



MEASURES OF TREND INFLATION IN HONG KONG

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Abstract

The concept of trend inflation is crucial for macroeconomic analysis and policy formulation by central banks. In this paper, we compare measures of trend inflation in Hong Kong estimated by the exclusion and statistical methods. Our findings suggest that the trend inflation estimated by the exclusion method (by excluding basic food, energy and other volatile items) and the principal component technique have strong predictive power on future changes in headline CPI or PCE inflation. Evaluation results based on qualitative and quantitative criteria suggest that the two estimation methods have their own strengths and weaknesses, and none of the methods has clear absolute advantage over the other for measuring trend inflation.

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<p>The views and analysis expressed in this paper are those of the authors, and do not necessarily represent the views of the Hong Kong Monetary Authority.</p>

Executive Summary

- *Accurate measurement of inflation is crucial for macroeconomic analysis and policy formulation by central banks. Headline inflation rates calculated from official price indices are often distorted by volatile and transitory shocks, rendering assessment of the underlying inflationary pressure difficult. This paper constructs alternative measures of trend inflation and assesses their merits in gauging the underlying inflationary pressure.*
- *As the consumer price index (CPI) and personal consumption expenditure (PCE) deflator are most commonly used for measuring the general cost of living and demand pressures at the aggregate level, they form the basis for the construction of our measures of trend inflation. Two approaches are adopted to extract trend movements from the two price indices, namely the exclusion method and the statistical method. Under the exclusion method, the food and energy-related components are excluded from the composite CPI to arrive at the core CPI inflation, while for the PCE deflator, apart from food and energy, financial services are also excluded to obtain the core measure. Under the statistical method, the principal component technique is adopted to extract trend movements of prices from the composite CPI and PCE deflator.*
- *Tests for co-integrating relationship between the headline inflation rate and the trend inflation measures obtained from the two methods suggest that the headline inflation rate and the trend inflation measures are co-integrated with unitary coefficient. Short-run adjustment equations show that the headline inflation rate converges to the trend inflation measures but not vice versa, suggesting that both methods can successfully eliminate transitory shocks.*
- *Within-sample forecasting tests suggest that the trend inflation rate estimated by the principal component method outperforms the core inflation rate obtained from the exclusion method, while neither of the methods has absolute advantage over the other in out-of-sample forecasting tests.*
- *Overall, each method has its own merits. The exclusion method is more transparent and easier to implement than the statistical method, but is less comprehensive in terms of information content. Co-integration tests suggest that both methods can successfully eliminate transitory shocks and isolate the trend component, while within-sample and out-of-sample forecasting tests suggest that neither method has dominant forecasting power over the other.*

I. INTRODUCTION

The search for an appropriate measure of inflation has been an important task for central banks around the world, particularly for those with an inflation targeting framework. Given that the principal monetary policy objective of the 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, 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 step is to select an appropriate price index which is a good indicator of the general cost of living and is representative of the 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 extract the trend movements from price indices compiled by official bodies, namely the exclusion method and the statistical method. The exclusion method removes the price components which are mostly influenced by transitory supply shocks. The most commonly excluded items include fresh or unprocessed food and energy. In 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.

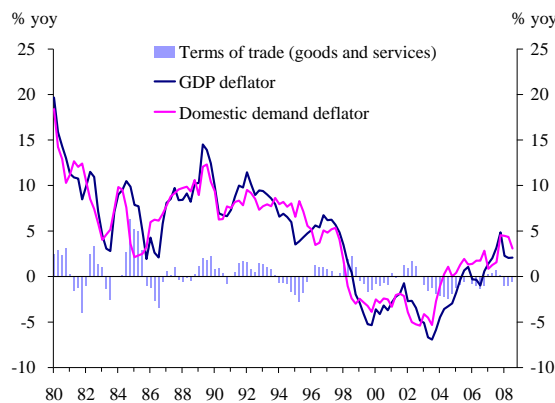
This paper discusses various measures of trend inflation in Hong Kong. Section II searches for a representative price index which can be used to derive the trend rate of inflation. Section III compares and discusses the properties of trend inflation obtained from the exclusion and

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, which 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 moved closely together over the past 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 rate 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 rate due to deterioration in terms of trade.

Chart 1: GDP deflator, domestic demand deflator and terms of trade

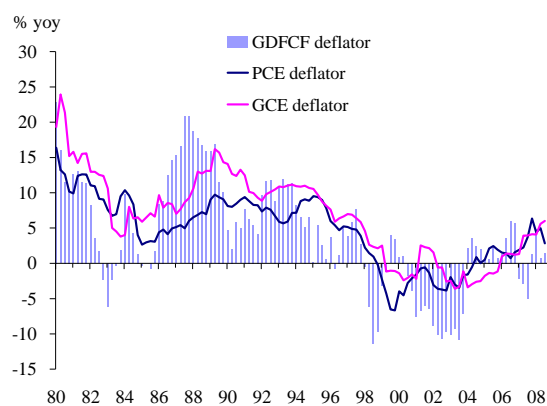


Sources: C&SD and staff estimates.

Since a large component of Hong Kong's trading activities is re-exports whose price movements have little implications 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, one may 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

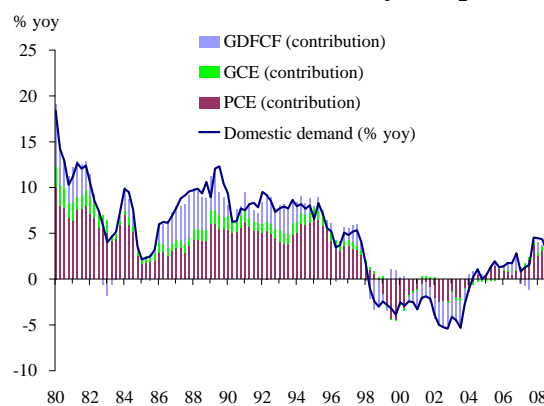
components, namely personal consumption expenditure (PCE) deflator, gross domestic fixed capital formation (GDFCF) deflator and the government consumption expenditure (GCE) deflator. Chart 2 shows the year-on-year growth rates of the three deflators. The price deflator of GDFCF has been the most volatile component among 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 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 that 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

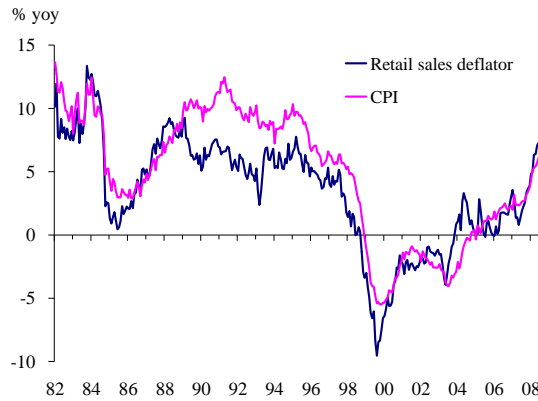


Sources: C&SD and staff estimates.

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 generally show 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 CPI and retail sales deflator, they are different 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 costs of living. In terms of compilation method, CPI is constructed based on a basket of consumer goods and services with fixed weights, while the basket weights in the retail sales deflator are time-varying. As a result, the CPI may overstate the growth rate of general consumer prices while the retail sales deflator may understate the growth rate 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 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 basket of goods and services consumed by households, they are different 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 CPI, while services account for 42%. The composition is quite different in the PCE deflator, with goods constituting 33% and services 51% of the consumption basket, while the weight of housing is the smallest, at about 16%. In other words,

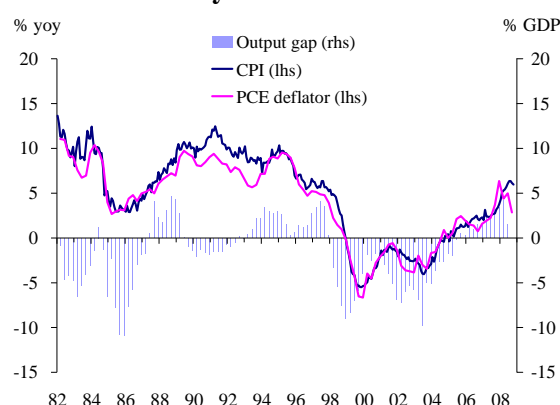
changes in housing rents will have a bigger impact on CPI inflation than on PCE inflation. Apart from the difference in the composition of consumption weights, the PCE deflator includes financial services charges in its consumption basket, while the CPI excludes them. This subtle difference can be seen in a more volatile inflation rate calculated from the PCE deflator in recent quarters when the domestic stock market and financial sector activities are exceptionally volatile (Chart 5). Despite these differences, the inflation rates calculated by CPI and PCE deflator tended to move together and 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 CPI and PCE deflator



Sources: C&SD and staff estimates.

III. ESTIMATION OF TREND INFLATION IN HONG KONG

With their desirable properties, the CPI and PCE deflator are selected to be the 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 to estimate the trend rate of inflation based on the headline figures, namely the exclusion and statistical methods.

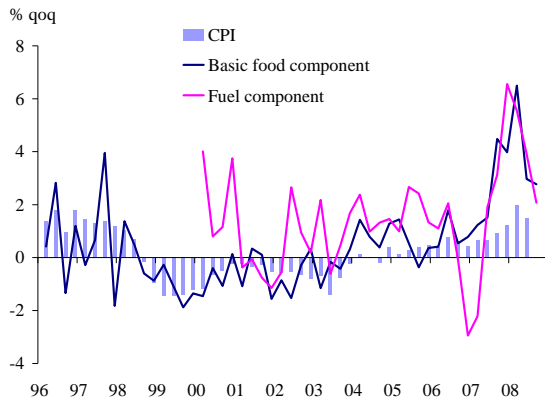
A. Exclusion method

The exclusion method is widely used to extract information on the trend movement of inflation rate calculated from the headline price index. The idea is to strip out those components which are most influenced by short-term price shocks. The commonly excluded items are basic or unprocessed food and energy, whose prices 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 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.

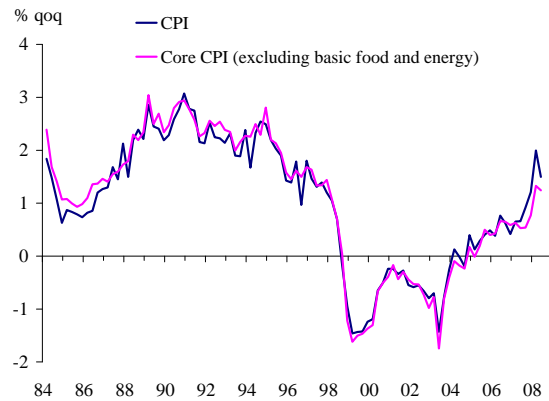
In Hong Kong, basic food and energy-related items such as electricity and motor fuel are excluded from the composite CPI in the estimation of the core CPI inflation rate. These two items account for roughly 15% of the CPI basket in Hong Kong compared with 21% in the US. The rationales for excluding these two components are twofold. First, basic food prices and energy costs have been the most volatile components in Hong Kong’s CPI (Chart 6). Secondly, 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 CPIs with the 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.

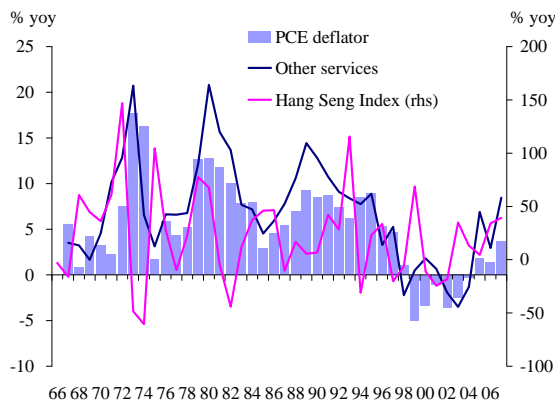
Chart 7: Headline vs core CPI inflation



Sources: C&SD and staff estimates.

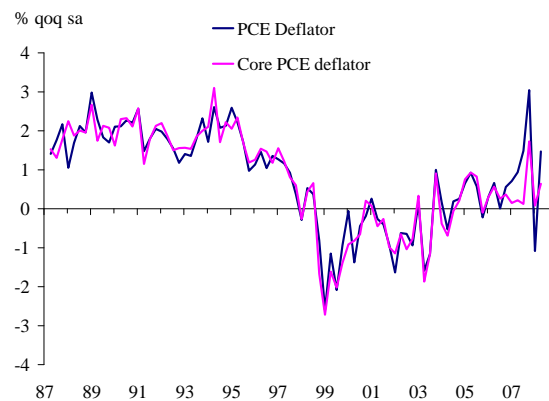
Based on the same rationale for the construction of the core measure of CPI, basic food and energy-related items are excluded in the estimation of core PCE deflator. Moreover, the PCE deflator includes the fees and charges of financial services in its consumption basket, which are pro-cyclical and highly 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 PCE deflator with the core PCE deflator. Similar to core CPI inflation, core PCE inflation tracked the headline PCE inflation closely.

Chart 8: Other services component of 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 to address these concerns is to use the statistical method, which estimates an optimal measure of trend inflation based on data property 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 trimmed median or trimmed mean approach to identify and eliminate volatile items from the price index.¹ Other statistical methods such as exponential smoothing make use of time-series property 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 CPI and 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.² The trend which explains the largest part of the movements in various price components of the price index is used as our measure of trend inflation.³ 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 to the official basket weights, the weights estimated by the principal component method show that housing rents and cost of dining 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 be found in the weights of key items of the PCE deflator estimated by the principal component method.

¹ See, for example, Fan (2001).

² Shu and Tsang (2004) also used the principal component method to compare measures of trend inflation for Mainland China.

³ The technical note in Annex A explains the details on the estimation of trend inflation using the method of principal component.

Table 2: Weights estimated by the principal component method for the CPI and PCE deflator

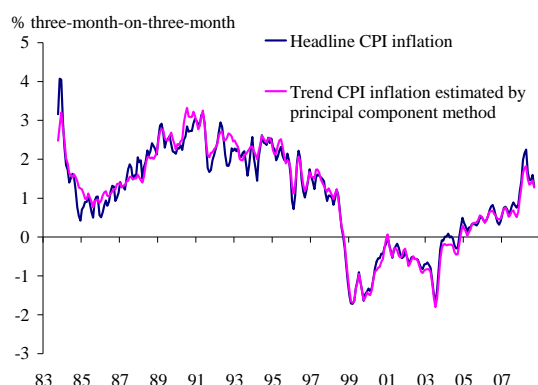
	Official weight in CPI basket (%)	Weight based on the principal component method (%)
Alcoholic drinks & tobacco	0.87	2.18
Clothing and footwear	3.91	4.43
Durable goods	5.50	6.91
Electricity, gas and water	3.59	2.39
Basic food	10.08	3.26
Housing	29.17	36.72
Meal away from home	16.86	20.65
Miscellaneous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

Source: Staff estimates

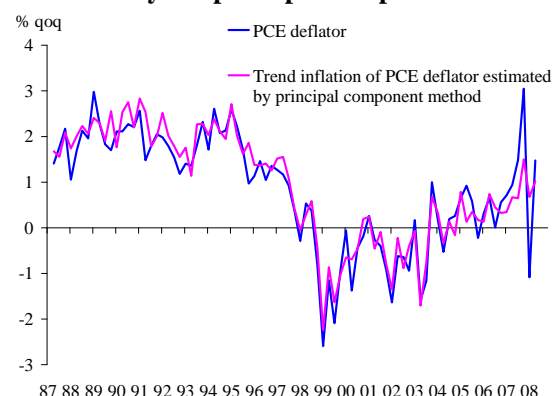
The main advantage of the principal component method is that it helps identify the relative importance of different price components in driving the trend movement of the CPI/PCE deflator, based on the weights estimated by the principal component method. This is superior to other statistical methods such as the trimmed mean/median and the exponential smoothing approaches in terms of transparency, information usage and analytical contents. Charts 10 and 11 compare the 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 the 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 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 the 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 which can help explain the largest part of variations of the headline figures. That said, with enhancement in computing resources, it becomes less time-consuming to carry out the 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 the trend CPI and PCE inflation using the exclusion and principal component methods. It shows that the 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 (exclusion 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 (exclusion 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 to 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. To test the property of convergence is equivalent to testing the existence of co-integration relationship between the 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.⁴ For the PCE deflator, the sample consists of quarterly data from 1987 Q1 to 2008 Q2, 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 step 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

⁴ The one-off effects of relief measures introduced by the Government are removed from the CPI.

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.⁵ The next step is to test the existence of 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 on 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 unitary coefficient.
2. The headline inflation rate tends to converge to 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 to 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 the 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 to 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.

⁵ 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 on $\pi_{t-1} - \pi_{t-1}^{Trend}$ (Adjustment coefficient)	-0.224 (-3.117)**	0.083 (1.679)	-0.324 (-4.549)**	-0.032 (-0.887)
Coefficient on $\Delta\pi_{t-1}$	0.514 (6.721)**	- -	0.526 (7.561)**	- -
Coefficient on $\Delta\pi_{t-1}^{Trend}$	- -	0.540 (11.968)**	- -	0.554 (11.590)**
Adjusted R-square ($\overline{R^2}$)	0.239	0.313	0.279	0.300

The t-statistics are in parentheses.

** indicates 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 on $\pi_{t-1} - \pi_{t-1}^{Trend}$ (Adjustment coefficient)	-0.820 (-2.492)**	0.162 (0.819)	-0.946 (-3.265)**	0.137 (0.794)
Coefficient on $\Delta\pi_{t-3}$	0.202 (1.833)	- -	0.183 (2.232)**	- -
Coefficient on $\Delta\pi_{t-3}^{Trend}$	- -	0.262 (2.030)**	- -	0.227 (2.212)**
Adjusted R-square ($\overline{R^2}$)	0.169	0.055	0.254	0.049

The t-statistics are in parentheses.

** indicates 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.

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

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 larger is the absolute value of β , the faster the headline inflation reverts to its underlying trend over the h period.

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 the 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 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 (-2.081)**	-0.714 (-3.591)**	-0.854 (-2.722)**	-1.023 (-3.597)**
$\overline{R^2}$	0.051	0.109	0.145	0.242
	$h = 6$		$h = 2$	
β	-0.430 (-1.310)	-0.586 (-1.747)*	-0.497 (-1.870)*	-0.825 (-4.438)**
$\overline{R^2}$	0.021	0.047	0.033	0.118
	$h = 12$		$h = 4$	
β	-0.257 (-0.624)	-0.429 (-0.804)	-0.453 (-1.436)	-0.786 (-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

**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 (-1.973)**	-0.784 (-4.248)**	-0.906 (-2.935)**	-1.012 (-3.607)**
γ	0.211 (2.880)**	0.243 (3.475)**	0.213 (4.027)**	0.187 (3.863)**
$\overline{R^2}$	0.077	0.179	0.241	0.315
	$h = 6$		$h = 2$	
β	-0.395 (-1.096)	-0.686 (-2.079)**	-0.536 (-1.966)*	-0.827 (-4.281)**
γ	0.264 (2.132)**	0.293 (2.401)**	0.115 (1.678)*	0.101 (1.475)
$\overline{R^2}$	0.066	0.113	0.051	0.130
	$h = 12$		$h = 4$	
β	-0.347 (-0.765)	-0.578 (-1.097)	-0.529 (-1.716)*	-0.765 (-3.596)**
γ	0.415 (1.992)**	0.446 (2.174)**	0.238 (2.399)**	0.224 (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

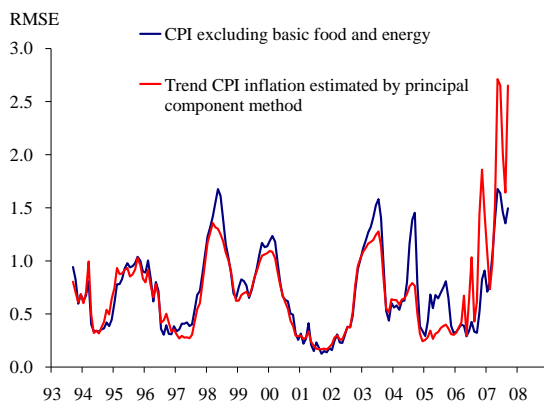
The regression results in Table 6 (without the output gap as an independent variable) show that the trend CPI inflation estimated by the principal component method better forecasts future change in headline CPI inflation, as indicated by the more significant estimated coefficient (β) and a larger adjusted R^2 over different h periods. Similar conclusion holds for the trend PCE inflation, suggesting that the 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

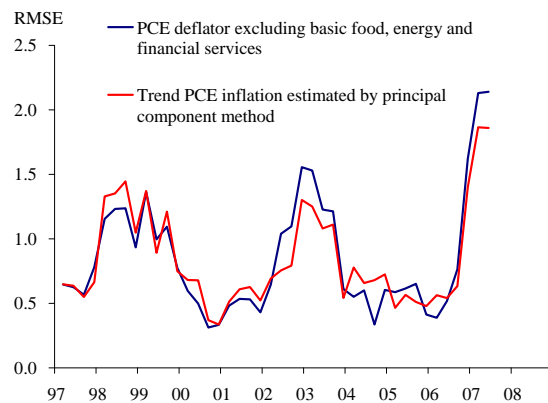
In addition to the within-sample test of forecasting ability, an out-of-sample test is used to compare the forecast performance of different measures of trend inflation. Using a rolling window of 10 years of observations, recursive regressions are estimated based on the model specification in Equation (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.⁶ 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.⁷ 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 plot⁸



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

⁶ The dynamic forecast in this exercise is an ex post forecast, in that future exogenous variables of trend inflation are known.

⁷ 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.

⁸ 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.

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 forecast performance of the CPI trend inflation estimated by the principal component method is 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, the 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

Method	CPI			
	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

Method	PCE deflator		
	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 by 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 the headline inflation converging to 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 each other, although there is some evidence to suggest that the trend PCE inflation estimated by the principal component method has stronger within and out of sample predictive ability of 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 ⁹	Headline inflation converges to core inflation but not vice versa Adjustment coefficient of headline inflation equation = -0.533	Headline inflation converges to core inflation but not vice versa Adjustment coefficient of headline inflation equation = -0.691	Headline inflation converges to trend inflation but not vice versa Adjustment coefficient of headline inflation equation = -0.820	Headline inflation converges to 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

⁹ The adjustment coefficients of the headline CPI inflation equations are converted to quarterly basis for comparison purposes.

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 the core inflation using the exclusion method, basic food and energy-related items are removed from the CPI, while similar items and financial services are taken out from the PCE deflator. These two core measures of inflation are compared with the trend CPI and PCE inflation estimated by the principal component method, which statistically finds out a linear combination of individual price items that explain 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 strength and weakness, and none 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 the trend CPI and PCE inflation.

Methodology

Principal components are linear transformation of multivariate data into a few uncorrelated components which 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 the principal component analysis, the inflation rates of individual items of the price index are subtracted by the sample mean and 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:

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

where z_{it} is the standardised inflation rate with zero mean and unit standard deviation for item i in the consumption basket of CPI or PCE deflator in period t . π_{it} denotes the inflation rate for item i in period t . $\bar{\pi}_i$ 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 due to data non-stationarity. This is crucial since variance of non-stationary time series is time dependent. We follow Machado et al (2001) to use the sample standard deviation calculated from the first difference of π_{it} as the denominator, that is

$$z_{it}^* = \frac{\pi_{it} - \bar{\pi}_i}{s_{\Delta i}}$$

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.¹⁰ i.e.

$$\begin{aligned} &\text{Maximise } \text{Var}(\omega Z) = \omega' S \omega \text{ subject to } \omega' \omega = 1 \\ &\text{with } \omega^* \text{ maximising the above problem.} \end{aligned}$$

Z is the standardised multivariate inflation rate of the constituent items of 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 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 the trend inflation. That is

¹⁰ Other principal components (i th principal component) are calculated by solving the above problem with the 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.

$$\pi_i^{Trend} = \sum_{i=1}^n \omega_i^* \pi_{it} \quad \text{with } \omega_i^* \text{ representing the elements inside the normalised } \omega^*.$$

To update the trend inflation with new data on 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 CPI or PCE deflator. The sample starts from October 1983 to September 2008 for CPI inflation, and from 1987 Q2 to 2008 Q2 for PCE inflation. To update the estimated trend inflation rate of 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 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 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.

Table A1: Weight distribution of the first five principal components for CPI September 2008

Variables	PC 1	PC 2	PC 3	PC 4	PC 5
Alcoholic drinks & 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
Meal 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 CPI based on a sample from October 1983 to September 2008. This is in contrast to the second principal component that explains only 9% of total variations of the data.

Table A2: Eigenvalues for and proportion of variance explained by principal components in 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 (the 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% by the principal component method, compared with 1.16% estimated by the exclusion method during 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 1987 Q.2 to 2008 Q2.

**Table A3: Weight distribution of the first five principal components for 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 with 0.64% estimated from the exclusion method during the same period.

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.

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

$I(\lambda) = 1$ 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 minimum t-statistic for testing $\alpha = 1$ across the set of possible break points throughout the series. The corresponding t-statistic is then compared with 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 shown 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 Asian financial crisis.

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