

Core Inflation and the Business Cycle

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We estimate various measures of core inflation which remove temporary disturbances from price indicators and examine their characteristics over the business cycle. In particular, we focus on some new measures of core inflation for Japan, the mode and weighted median inflation rates, which represent shifts in the price change distribution, as well as the CPI excluding fresh food and energy, which the Bank of Japan has recently focused on. Measures of core inflation that simply exclude volatile items closely follow the business cycle as measured by the output gap, while measures such as the mode and the weighted median are much more weakly linked to developments in the output gap.

Introduction

Monthly figures of the Consumer Price Index (CPI) are affected by various factors, and in the conduct of monetary policy, it is vital for the central bank to capture the underlying trend of inflation, which reflects changes in economic slack – as measured, for instance, by the output gap – as well as inflation expectations. In practice, this is done by obtaining estimates of underlying inflation that are designed to remove temporary disturbances in the data, and many of the major central banks have endeavored to calculate and release various types of "core" inflation measures (Chart 1).

This paper has three objectives. First, we estimate new measures of core inflation, the mode and weighted median inflation rates, which represent shifts in the price change distribution, to complement traditional measures such as the CPI excluding fresh food, the CPI excluding food and energy, the trimmed mean, and the CPI excluding fresh food and energy, which the Bank of Japan has recently focused on. Second, we examine the link between these core inflation measures and the business cycle by estimating various Phillips curves showing the relationship between these measures and the output gap. Lastly, based on our results, we review recent developments in inflation in Japan as well as the mechanisms underlying these developments.

"Core" Inflation Measures and Estimation Procedures

There are two main approaches to estimating measures of underlying or "core" inflation.¹

The first approach determines in advance which items in the price index are relatively volatile and excludes them to measure core inflation. The Bank of Japan has traditionally focused on the CPI excluding fresh food, but recent price swings in the oil market have led the Bank to pay more attention to the CPI excluding fresh food and energy and to release this measure via publications such as the "Monthly Report of Recent Economic and Financial Developments" and the "Outlook for Economic Activity and Prices." In the United States, it is traditionally all items excluding food and energy on which attention has focused, and this measure is also compiled in Japan, where it is released by the Ministry of Internal Affairs and Communications. However, it is worth noting some concerns associated with this type of measure. First, when too many items are excluded from the consumption basket, the resulting basket may no longer reflect households' expenditure patterns. Second, the decision regarding which items are excluded is purely an empirical issue in the sense that it is not clear which items to exclude a priori, and the decision is usually based on the structure of the economy or exogenous developments.

[Chart 1] Core Inflation Measures Used by Different Central Banks

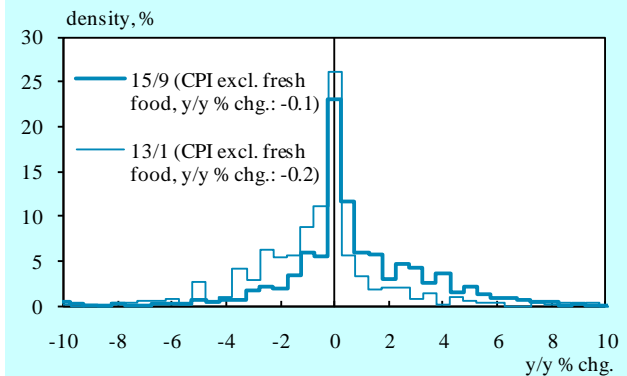
		BOJ	FRB ¹	ECB	BOE
Inflation measures for projections		Excl. fresh food	All items, Excl. food and energy	All items, Excl. energy, Excl. food and energy	All items
Monitored core inflation measures	Exclusion measures	Excl. fresh food Excl. fresh food and energy Excl. food and energy	Excl. food and energy	Excl. energy Excl. unprocessed food and energy Excl. food and energy etc.	Excl. food and energy Excl. food, energy, non-alcohol beverages etc.
	Measures from cross-sectional distributions	Trimmed mean Diffusion index (share of increasing items minus share of decreasing items)	Trimmed mean Weighted median Share of increasing and decreasing items etc.	Trimmed mean Weighted median Share of increasing items	Weighted median
	Others	-	-	Estimates from dynamic factor models	Volatility adjusted CPI

Note: 1. The measure for inflation projection in the U.S. is the PCE deflator. Estimates of the trimmed mean, weighted median, and the share of increasing and decreasing items are calculated by regional Federal Reserve Banks (Cleveland, Dallas, and San Francisco).

Source: Collated from materials published by the central banks.

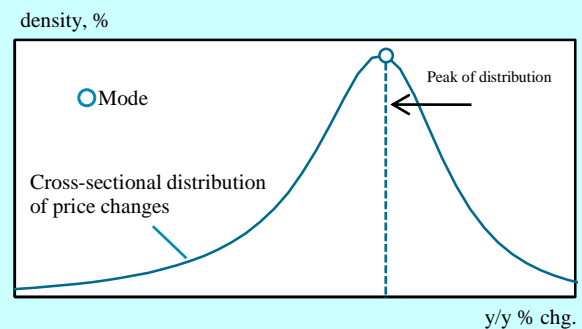
The second approach does not exclude volatile items in advance, but rather focuses on the cross-sectional distribution of price changes of items included in the price index and removes temporary disturbances based on a certain rule. To illustrate this, Chart 2 shows two histograms, where each shows the distribution of the annual rates of change in the 524 individual items in the CPI less fresh food.² Comparing the most recent distribution in September 2015 with that in January 2013, that is, prior to the introduction of the "Quantitative and Qualitative Monetary Easing Policy" in April 2013, the chart shows that the distribution has shifted somewhat to the right (i.e., in the direction of inflation). In order to quantitatively measure the degree of shift, one can calculate and observe developments in the mean of the distribution, as in the case of the CPI for all items. However, in times when, as a result of temporary factors, there is a large degree of skewness in the distribution, it becomes difficult to detect changes in underlying inflation, so that it is useful to employ additional measures such as the mode, the weighted median, and the trimmed mean (Charts 3 and 4). The mode is the inflation rate with the highest density in the distribution,³ while the weighted mean is the inflation rate obtained when arranging the rates of price change of individual items in descending order such that 50% of observations lie above and 50% below the value.⁴ The "trimmed mean" excludes outliers located in the upper and lower tails of the weighted price change distribution. The Bank of Japan has long released the "10% trimmed mean" in the publications mentioned above.⁵ It should be noted that the values obtained for these measures may differ depending on how exactly they are calculated – for

[Chart 2] Histogram of Price Changes

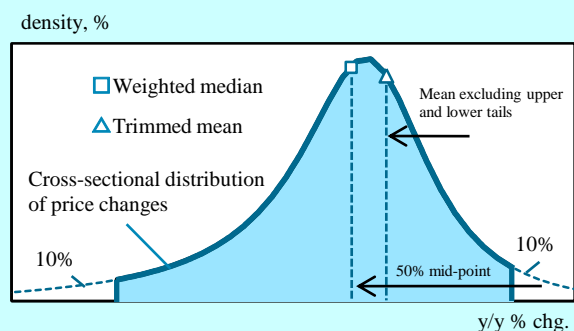


Source: Ministry of Internal Affairs and Communications, "Consumer Price Index."

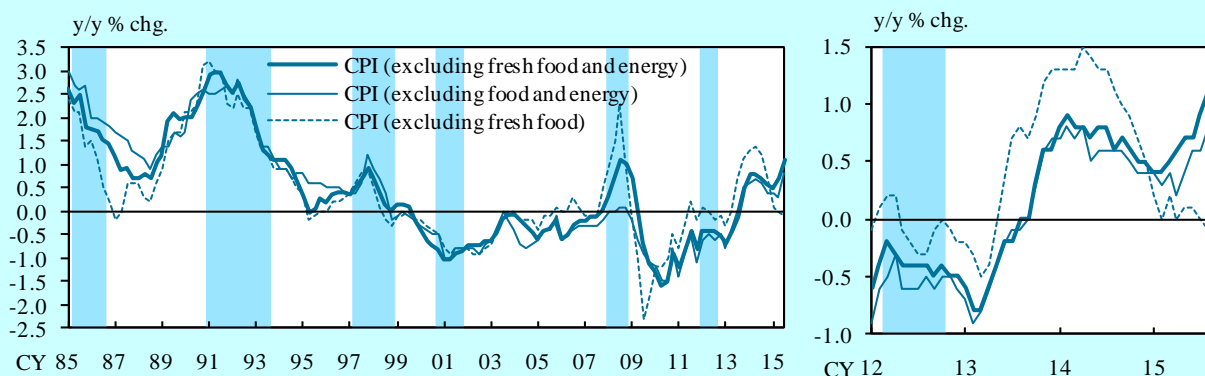
[Chart 3] Mode



[Chart 4] Weighted Median and Trimmed Mean

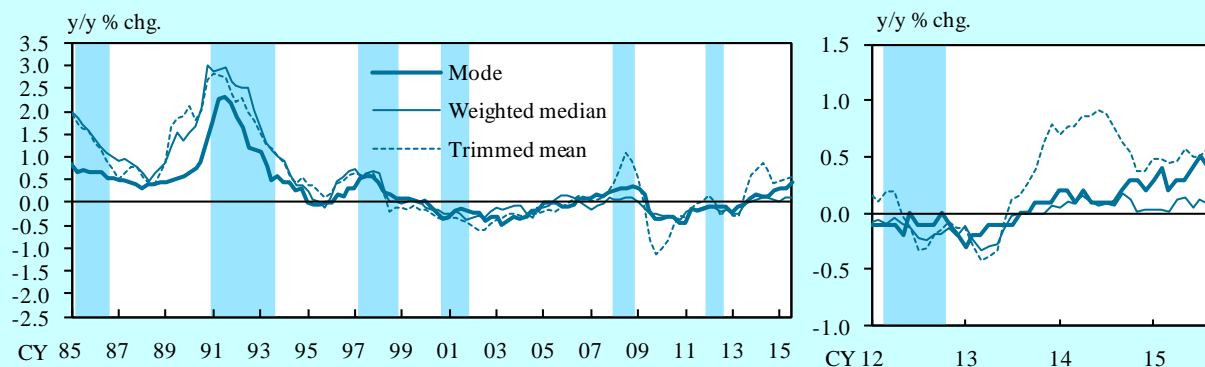


[Chart 5] Core Inflation Measures which Exclude Specific Items



Notes: 1. Figures for the CPI (excluding fresh food and energy) are calculated by the Research and Statistics Department, Bank of Japan. Figures are adjusted to exclude the estimated effect of changes in the consumption tax rate. The same applies to all charts below.
2. Shaded areas indicate recession periods.
Source: Ministry of Internal Affairs and Communications, "Consumer Price Index."

[Chart 6] Core Inflation Measures from Cross-Sectional Distribution of Price Changes



Notes: 1. Figures for the mode are from the estimated distribution.
2. The weighted median is calculated using the year-on-year price changes and weights of individual CPI items in each base year. For the period before 2005, the year-on-year price changes of minor groups and subgroups are used.
3. Shaded areas indicate recession periods.
Source: Ministry of Internal Affairs and Communications, "Consumer Price Index."

example, how the distribution is calculated when estimating the mode, how many items are included around the 50% point when calculating the weighted median,⁶ and how large the tails are for the trimmed mean.

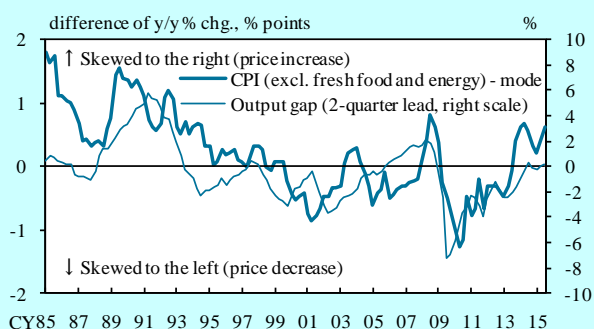
The next section examines whether and how the above measures of core inflation are linked to the business cycle, focusing in particular the CPI excluding fresh food and energy and the mode and the weighted median.

The Link between Core Inflation and the Business Cycle

Comparing developments in the CPI excluding fresh food and energy (Chart 5) and the mode and weighted median of price changes (Chart 6) shows that the former displays much larger fluctuations in response to the business cycle. Further, when we take the difference between the CPI excluding fresh food and energy and the mode (Chart 7), a clear positive

correlation with the output gap can be observed. This confirms that the CPI excluding fresh food and energy more closely follows the business cycle than the mode or the weighted median. This suggests that in periods of economic expansion, increases in the CPI excluding fresh food and energy tend to be mainly driven by an increased skewness in the price change distribution reflecting that some items are more susceptible to improvements in the output gap than others. On the other hand, as long as the number of these sensitive items is limited, the mode and the weighted median are hardly affected. In other words, these measures are less sensitive to the output gap, and it takes longer for the whole distribution to shift to the right. To examine this further, Chart 8 depicts the skewness of the price change distribution. The chart shows that there is a high correlation between the skewness and the output gap, indicating that the close link between the CPI excluding fresh food and energy and the business cycle is due not only to shifts in the price distribution but also to changes in the skewness.

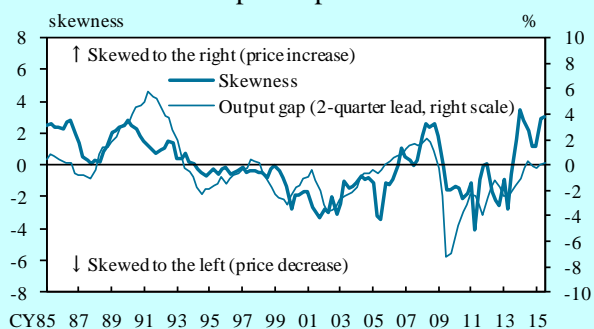
[Chart 7] Output Gap and the Difference between the CPI Excl. Fresh Food and Energy and the Mode



Notes: 1. Figures for the mode are from the estimated distribution.
2. Figures for the output gap are estimates by the Research and Statistics Department, Bank of Japan. The same applies to all charts below.

Sources: Ministry of Internal Affairs and Communications, "Consumer Price Index", Cabinet Office, "National Accounts," etc.

[Chart 8] Skewness of the Price Change Distribution and the Output Gap



Note: Figures for the skewness are from the estimated distribution.

Sources: Ministry of Internal Affairs and Communications, "Consumer Price Index"; Cabinet Office, "National Accounts," etc.

We investigate the link between the measures of core inflation and the business cycle further by estimating "hybrid" Phillips curves, which incorporate both backward- and forward-looking inflation expectations and the output gap. Backward-looking expectations capture inflation persistence associated with past realizations of inflation, while forward-looking expectations capture long-run inflation expectations, which tend to be tied to the central bank's inflation target. The estimation results are shown in Chart 9 and suggest that the CPI indicators excluding price-volatile items are more sensitive to changes in the output gap than the indicators representing shifts in the price change distribution. A closer look at the coefficients on the output gap (α) shows that the coefficient for the CPI excluding fresh food and energy is larger and more statistically significant than those for the mode or the weighted median.⁷ Furthermore, breaking down the

[Chart 9] Estimated Phillips Curves

CPI (y/y % chg.) = c (constant)
+ α \times output gap (2-quarter lag, %)
+ β \times mid- to long-term inflation expectations (6 to 10 years ahead, annual average, %)
+ $(1-\beta)$ \times own lagged value (4-quarter average, y/y % chg.)

CPI Inflation Measure	Weights	c	α	β	$1-\beta$	Adj. R ²
All items	10,000	-0.72***	0.17**	0.75***	0.25***	0.71
Excl. fresh food	9,604	-0.64***	0.15**	0.67***	0.33***	0.75
Excl. food and energy	6,828	-0.34***	0.06***	0.28***	0.72***	0.90
Excl. fresh food and energy	8,832	-0.38***	0.11***	0.37***	0.63***	0.87
Flexible price sector (All items excl. fresh food, energy, housing rents, public services)	5,707	-0.53***	0.17***	0.47***	0.53***	0.83
Housing rents	1,825	-0.14***	0.02	0.10***	0.90***	0.96
Public services, plus water charges	1,300	-0.29*	-0.01	0.33**	0.67**	0.32
Mode	—	-0.40*	0.04**	0.34**	0.66***	0.82
Weighted median	—	-0.30***	0.04	0.27**	0.73***	0.92
Trimmed mean	—	-0.48***	0.09***	0.49***	0.51***	0.88

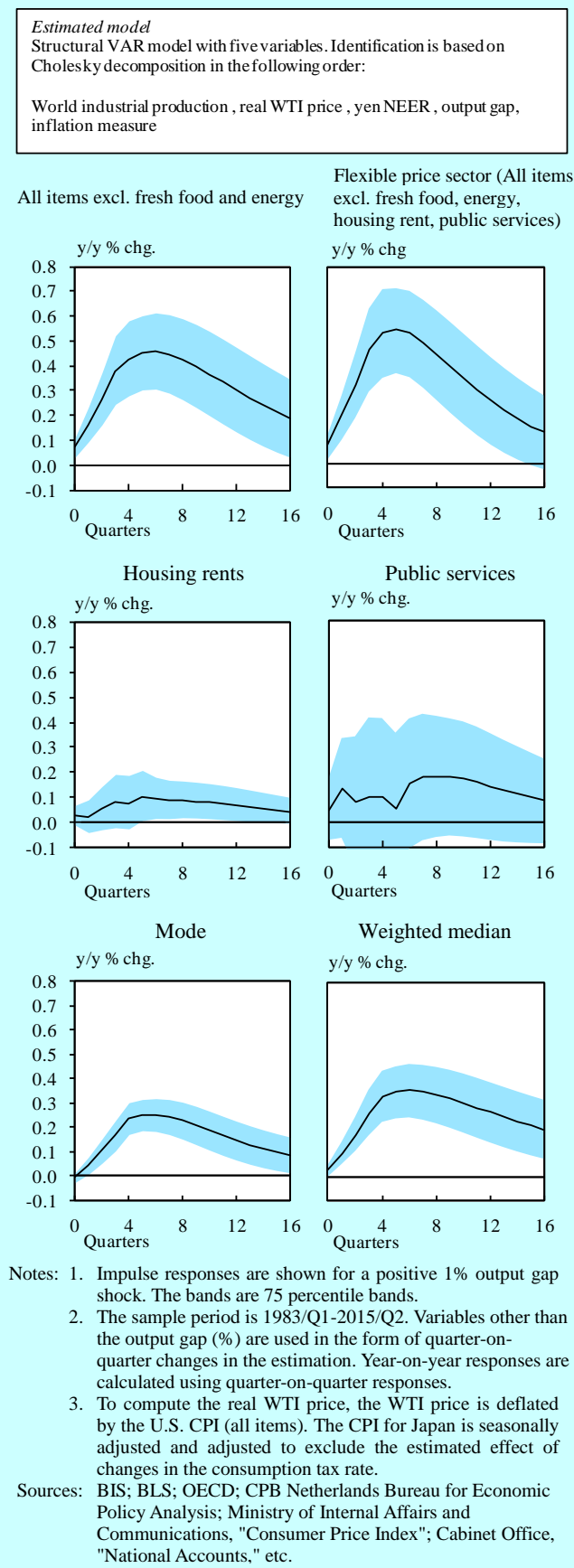
Notes: 1. Measures other than all items, Excl. fresh food, Excl. food and energy are calculated by the Research and Statistics Department, Bank of Japan.
2. The sample period is 1991/Q1-2015/Q2.
3. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

Sources: Ministry of Internal Affairs and Communications, "Consumer Price Index"; Cabinet Office, "National Accounts"; Consensus Economics Inc., "Consensus Forecasts." etc.

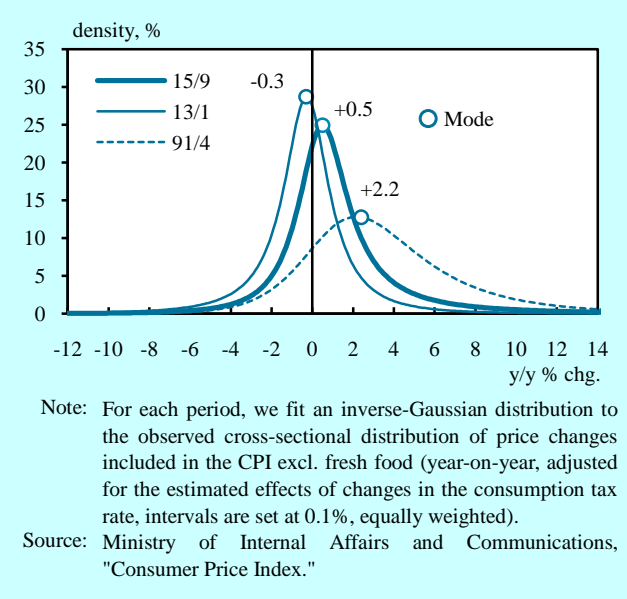
CPI excluding fresh food and energy into price indexes for three distinct categories, namely, housing rents, public services, and the flexible price sector (defined as the CPI excluding fresh food, energy, housing rents, and public services) we can see that the estimated α for the flexible price sector is much higher than those for housing rents and public services. Therefore, the close link between the CPI excluding fresh food and energy and the business cycle is brought about by price movements in the flexible price sector rather than in housing rents or prices for public services, which tend to be sticky.

These differences in sensitivity to the output gap are robust to other specifications that take changes in the exchange rate and oil prices as well as interdependence among variables and the lag structure into account. Specifically, we estimate a vector autoregression (VAR) model incorporating the following five variables: world industrial production, the real oil price (for which the price of West Texas

[Chart 10] Impulse Responses to Output Gap Shock



[Chart 11] Estimated Price Change Distribution

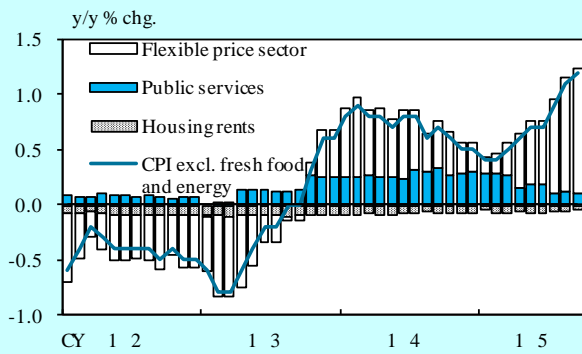


output gap and shows that the response of the CPI excluding fresh food and energy is clearly greater than that of the mode or the weighted median. Further, when the CPI excluding fresh food and energy is broken down as before, the price response in the flexible price sector to changes in the output gap is again far greater than in housing rents and public services.

Keeping the findings so far in mind, let us examine recent developments in the mode and the weighted median (Chart 6 above and Chart 11). The charts indicate that both are on the rise and the rate of increase currently is in the range of 0-0.5%, but the pace of increase is much slower than that in the CPI excluding fresh food and energy, which is currently rising at an annual rate of over 1.0%.⁸ It is likely that this difference among the core inflation measures is due to the differences in the way they respond to changes in the output gap discussed above. Indeed, when we break down recent developments in the CPI excluding fresh food and energy (Chart 12), the recent rise is primarily led by the flexible price sector, while housing rents continue to decline and the temporary rise in public service prices due to hikes in car insurance premiums and highway fees is dissipating. In other words, price increases in items that are more sensitive to the business cycle (mainly goods) have skewed the price change distribution to the right and have contributed to the recent rise in the CPI excluding fresh food and energy. However, service prices such as housing rents and public service prices have been highly rigid throughout this time, so that the shift of the price change distribution overall to the right has been somewhat slower.

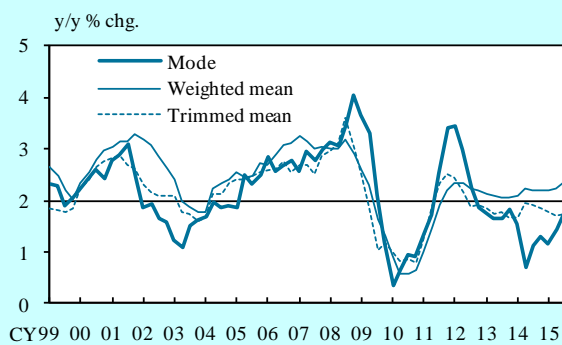
Intermediate, WTI, is used in the estimation), the nominal effective exchange rate (NEER) of the yen, the output gap, and the CPI measures. Chart 10 presents the impulse responses to a 1% increase in the

[Figure 12] CPI Excl. Fresh Food and Energy



Note: The flexible price sector is defined as the CPI for all items excl. fresh food, energy, housing rents, and public services.
Source: Ministry of Internal Affairs and Communications, "Consumer Price Index."

[Chart 13] Core Inflation Measures for the U.S. CPI



Note: Figures for the mode are from the estimated distribution.
Source: BLS, Federal Reserve Bank of Cleveland

As mentioned above, the mode and the weighted median inflation rates in Japan have recently been rising, but the rates are still much lower than in the United States, where they are fluctuating around 2% (Chart 13), or in Japan in the early 1990s, when they were also around 2% (see Chart 6). This raises the question what kind of pressure is needed so that the whole price change distribution shifts to the right and higher mode and weighted median inflation rates can be observed. The analysis above showed that the central tendency measures (the mode or the weighted median) are only weakly linked to the business cycle, meaning that not only do economic conditions need to improve, but it is also necessary for inflation expectations to rise further to push a wide range of items in an inflationary direction. In other words, if people's perception of inflation, that is, the inflation norm, rises, this will likely lead to a general shift of the price change distribution to the right and the central tendency of inflation will be higher than it is today. Thus, it is essential for a continuous rise in the inflation norm to become embedded in actual wage and price settings.

Conclusions

In this paper, we examined the business cycle characteristics of core inflation in Japan by estimating new measures of core inflation, the mode and the weighted median inflation rates, which are based on the distribution of price changes in individual items making up the CPI. Our analysis showed that measures of core inflation that simply exclude volatile items still closely follow the business cycle as measured by the output gap, while measures such as the mode and the weighted median are much more weakly linked to developments in the output gap. Such differences in the responsiveness to the business cycle also emerge when looking at recent developments, with the mode and the weighted median rising at a slower pace than the CPI excluding fresh food and energy in response to the improvement in the output gap. We also argued that in order for the mode and the weighted median to rise further and for the price change distribution overall to shift to the right, not only improvements in the output gap are necessary, but further rises in inflation expectations or the inflation norm are vital.

Our analysis highlights that in order to capture underlying inflation trends and their link to the business cycle and inflation expectations, it is useful to rely not on one specific measure of core inflation but to examine a variety of measures, including the mode and weighted median presented in this paper. Reflecting these considerations, the Research and Statistics Department of the Bank of Japan will release, via our website, estimates of these core inflation measures, namely the CPI excluding fresh food and energy, the shares of increasing and decreasing items in the CPI, the 10% trimmed mean, and the mode and weighted median on a regular basis, after the release of the monthly CPI statistics.

¹ For more details on core inflation measures, see S. Shiratsuka, "Core Indicators of Japan's Consumer Price Index," *Bank of Japan Review Series* (2006-E-7), and S. Shiratsuka, "Performance of Core Indicators of Japan's Consumer Price Index," *Bank of Japan Review Series* (2015-E-7).

² The increment of intervals in the histograms of Chart 2 is 0.5%, and the distribution does not take the CPI weights of individual items into account (i.e., it shows the unweighted distribution).

³ In this paper, we fit an inverse-Gaussian distribution to the observed cross-sectional distribution of price changes (year over year, adjusted for the estimated effects of changes in the consumption tax rate, increments of intervals set at 0.1%, equally weighted) in each period, using maximum likelihood estimation. This distribution is fairly flexible and fits the observed histogram well.

⁴ In this paper we estimate the weighted median by assigning CPI weights to price changes of individual items, arrange these in descending order up to the 50% mid-point in terms of cumulative weights, and take the inflation rates around this 50% mid-point. Alternatively, we can follow the same procedure without applying the CPI weights, but both series showed similar fluctuations throughout the whole sample period. Therefore, we follow the first method which is widely used at other central bank as well, such as the Cleveland Fed.

⁵ In order to see how widespread inflation is among individual items, the Bank of Japan also reviews other core inflation measures using the cross-sectional distribution of price changes such as the diffusion index defined as the share of items whose price has increased from a year earlier minus the share of items whose price has declined.

⁶ In this paper, in order to avoid that the estimated median inflation rate fluctuates excessively, we use not the price rate of change at the 50% mid-point but the average of price rates of change in the neighborhood of the 50% mid-point (specifically, 47.5% to 52.5%).

⁷ The main reason that, during the period examined here, the CPI excluding fresh food has the largest coefficient is the positive correlation between energy prices and the output gap reflecting the fact that developments in the world economy simultaneously influenced both oil prices and changes in Japan's output gap through exports. On the other hand, the reason for the low sensitivity of CPI excl. food and energy to the output gap is mainly due to the exclusion of food products, which tend to be highly sensitive to business cycle fluctuations.

The fact that the trimmed mean follow the output gap more closely than the mode or the median indicates that the effects from the skewness in the price change distribution, driven by items that are sensitive to the output gap, are still relatively present in the trimmed mean even after trimming the tails of the distribution.

⁸ On this point, Tsutomu Watanabe and Kota Watanabe (in "Defureki ni okeru kakaku no kouchokuka: genninn to ganni," CARF Working Paper released in Japanese, February 2015), point out that even after the inflation rate of the CPI excluding fresh food became positive in the spring of 2013, the cross-sectional distribution of price changes shows that 50% of all items, in weights, still remained in the range of no price change.

[Acknowledgements]

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