying inflationary pressures based on information extracted from different price indicators, of which the consumer price index (CPI) and the deflator of personal consumption expenditure (PCE) are the most commonly used. In general, there are two steps in constructing a measure of trend inflation. The first is to select a price index that is a good indicator of the general cost of living and is representative of price movement and demand pressure at the aggregate level. The next step is to strip out volatile price components, which are susceptible to transitory shocks that may distort the trend movement of general prices. Broadly speaking, there are two approaches to extracting the trend movements from price indices compiled by official bodies: the exclusion method and the statistical method. The exclusion method removes the price components that are mostly influenced by transitory supply shocks. The most commonly excluded items include fresh or unprocessed food, and energy. By contrast, the statistical method analyses the data property of the price index or its components to determine an optimal measure of trend movements of the price index. Various techniques, such as principal component, exponential smoothing and the Kalman filter have been adopted to arrive at a statistical measure of trend movements of prices.

This paper discusses various measures of trend inflation in Hong Kong. Section II searches for a representative price index that can be used to derive the trend rate of inflation. Section III compares and discusses the properties of trend inflation obtained from the exclusion and statistical methods. Section IV evaluates the performance of different measures of trend inflation. Section V concludes.

II. Comparison of different price indicators

There are a variety of price indices for measuring price movements. In terms of coverage, the GDP deflator may be the single most comprehensive price indicator. It is a price deflator of major expenditure components of GDP, and consists of the price deflator of domestic demand and terms of trade for goods and services. Chart 1 shows that the year-on-year growth rate of the GDP and domestic demand deflators have strongly converged over recent

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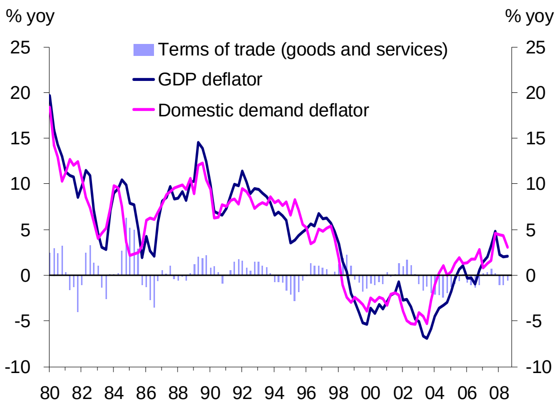
years, as domestic demand accounted for over 90% of GDP. Nevertheless, a significant shift in terms of trade could lead to large deviations in the growth rates of the two. For example, when the growth rate of the domestic demand deflator turned positive in the second half of 2004, the GDP deflator continued to register negative growth due to deterioration in terms of trade.

Chart 1

GDP deflator, domestic demand deflator and terms of trade

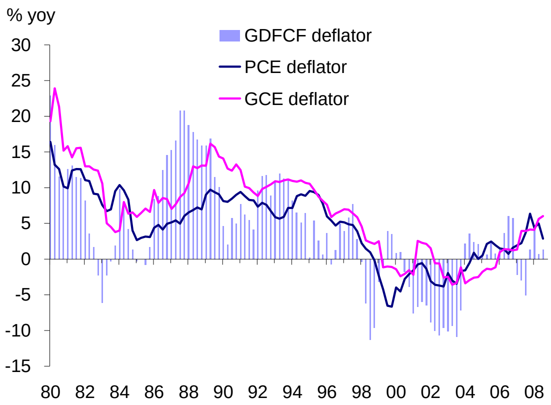


Sources: C&SD and staff estimates.

Since a large component of Hong Kong's trading activities is re-exports, the price movements of which have little implication for prices of retained imports or domestic price movements, fluctuations in terms of trade may compromise the use of GDP deflator as an indicator of trend movements of general price level. To remove the effect of terms of trade on the GDP deflator, we might use the price deflator of domestic demand as a measure of domestic inflation. In general, the domestic demand deflator can be disaggregated into three main components: personal consumption expenditure (PCE) deflator, gross domestic fixed capital formation (GDFCF) deflator, and the government consumption expenditure (GCE) deflator. Chart 2 shows the year-on-year growth rates of the three deflators. The price deflator of GDFCF has been the most volatile component of the three, as it captures movements in prices of machinery and equipment, construction costs, and volatile valuation gains or losses in changes of property ownership. It measures price pressures on capital inputs used in the early or intermediate stages of production. Meanwhile, the GCE price deflator measures prices of goods and services consumed by the government instead of the private sector. Consequently, these deflators are not directly related to price pressures at the end of the supply chain, which affect the general standard of living. The PCE deflator, which captures the price movement of goods and services consumed by households, is directly related to the general cost of living. It also serves as a good measure of overall domestic price pressures, given that private consumption accounts for two thirds of domestic demand (Chart 3). Overall, the PCE deflator is the price measure that has the desirable property of reflecting both the general cost of living and domestic demand pressures.

Chart 2

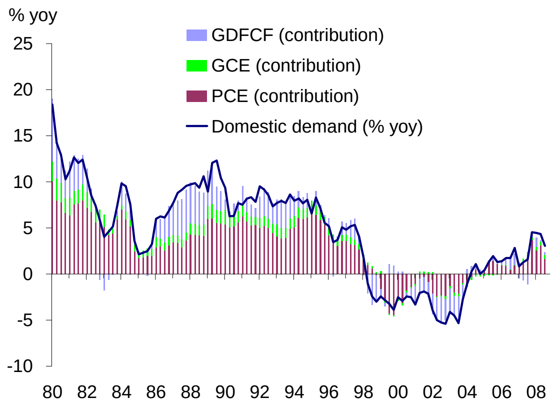
The price deflators of PCE, GDFCF and GCE



Sources: C&SD and staff estimates.

Chart 3

Contribution to changes in domestic demand deflator by component

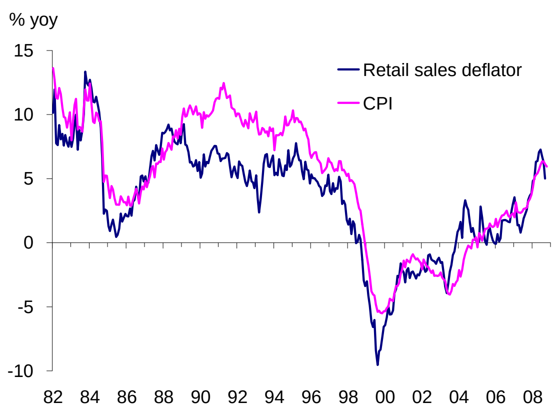


Sources: C&SD and staff estimates.

Other widely used indicators of domestic inflation that can reflect both the general cost of living and domestic demand pressures are the consumer price index (CPI) and the retail price index. CPI measures the price of a basket of goods and services consumed by a representative household, while the retail price index measures prices of goods sold at retail outlets. In Hong Kong, the retail price index is derived from the ratio of value and volume indices of retail sales, which is a price deflator of retail sales. Chart 4 shows that the CPI and the retail sales deflator have generally shown strong co-movement in the past.

Chart 4

Consumer price index and retail sales deflator



Sources: C&SD and staff estimates.

Despite the similarity of and close co-movement between the CPI and the retail sales deflator, they differ in terms of coverage and method of compilation. In terms of coverage, the retail sales deflator includes only tradable goods and excludes housing and other personal services, making it a narrower measure of the cost of living. In terms of compilation method, the CPI is constructed based on a basket of consumer goods and services with fixed weights, while the basket weights in the retail sales deflator vary over time. As a result, the CPI may overstate the growth rate of general consumer prices, while the retail sales deflator may understate it due to substitution effect. Judging from these differences, the CPI appears to be a better measure of consumer price inflation than the retail sales deflator.

The above discussion suggests that both the CPI and the PCE deflator could be representative measures of domestic price pressures, given their extensive coverage of price data on consumer goods and services. While both indices contain similar baskets of goods and services consumed by households, they differ in two major aspects. First, the weightings of goods and services are distributed differently in the CPI and the PCE deflator. Table 1 shows that tradable goods and housing have similar weights of 29% in the consumption basket of the CPI, while services account for 42%. The composition is quite different in the PCE deflator, with goods and services constituting 33% and 51%, respectively, of the consumption basket, while the weight of housing is the smallest, at about 16%. In other words, changes in housing rents will have greater impact on CPI inflation than PCE inflation. Apart from the difference in the composition of consumption weights, the PCE deflator includes financial services charges in its consumption basket, while the CPI excludes them. This subtle difference can be seen from a more volatile inflation rate calculated from the PCE deflator in recent quarters, when the domestic stock market and financial sector activities were exceptionally volatile (Chart 5). Despite these differences, the inflation rates calculated by the CPI and the PCE deflator have tended to converge, and have tracked closely the movements in the output gap, which is an indicator of demand pressures on the expenditure side of the economy.

Table 1

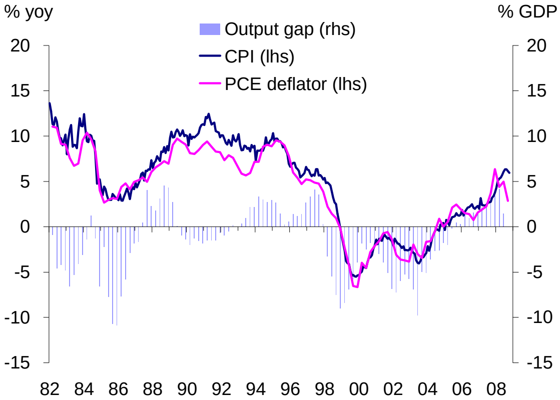
Composition of the consumption basket in the CPI and PCE deflator

(% weight)	Composite CPI	Chain-dollar PCE deflator
Tradable goods	29	33
Housing	29	16
Services ex-housing	42	51

Sources: C&SD and staff estimates.

Chart 5

Output gap and inflation rates calculated by the CPI and PCE deflator



Sources: C&SD and staff estimates.

III. Estimation of trend inflation in Hong Kong

Due to their desirable properties, the CPI and the PCE deflator are selected as inflation indicators for constructing measures of trend inflation in the first step. The next step is to extract the trend movement from the headline inflation rate calculated from the CPI and PCE deflator by stripping out transitory components. In general, there are two methods for estimating the trend rate of inflation based on the headline figures, namely the exclusion and statistical methods.

A. Exclusion method

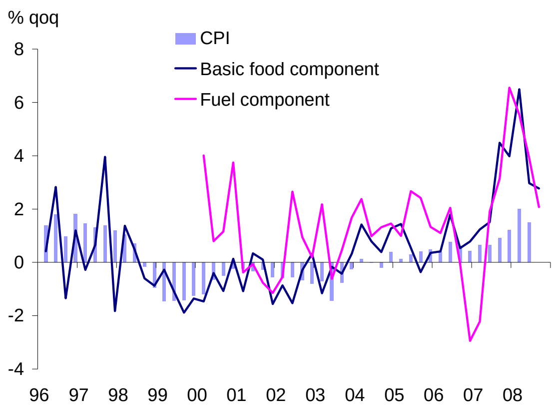
The exclusion method is widely used to extract information on the trend movement of the inflation rate calculated from the headline price index. The idea is to strip out those components that are most influenced by short-term price shocks. Commonly excluded items are basic or unprocessed food, and energy, the prices of which are volatile due to supply shocks. The inflation rate calculated based on this exclusion method is usually called the "core" measure of inflation, meaning that it captures the most representative movement of general prices and is free from distortions caused by short-term fluctuations in prices.

In practice, it may not be straightforward to decide which components should be excluded from the price index. While basic food and energy-related items are the most commonly excluded items in the construction of the core measure of inflation, a variety of exclusion criteria are used in different jurisdictions. For example, the preferred measure of core inflation in Japan is calculated by the CPI excluding fresh food. For developing Asian economies where fresh and unprocessed food accounts for a significant share of the consumption basket of households, excluding this item from the CPI may not be a good way to measure core inflation.

In Hong Kong, basic food and energy-related items such as electricity and motor fuel are excluded from the composite CPI in the estimation of the core CPI inflation rate. These two items account for roughly 15% of the CPI basket in Hong Kong, as compared to 21% in the CPI basket of the United States. The rationales for excluding these two components are twofold. First, basic food prices and energy costs have been the most volatile components in Hong Kong's CPI (Chart 6). Second, their prices are sensitive to changes in demand and supply conditions in the international market, which could be transitory and have limited lasting effect on overall costs and prices in the domestic market. Chart 7 compares the quarter-on-quarter rate of change of the headline and core CPIs. It shows that the core inflation rate tracks the headline inflation rate closely.

Chart 6

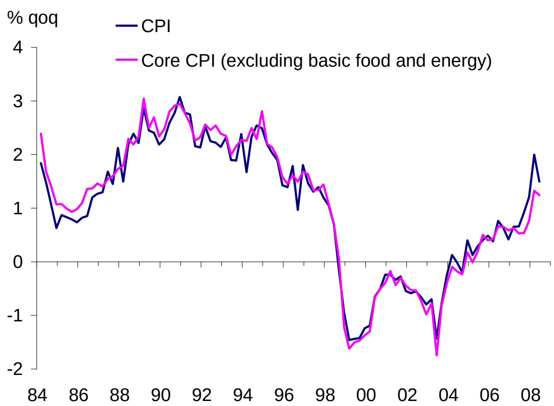
CPI inflation and the basic food and energy components



Sources: C&SD and staff estimates.

Chart 7

Headline vs core CPI inflation

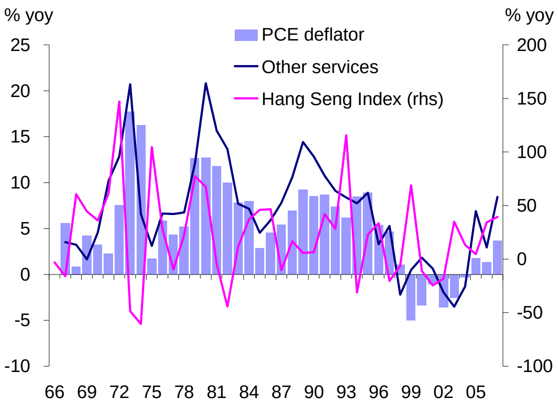


Sources: C&SD and staff estimates.

Based on the same rationale for the construction of the core measure of the CPI, basic food and energy-related items are excluded in the estimation of the core PCE deflator. Moreover, the PCE deflator includes the fees and charges of financial services in its consumption basket, which are pro-cyclical and highly volatile, so this component is also removed in the construction of the core measure of PCE deflator. Past developments show that the other services component (including financial services) of the PCE deflator is positively correlated with stock market performance, which has limited correlation with the general price movement (Chart 8). Thus, excluding financial service charges does not distort the underlying inflation of the PCE deflator. Chart 9 compares the quarter-on-quarter inflation rate of the headline and core PCE deflator. Similarly to core CPI inflation, core PCE inflation tracked the headline PCE inflation closely.

Chart 8

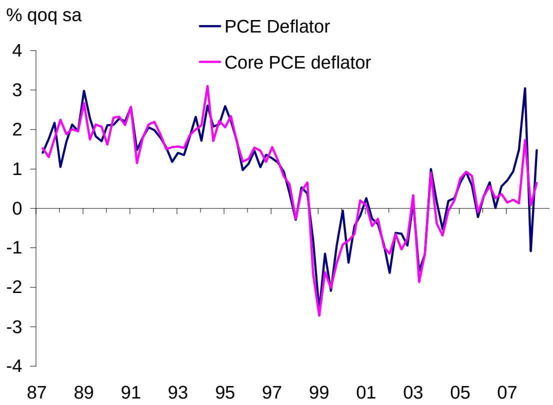
Other services component of the PCE deflator and stock price movement



Sources: C&SD and staff estimates.

Chart 9

Headline vs core PCE inflation



Sources: C&SD and staff estimates.

B. Statistical method

The exclusion method requires judgement on the price component to be excluded in the calculation of core inflation. Furthermore, to keep the core measure credible and consistent, it is preferable not to change the excluded items. These raise concerns about the objectivity and flexibility of the method in removing a variety of price shocks. One possible way of addressing these concerns is to use the statistical method, which estimates an optimal measure of trend inflation based on data properties of the price index.

A number of statistical methods have been explored to produce a trend measure of inflation. These include classical statistical methods such as the trimmed median or trimmed mean approach to identify and eliminate volatile items from the price index. Other statistical methods such as exponential smoothing make use of time-series properties of the price index to estimate the trend inflation from the headline figure. Alternatively, some data reduction methods such as principal component could be used to extract the common trend of movements in various price components embedded in the price index. To extract the most representative trend movement of the CPI and the PCE deflator, we use the principal component method to decompose the movements of headline inflation into a number of distinct trends, which are uncorrelated with each other. The trend that explains the largest part of the movements in various price components of the price index is used as our measure of trend inflation.[2] This estimate of trend inflation is then subject to various statistical tests to ascertain its data property.

Table 2 shows the weights of the price components of CPI and PCE deflator estimated by the principal component method. In comparison with the official basket weights, the weights estimated by the principal component method show that housing rents and the cost of eating out are the major items in the trend CPI inflation, while the weights of basic food, electricity and beverages are the smallest. This suggests that basic food and energy-related items explain little of the trend movement of CPI inflation estimated by the principal component method, which supports removing these items in the exclusion method. Similar results can

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[2] The technical note in Annex A explains the details on the estimation of trend inflation using the method of principal component.

be found in the weights of key items of the PCE deflator estimated by the principal component method.

Table 2

Weights estimated by the principal component method for the CPI and PCE deflator

	Official weight in CPI basket (%)	Weight based on the principal component method (%)
Alcoholic drinks and tobacco	0.87	2.18
Clothing and footwear	3.91	4.43
Durable goods	5.50	6.91
Electricity, gas and water	3.59	2.39
Basic food	10.08	3.26
Housing	29.17	36.72
Meals away from home	16.86	20.65
Miscellaneous goods	4.78	3.56
Miscellaneous services	16.15	10.74
Transport	9.09	9.15
Sum	100.00	100.00

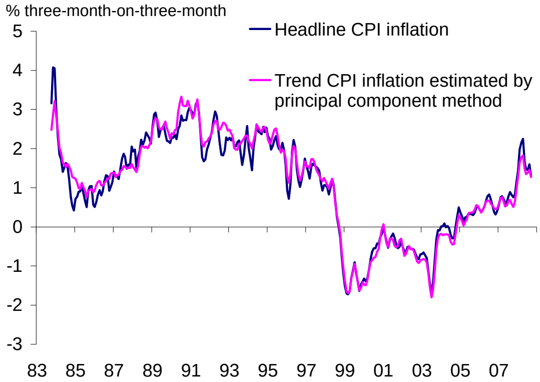
	Official weight in PCE deflator (%)	Weight based on the principal component method (%)
Alcoholic beverages	0.48	0.69
Clothing, footwear and other personal effects	12.00	9.73
Education	1.97	6.65
Food and non-alcoholic beverages	11.15	7.25
Fuel and light	1.70	0.84
Furniture, furnishing and household equipment	7.75	6.17
Household operation	1.88	11.15
Rent, rates, water and housing maintenance charges	15.70	11.97
Medical care and health expense	4.22	12.33
Other services	25.46	5.17
Personal care	2.31	8.15
Recreation and entertainment	6.34	6.81
Tobacco	0.46	2.14
Transport and communication	8.58	10.95
	100.00	100.00

Source: Staff estimates

The main advantage of the principal component method is that it helps identify the relative importance of different price components in driving the trend movement of the CPI/PCE deflator, based on the weights estimated by the principal component method. This is superior to other statistical methods such as the trimmed mean/median and exponential smoothing approaches in terms of transparency, information usage and analytical contents. Charts 10 and 11 compare trend inflation estimated by the principal component method and the headline CPI and PCE inflation respectively.

Chart 10

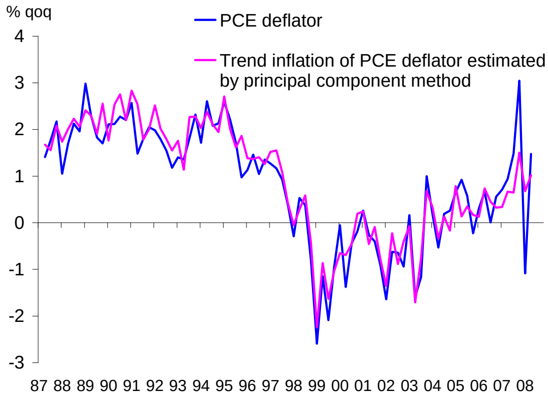
Headline vs trend CPI inflation estimated by the principal component method



Sources: C&SD and staff estimates.

Chart 11

Headline vs trend PCE inflation estimated by the principal component method



Sources: C&SD and staff estimates.

IV. Evaluation of different measures of trend inflation

To compare and evaluate trend inflation estimated by the exclusion and principal component methods for the CPI and PCE deflator, the following criteria are used to identify the strength and weakness of the two estimation methods:

- Transparency, consistency and simplicity of construction
- Information content on underlying inflationary pressures
- Co-integrating relationship between headline and trend inflation
- Forecast performance

Transparency, consistency and simplicity of construction

The exclusion method is more transparent and straightforward than the principal component method in the construction of the trend inflation rate. Given that the weights of individual price components are fixed in the CPI basket, one can easily calculate the core inflation rate by removing the effects of changes in basic food prices and fuel costs. It is also straightforward to construct the core PCE deflator by excluding the items of basic food, fuel and financial service charges from the value and volume measures of the PCE, which are published along with other national account statistics by official sources.

In terms of computational effort, it would be more demanding to estimate core inflation using the principal component method, which makes use of data on individual price items of the CPI and PCE deflator to estimate a set of weights that can help explain the largest part of variations of the headline figures. That said, with enhancement in computing resources, it is becoming less time-consuming to carry out principal component analysis. Our results also show that the weights estimated from the principal component method are remarkably stable over time when the sample size increases.

Data consistency is another consideration in the evaluation of the property of trend inflation estimated by the exclusion and principal component methods. With transitory shocks tapering off over time, the headline inflation rate tends to revert to its underlying trend. This suggests the long-term average of the trend measure should be close to that of the headline measure of inflation, while the volatility of the former is expected to be smaller than the latter. Table 3 compares the mean and the standard deviation of the first difference, a measure of volatility, of trend CPI and PCE inflation using the exclusion and principal component methods. It shows that trend inflation estimated by the principal component method performs better than the exclusion method in terms of reduction of volatility. In terms of similarity of mean, the principal component method performs better for the composite CPI, and the exclusion method performs better for the PCE deflator.

Table 3

Mean and standard deviation of headline and trend inflation

	Composite CPI (% 3m/3m)	**PCE deflator (% qoq)**
Mean	**1983Q4 - 2008Q3**	**1987Q2 - 2008Q2**
Headline inflation	1.054	0.824
Core inflation (exlusion method)	1.083	0.772
Trend inflation (principal component method)	1.074	0.917
Standard deviation of the first difference of inflation rate		
Headline inflation	0.240	0.884
Core inflation (exlusion method)	0.202	0.718
Trend inflation (principal component method)	0.169	0.606

Sources: C&SD and staff estimates.

Information content on underlying inflationary pressures

Both the exclusion and principal component methods make use of price data on individual items of the CPI and PCE deflator in the estimation of the trend inflation rate. By calculating the contribution of individual price items to changes in the trend measure of inflation, the key price factor driving the underlying inflation can be identified, which is an important piece of information for policy formulation. The merit of using the principal component method to estimate the trend inflation is that it retains all price items of the CPI and PCE deflator, while basic food, fuel and other volatile items are removed in the exclusion method. Since these excluded items may contain useful hints about the movements of underlying inflation, the trend information estimated by the exclusion method is less comprehensive than that estimated by the principal component method.

Co-integrating relationship between headline and trend inflation

One salient data property of trend inflation is that the headline inflation rate should converge with the trend inflation rate in the long run. This suggests that only noisy signals and temporary shocks should be stripped out from headline inflation in the estimation of the trend inflation rate. Testing the property of convergence is equivalent to testing the existence of a co-integration relationship between headline and trend inflation.

Empirical tests on co-integration are conducted on sequential movements of CPI/PCE deflator and their trend measures. CPI and PCE deflator data used in our empirical analysis are different in terms of data frequency and sample size. For the CPI, the sample consists of monthly data from October 1983 to September 2008, and the three-month-on-three-month percentage change is calculated to capture the sequential movements of CPI inflation and its trend measure.[3] For the PCE deflator, the sample consists of quarterly data from 1987Q1 to 2008Q2, and the quarter-on-quarter percentage change is calculated to measure inflation. All inflation rates are seasonally adjusted.

The test for co-integration involves two steps. The first is to test whether the headline and trend measures of CPI and PCE inflation are stationary. Augmented Dickey-Fuller tests and Zivot and Andrews unit root tests suggest that unit roots are present in the measures of inflation, including both headline and trend CPI and PCE inflation. This means that the inflation series are non-stationary.[4] The next step is to test the existence of a co-integration relationship between the headline and trend inflation. The following error-correction models are constructed to examine the co-integrating relationship between headline inflation (π_t) and trend inflation measures (π_t^{Trend}) of the CPI and PCE deflator.

$$\Delta\pi_t = \beta_1(\pi_{t-1} - \pi_{t-1}^{Trend}) + \text{lag terms for first difference of headline inflation} + \varepsilon_{1t}$$

$$\Delta\pi_t^{Trend} = \beta_2(\pi_{t-1} - \pi_{t-1}^{Trend}) + \text{lag terms for first difference of trend inflation} + \varepsilon_{2t}$$

Following the idea of Marques et al (2003), trend inflation should satisfy the following criteria:

1. The trend and headline inflation rates should evolve along the same path in the long run. Technically speaking, both trend inflation and headline inflation follow an I(1) process and are co-integrated with a unitary coefficient.

2. The headline inflation rate tends to converge with the trend inflation rate. This means that the adjustment coefficient of the error-correction term should be negative and statistically significant in the equation, with the first difference of headline inflation as the dependent variable.

3. The trend inflation rate should not converge with the headline inflation rate, suggesting that the trend measure is exogenous. This means the adjustment coefficient of the error-correction term should be statistically insignificant in the equation, with the first difference of trend inflation as the dependent variable.

Tables 4 and 5 summarise the results of the test of co-integration for headline and trend CPI and PCE inflation respectively. The adjustment coefficients on the error-correction terms in the equation of headline CPI/PCE inflation are negative and statistically significant, while those in the equation of core CPI/PCE inflation are statistically insignificant. These imply that the headline inflation rate tends to converge with the trend rate of inflation when the former deviates from the latter. Meanwhile, changes in trend CPI or PCE inflation do not depend on changes in headline inflation in the past, suggesting that trend inflation is exogenous. Overall, both measures of trend inflation satisfy convergence criteria 2 and 3 discussed above.

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[3] The one-off effects of relief measures introduced by the government are removed from the CPI.

[4] The results of unit root tests are summarised in Annex B.

Table 4

Error correction model for testing co-integrating relationship between headline and trend CPI inflation

	Core CPI inflation (excluding food and energy)		Trend CPI inflation estimated by the principal component method	
	Equation of headline inflation	**Equation of core inflation**	**Equation of headline inflation**	**Equation of trend inflation**
Dependent variable	$\Delta\pi_t$	$\Delta\pi_t^{Trend}$	$\Delta\pi_t$	$\Delta\pi_t^{Trend}$
Coefficient of $\pi_{t-1} - \pi_{t-1}^{Trend}$	–0.224	0.083	–0.324	–0.032
(Adjustment coefficient)	(–3.117)**	(1.679)	(–4.549)**	(–0.887)
Coefficient of $\Delta\pi_{t-1}$	0.514	–	0.526	–
	(6.721)**	–	(7.561)**	–
Coefficient of $\Delta\pi_{t-1}^{Trend}$	–	0.540	–	0.554
	–	(11.968)**	–	(11.590)**
Adjusted R-square ($\overline{R^2}$)	0.239	0.313	0.279	0.300

The t-statistics are in parentheses.

** indicates that the coefficient is statistically significant at the 5% level.

Source: Staff estimates.

Table 5

Error correction model for testing co-integrating relationship between the headline and trend PCE inflation

	Core PCE deflator (excluding basic food, energy and financial services)		Trend PCE deflator estimated by the principal component method	
	Equation of headline inflation	**Equation of core inflation**	**Equation of headline inflation**	**Equation of trend inflation**
Dependent variable	$\Delta\pi_t$	$\Delta\pi_t^{Trend}$	$\Delta\pi_t$	$\Delta\pi_t^{Trend}$
Coefficient of $\pi_{t-1} - \pi_{t-1}^{Trend}$	–0.820	0.162	–0.946	0.137
(Adjustment coefficient)	(–2.492)**	(0.819)	(–3.265)**	(0.794)
Coefficient of $\Delta\pi_{t-3}$	0.202	–	0.183	–
	(1.833)	–	(2.232)**	–
Coefficient of $\Delta\pi_{t-3}^{Trend}$	–	0.262	–	0.227
	–	(2.030)**	–	(2.212)**
Adjusted R-square ($\overline{R^2}$)	0.169	0.055	0.254	0.049

The t-statistics are in parentheses.

** indicates that the coefficient is statistically significant at the 5% level.

Source: Staff estimates.

Forecast performance

In addition to the data properties discussed in the previous section, a good measure of trend inflation should have the ability to forecast the near-term movement of consumer prices, which can be used to gauge inflation expectations. To compare the forecast performance of the trend inflation estimated by the exclusion and principal component methods for the CPI and PCE deflator, both within-sample and out-of-sample forecast tests are conducted.

Within-sample forecast ability of trend inflation

Following the method proposed by Clark (2001), Fan (2001), Cogley (2002) and Rich and Steindel (2005), the following regression is used to evaluate the within-sample forecast ability of the trend CPI and PCE inflation.

$$\pi_{t+h} - \pi_t = \alpha + \beta(\pi_t - \pi_t^{Trend}) + \varepsilon_{t+h} \tag{1}$$

Equation (1) suggests that the trend inflation (π_t^{Trend}) is useful for forecasting the headline inflation (π_t), given that its deviation of the headline inflation from the trend inflation will correct over the *h* period. This suggests that β is negative. The speed of correction depends on the size of β. The greater the absolute value of β, the faster the headline inflation reverts to its underlying trend over the *h* period.

Table 6

Estimation results of within-sample forecast ability (without the output gap as an independent variable)

	CPI		PCE deflator	
	Core CPI inflation (exclusion method)	**Trend CPI inflation (principal component method)**	**Core PCE inflation (exclusion method)**	**Trend PCE inflation (principal component method)**
	h = 3		*h* = 1	
β	–0.550	–0.714	–0.854	–1.023
	(–2.081)**	(–3.591)**	(–2.722)**	(–3.597)**
$\overline{R^2}$	0.051	0.109	0.145	0.242
	h = 6		*h* = 2	
β	–0.430	–0.586	–0.497	–0.825
	(–1.310)	(–1.747)*	(–1.870)*	(–4.438)**
$\overline{R^2}$	0.021	0.047	0.033	0.118
	h = 12		*h* = 4	
β	–0.257	–0.429	–0.453	–0.786
	(–0.624)	(–0.804)	(–1.436)	(–3.567)**
$\overline{R^2}$	0.001	0.012	0.011	0.060

The t-statistics are in parentheses.

* and ** indicate that the coefficient is statistically significant at 10% and 5% levels.

The standard errors are calculated using the Newey-West method.

Source: Staff estimates

As suggested by Cogley (2002) and Rich and Steindel (2005), indicator of demand pressure or other macroeconomic valuables can be added to equation (1) to test the within-sample forecast ability of the estimated trend measure of inflation. To test whether changes in headline inflation respond to changes in demand pressure, the change in the output gap (x_t) is included in equation (1) to evaluate the prediction performance of the estimated trend inflation.

$$\pi_{t+h} - \pi_t = \alpha + \beta(\pi_t - \pi_t^{Trend}) + \gamma \Delta x_t + \varepsilon_{t+h} \quad (2)$$

For trend CPI inflation, the *h* period is set to 3, 6 and 12 for monthly data. For the trend PCE inflation, the *h* period is set to 1, 2 and 4 for quarterly data. Tables 6 and 7 summarise the estimation results of equations (1) and (2).

Table 7

Estimation results of within-sample forecast ability (with the output gap as an independent variable)

	CPI		**PCE deflator**	
	Core CPI inflation (exclusion method)	**Trend CPI inflation (principal component method)**	**Core PCE inflation (exclusion method)**	**Trend PCE inflation (principal component method)**
	h = 3		*h* = 1	
β	–0.425	–0.784	–0.906	–1.012
	(–1.973)**	(–4.248)**	(–2.935)**	(–3.607)**
γ	0.211	0.243	0.213	0.187
	(2.880)**	(3.475)**	(4.027)**	(3.863)**
$\overline{R^2}$	0.077	0.179	0.241	0.315
	h = 6		*h* = 2	
β	–0.395	–0.686	–0.536	–0.827
	(–1.096)	(–2.079)**	(–1.966)*	(–4.281)**
γ	0.264	0.293	0.115	0.101
	(2.132)**	(2.401)**	(1.678)*	(1.475)
$\overline{R^2}$	0.066	0.113	0.051	0.130
	h = 12		*h* = 4	
β	–0.347	–0.578	–0.529	–0.765
	(–0.765)	(–1.097)	(–1.716)*	(–3.596)**
γ	0.415	0.446	0.238	0.224
	(1.992)**	(2.174)**	(2.399)**	(2.212)**
$\overline{R^2}$	0.081	0.102	0.105	0.142

The t-statistics are in parentheses.

* and ** indicate that the coefficient is statistically significant at the 10% and 5% level.

The standard errors are calculated using the Newey-West method.

Source: Staff estimates

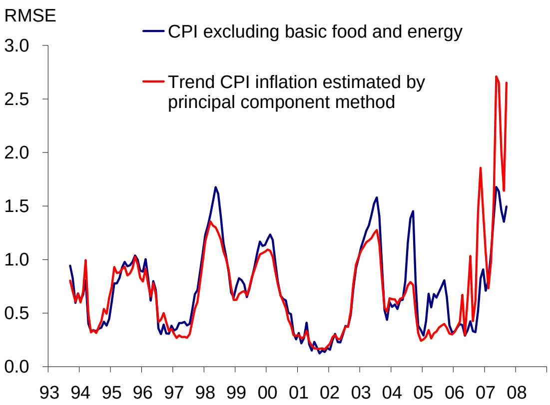
The regression results in Table 6 (without the output gap as an independent variable) show that the trend CPI inflation estimated by the principal component method better forecasts future change in headline CPI inflation, as indicated by the more significant estimated coefficient (β) and a larger adjusted R^2 over different *h* periods. A similar conclusion holds for the trend PCE inflation, suggesting that trend inflation estimated by the principal component method performs better in predicting future changes in headline inflation for both CPI and PCE deflator. After adding the change in output gap as an independent variable, the regression results again show that the trend CPI /PCE inflation estimated by the principal component method has better forecast performance than that estimated by the exclusion method. Overall, the trend CPI and PCE inflation rates estimated by the principal component method outperform the exclusion method in forecasting future changes in headline inflation in within-sample tests.

Out-of-sample forecast ability of trend inflation

In addition to the within-sample test of forecasting ability, an out-of-sample test is used to compare the forecast performance of different measures of trend inflation. Using a rolling window of 10 years of observations, recursive regressions are estimated based on the model specification in equation (1) with the *h* period set to one. A series of forecast error of headline inflation over a forecasting horizon of one year is computed for different measures of trend inflation.[5] The out-of-sample forecast ability of the trend inflation calculated from the exclusion and principal component methods can be evaluated based on the root-mean-square error (RMSE) estimated from the rolling regression.[6] The decision rule is that the smaller the RMSE, the stronger the forecast ability of the trend inflation measure.

Chart 12

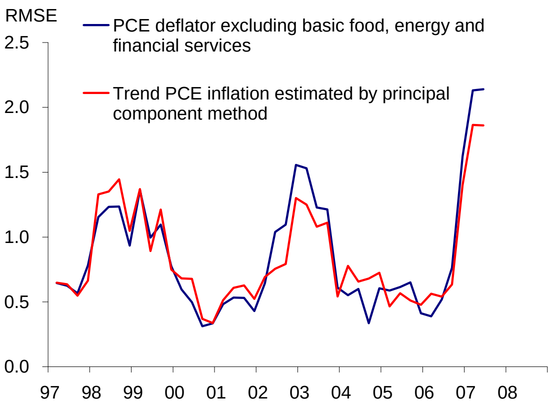
Out-of-sample forecast ability of the trend CPI inflation: RMSE plot[7]



Source: Staff estimates.

Chart 13

Out-of-sample forecast ability of the trend PCE inflation: RMSE plot



Source: Staff estimates.

Charts 12 and 13 plot the series of out-of-sample RMSE estimated from the rolling regression. Overall, the out-of-sample RMSE of forecasting the headline inflation using the trend inflation estimated by the principal component method do not have absolute advantage over the exclusion method. For the composite CPI, using the trend inflation estimated by the principal component method to perform out-of-sample forecasts yields a lower RMSE for the period from July 1997 to April 2003, but yields higher RMSE for the periods from September 1993 to June 1997 and from May 2003 to September 2008 (Table 8). In particular, the

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5 The dynamic forecast in this exercise is an ex post forecast, in that future exogenous variables of trend inflation are known.

6 Root mean square error (RMSE) is defined as $\sqrt{\frac{\sum_{t=1}^{T}(\pi_t - \hat{\pi}_t)^2}{T}}$, where π_t and $\hat{\pi}_t$ are the actual and forecast value of trend inflation, respectively.

7 For the CPI, the quarterly base is adopted such that the root mean square error is multiplied by $\sqrt{3}$ to align with the scale of the PCE deflator.

forecasting performance of the CPI trend inflation estimated by the principal component method has been worse in recent years, as shown by distinctly high RMSE in the recent period (Chart 12). Although the principal component method yields lower RMSE in the overall testing period, the results suggest that the out-of-sample forecasting performance varies in different periods. On the other hand, trend PCE inflation estimated by the principal component method outperforms the exclusion method in out-of-sample forecasting, with the principal component method yielding smaller average RMSE than the exclusion method for the whole sample period and the sub-periods (Table 9). Overall, trend inflation estimated by the principal component method outperforms the exclusion method in the within-sample forecast test, but does not consistently outperform in the out-of-sample forecast test.

Table 8

Average RMSE for forecasting the headline CPI inflation

	CPI			
Method	**All**	**Sep 1993 - Jun 1997**	**Jul 1997 - Apr 2003**	**May 2003 - Sep 2008**
Excluding food and energy	0.718	0.619	0.734	0.785
Principal component	0.712	0.620	0.683	0.830

Table 9

Average RMSE for forecasting the headline PCE inflation

	PCE deflator		
Method	**All**	**Q1 1997 - Q2 2003**	**Q3 2003 - Q2 2008**
Excluding food, energy and finance	0.856	0.855	0.859
Principal component	0.845	0.850	0.836

The evaluation results of various measures of trend inflation using different selection criteria are summarised in Table 10. In terms of the qualitative criteria such as simplicity and information content, core measures of CPI and PCE inflation estimated by the exclusion method are more familiar to the public, and their information content is also high. In terms of quantitative selection criteria, the trend inflation rates calculated from both the exclusion and principal component methods pass the co-integration test, with headline inflation converging with the trend measures in the long run. The trend inflation rates estimated by the exclusion and principal component methods have relatively strong forecast ability for future changes in headline inflation, which is consistent with their co-integrating property. Based on the forecasting results from the within-sample and out-of-sample tests, neither the principal component nor the exclusion method has clear advantage over the other, although there is some evidence to suggest that trend PCE inflation estimated by the principal component method has had stronger within and out-of-sample predictive ability for changes in headline PCE inflation in recent periods.

Table 10

Evaluation of various measures of trend inflation based on different selection criteria

	CPI		PCE deflator	
	Core CPI inflation (exclusion method)	**Trend CPI inflation (principal component method)**	**Core PCE inflation (exclusion method)**	**Trend PCE inflation (principal component method)**
Transparency and simplicity	High	Medium	High	Medium
Information content	High	Very high	High	Very high
Co-integrating relationship and error-correction model[8]	Headline inflation converges with core inflation but not vice versa Adjustment coefficient of headline inflation equation = –0.533	Headline inflation converges wit core inflation but not vice versa Adjustment coefficient of headline inflation equation = –0.691	Headline inflation converges with trend inflation but not vice versa Adjustment coefficient of headline inflation equation = –0.820	Headline inflation converges with trend inflation but not vice versa Adjustment coefficient of headline inflation equation = –0.946
Within-sample forecast ability	Principal component approach dominates the exclusion-based measure in terms of size and significance of coefficient and R-square statistics.		Principal component approach dominates the exclusion-based measure in terms of size and significance of coefficient and R-square statistics.	
Out-of-sample forecast ability	Principal component approach has stronger out-of-sample forecast ability in the overall period, but does not consistently outperform in sub-periods.		Weaker out-of-sample forecast ability Average RMSE = 0.856	Stronger out-of-sample forecast ability Average RMSE = 0.845

V. Conclusions

This paper reviews different price indicators for measuring domestic inflation in Hong Kong. As indicators of prices of consumer goods and services, the CPI and PCE deflator are found to be representative measures of the cost of living and domestic price pressures. Trend measure of CPI and PCE inflation can be obtained by removing the effects of volatile price components from them. Both the exclusion and statistical methods are used to construct measures of trend inflation to gauge the underlying inflationary pressures. To estimate core inflation using the exclusion method, basic food and energy-related items are removed from the CPI, while similar items and financial services are removed from the PCE deflator. These two core measures of inflation are compared with the trend CPI and PCE inflation estimated

8 The adjustment coefficients of the headline CPI inflation equations are converted to quarterly basis for comparison purpose.

by the principal component method, which statistically finds a linear combination of individual price items that explains most of the movements in general prices.

Evaluation results based on qualitative and quantitative criteria suggests that the trend CPI and PCE inflation estimated by the exclusion and principal component methods have their own strengths and weaknesses, and neither of the methods has clear absolute advantage over the other for measuring trend inflation.

Annex A:
Technical note on principal component analysis

This annex describes and illustrates the procedure of using the principal component method to estimate trend CPI and PCE inflation.

Methodology

Principal components are a linear transformation of multivariate data into a few uncorrelated components that explain most of the variations of the underlying variables. In technical terms, the linear combination of the underlying variables represents the eigenvector estimated from the variance-covariance matrix of the data. The value corresponding to the eigenvector is the eigenvalue, which represents the portion of total variations of the data explained by the principal component formed by the eigenvector. Usually, the first principal component explains most of the variations of the data, followed by the second and the third ones. It should be noted that if there are p variables, only k principal components are needed to largely explain or represent the variation of the data, where k is less than p. In view of this property, the first principal component that explains most of the movements in headline inflation is used as the measure of trend inflation.

To perform principal component analysis, the sample mean is subtracted from the inflation rates of individual items of the price index and the result is divided by the sample standard deviation for standardisation. This eliminates the distortion caused by differences in measurement units. The standardised data can be represented by:

$$z_{it} = \frac{\pi_{it} - \overline{\pi}_i}{s_i}$$

where z_{it} is the standardised inflation rate with zero mean and unit standard deviation for item *i* in the consumption basket of the CPI or PCE deflator in period *t*. π_{it} denotes the inflation rate for item *i* in period *t*. $\overline{\pi}_i$ denotes the sample mean for the inflation rate of item *i*. s_i denotes the standard deviation for the inflation rate of item *i*.

An alternative but similar measure is to use the standard deviation of the first difference of the underlying data as the denominator, which eliminates the problem of non-stationarity in the data. This is crucial since variance of non-stationary time series is time dependent. We follow Machado et al (2001) in using the sample standard deviation calculated from the first difference of π_{it} as the denominator, ie

$$z^*_{it} = \frac{\pi_{it} - \overline{\pi}_i}{s_{\Delta i}}$$

z^*_{it} is the adjusted standardised inflation rate for item *i* in period *t* and $s_{\Delta i}$ is the adjusted standard deviation calculated from the first difference of π_{it} .

The weights used to construct the first principal component (ω^*) maximise the overall variance of the data subject to the normalised vector constraint,[9] ie

maximise $Var(\omega Z) = \omega' S \omega$ subject to $\omega' \omega = 1$

with ω^* maximising the above problem.

Z is the standardised multivariate inflation rate of the constituent items of the CPI or PCE deflator. *S* is the variance-covariance matrix of *Z*.

In technical terms, ω^* is the eigenvector of the variance-covariance matrix *S* with the corresponding eigenvalue that maximises the variance of the dataset *Z*. The eigenvalue indicates the portion of total variance of Z, which is explained by the linear combination of the constituent items of the CPI or PCE deflator based on the estimated eigenvector.

The weights of the first principal component are normalised to sum to one, as illustrated in Table 2 of the main text. The normalised weights are then assigned to the inflation rate of constituent items in the consumption basket to calculate trend inflation. That is,

$\pi_t^{Trend} = \sum_{i=1}^{n} \omega_i^* \pi_{it}$ with ω_i^* representing the elements inside the normalised ω^*.

To update the trend inflation with new data on the CPI or PCE deflator, the above procedure is repeated with the latest inflation data incorporated to obtain a new estimate of the principal component. In this study, the weights of the first principal component are volatile in early periods due to limited sample size, but as more data are included in the sample the weights become largely stable in recent periods.

Illustration

Throughout our principal component analysis, we adopt the adjusted standard deviation to standardise the inflation rate of constituent items of the CPI or PCE deflator. The sample runs from October 1983 to September 2008 for CPI inflation, and from Q2 1987 to Q2 2008 for PCE inflation. To update the estimated trend inflation rate of the CPI and PCE deflator, we repeat the estimation procedure of the principal components when the dataset expands.

For illustration purposes, the estimation method of the latest trend inflation rate of the CPI and PCE deflator are summarised below.

The principal components estimated based on time series data on the constituent items of the CPI are shown in Table A1. It shows the weight distribution of the constituent items of the CPI for the first five principal components, which are derived from the eigenvectors of the variance-covariance matrix of the dataset by normalising the elements of the eigenvector to sum to one.

[9] Other principal components (*i*th principal component) are calculated by solving the above problem with orthogonal restrictions such that the *i*th principal component is not correlated to the 1st, 2nd, … (*i*-1)th principal components. The maximum number of principal components equals the number of variables in the dataset. In most cases, a few principal components are sufficient to explain the variations of the underlying data. See Johnson and Wichern (2007) for further details.

Table A1

Weight distribution of the first five principal components of the CPI

September 2008

Variables	PC 1	PC 2	PC 3	PC 4	PC 5
Alcoholic drinks and tobacco	0.022	0.071	0.065	–0.290	0.134
Clothing and footwear	0.044	0.005	0.326	0.258	–0.548
Durable goods	0.069	0.161	0.674	0.098	0.275
Electricity, gas and water	0.024	0.123	–0.264	0.889	0.973
Basic food	0.033	0.065	0.021	0.229	–0.697
Housing	0.367	–0.474	–0.063	0.049	0.017
Meals away from home	0.207	0.556	–0.330	–0.085	–0.984
Miscellaneous goods	0.036	0.111	0.378	0.386	–0.412
Miscellaneous services	0.107	0.150	0.202	–0.366	0.518
Transport	0.092	0.230	–0.009	–0.166	1.725

The corresponding explanatory power of the principal components, which are the eigenvalues calculated from the weight distributions in Table A1, are shown in Table A2. It shows that the first principal component explains about 77% (the third column in Table A2) of the total variations of the constituent items of the CPI based on a sample from October 1983 to September 2008. This is in contrast to the second principal component, which explains only 9% of total variations of the data.

Table A2

Eigenvalues for and proportion of variance explained by principal components of the CPI

Sum of eigenvalues = 156.127, average of eigenvalues = 15.613					
Order of principal component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative value**	**Cumulative proportion**
1	120.529	106.547	0.772	120.529	0.772
2	13.982	8.166	0.090	134.511	0.862
3	5.817	2.080	0.037	140.328	0.899
4	3.737	0.672	0.024	144.065	0.923
5	3.066	0.708	0.020	147.131	0.942
6	2.357	0.149	0.015	149.488	0.958
7	2.208	0.424	0.014	151.696	0.972
8	1.784	0.244	0.011	153.481	0.983
9	1.540	0.433	0.010	155.021	0.993
10	1.107	---	0.007	156.127	1.000

The weight distribution of the first principal component (first column in Table A1) is assigned to the inflation rate of the constituent items of the CPI to obtain the estimated trend CPI inflation. The three-month-on-three-month trend inflation rate in September 2008 is estimated to be 1.28% using the principal component method, compared to 1.16% estimated using the exclusion method for the same period.

For the PCE deflator, the weight distribution of the first five principal components are summarised in Table A3. Table A4 shows that the first principal component explains about 52% of total variations of the constituent items of the PCE deflator based on a sample from Q2 1987 to Q2 2008.

Table A3

Weight distribution of the first five principal components for the PCE deflator

Second quarter of 2008

Variables	PC 1	PC 2	PC 3	PC 4	PC 5
Alcoholic beverages	0.007	–2.189	1.068	0.114	0.391
Clothing, footwear and other personal effects	0.097	8.864	1.755	–0.718	0.070
Education	0.066	–2.010	–2.112	–0.133	–0.166
Food and non-alcoholic beverages	0.072	5.716	–0.708	0.619	0.005
Fuel and light	0.008	1.337	1.044	0.532	0.009
Furniture, furnishing and household equipment	0.062	1.794	–2.200	–0.038	–0.380
Household operation	0.111	–3.749	–0.038	–0.249	0.139
Rent, rates, water and housing maintenance charges	0.120	–1.813	2.865	0.467	–0.820
Medical care and health expense	0.123	-3.656	–1.701	–0.284	–0.104
Other services	0.052	-1.302	0.700	0.567	0.324
Personal care	0.082	-2.368	0.996	–0.406	0.121
Recreation and entertainment	0.068	–1.672	2.498	–0.050	0.569
Tobacco	0.021	0.164	–0.803	0.208	0.425
Transport and communication	0.110	1.883	–2.365	0.370	0.416

Table A4

Eigenvalues for and proportion of variance explained by principal components of the PCE deflator

Sum of eigenvalues = 12.910, average of eigenvalues = 0.922)					
Order of principal component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative value**	**Cumulative proportion**
1	6.677	5.822	0.517	6.677	0.517
2	0.855	0.103	0.066	7.532	0.583
3	0.752	0.060	0.058	8.283	0.642
4	0.692	0.032	0.054	8.976	0.695
5	0.660	0.027	0.051	9.636	0.746
6	0.633	0.095	0.049	10.269	0.795
7	0.538	0.086	0.042	10.807	0.837
8	0.452	0.101	0.035	11.258	0.872
9	0.350	0.027	0.027	11.609	0.899
10	0.323	0.039	0.025	11.932	0.924
11	0.284	0.021	0.022	12.217	0.946
12	0.263	0.043	0.020	12.480	0.967
13	0.220	0.010	0.017	12.700	0.984
14	0.210	---	0.016	12.910	1.000

Similarly, the weight distribution of the first principal component is assigned to the inflation rate of the constituent items of the PCE deflator to estimate the trend PCE inflation. The quarter-on-quarter trend inflation rate in the second quarter of 2008 is estimated to be 1.06% using the principal component method, compared to 0.64% estimated using the exclusion method for the same period.

Annex B:
Results of unit root tests on inflation series

Augmented Dickey-Fuller unit root tests

The augmented Dickey-Fuller (ADF) unit root tests are carried out on various inflation measures. The results do not reject the presence of unit roots in the inflation measures.

Table A5

ADF test on various inflation measures

Hypothesis: the series has a unit root.

Intercept and trend are not included in the test equation.

CPI

	P-value	No. of lags
CCPI adjusted by one-off measures	0.1268	0
CCPI (adjusted) excluding food and energy	0.1655	0
Trend inflation estimated by principal component	0.1679	0

PCE deflator

	P-value	No. of lags
PCE deflator	0.0589	1
PCE deflator excluding food, energy and finance	0.0764	1
Trend inflation estimated by principal component	0.1433	1

Unit root test with structural break

To consider the possibility of a structural break, Zivot and Andrews (1992) unit root test is conducted to test the null hypothesis of the presence of unit root against the alternative hypothesis of trend stationary process with an unknown one-time break point. The testing equation is constructed as follows:

$$y_t = \hat{\theta} I(\hat{\lambda}) + \hat{\mu} + \hat{\beta} t + \hat{\alpha} y_{t-1} + \hat{e}_t$$

$I(\lambda) = 1$ if $t > T\lambda$ with λ representing the location of the break point in terms of proportion and *T* representing the length of the sample period.

The equation considers the one-time break point in the parallel level of the series. Since the break point is unknown, this is determined by choosing a minimum t-statistic for testing $\hat{\alpha} = 1$ across the set of possible break points throughout the series. The corresponding t-statistic is then compared to the asymptotic significance level. If the t-statistic is less than the asymptotic significance level, the null hypothesis of the presence of the unit root is rejected. Results of unit root tests are given below.

Table A6

Zivot and Andrews (1992) test on various inflation measures

	t-statistics	No. of lags	Date of structural break
Headline CCPI	–4.404	4	Jun.98
Core CPI excluding food and energy	–4.602	4	Jan.98
Trend CPI estimated by principal component	–4.267	4	May.97
Headline PCE deflator	–3.138	2	Q4 2003
Core PCE deflator excluding food, energy and financial services	–3.175	2	Q3 1997
Trend PCE deflator estimated by principal component	–3.014	2	Q3 1997

Critical value (asymptotic):
intercept: 5%: –4.80
intercept: 1%: –5.43

The above results show that the null hypothesis of the presence of unit roots are not rejected for all the inflation series, since the t-statistics of the inflation measures are greater than the critical values with 5% significance level. Regarding the structural break, except for the headline PCE deflator, most of the possible structural breaks are located in the period of the Asian financial crisis.

References

Clark, Todd E (2001): "Comparing measures of core inflation", *Economic review*, Second Quarter, Federal Reserve Bank of Kansas City.

Cogley, Timothy (2002): "A simple adaptive measure of core inflation", *Journal of money, credit and banking*, vol 34, no 1, February.

Fan, Kelvin (2001): "Measures of core inflation in Hong Kong", *HKMA Research Memorandum*, October.

Johnson, Richard A. and Wichern, Dean W (2007): *Applied multivariate statistical analysis*, Pearson Prentice Hall, 6th edition.

Machado, Jose F, Marques, Carlos R, Neves, Pedro D and Da Silva, Alfonso G (2001): "Using the first principal component as a core inflation indicator", Banco de Portugal, WP 9-01, September.

Marques, Carlos R, Neves, Pedro D and Sarmento, Luis M (2003): "Evaluating core inflation indicators", *Economic modelling* 20, 765–75.

Rich, Robert and Steindel, Charles (2005): "A review of core inflation and an evaluation of its measures", Federal Reserve Bank of New York, *Staff report* no 236, December.

Zivot, Eric and Andrews, Donald WK (1992): "Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis", *Journal of business and economic statistics*, vol 10, no 3, July.