PRACE NAUKOWE
Uniwersytetu Ekonomicznego we Wrocławiu

RESEARCH PAPERS
of Wrocław University of Economics

Nr 381

Financial Investments and Insurance – Global Trends and the Polish Market

edited by
Krzysztof Jajuga
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Publishing House of Wrocław University of Economics
Wrocław 2015

Copy-editing: Agnieszka Flasińska
Layout: Barbara Łopusiewicz
Proof-reading: Barbara Cibis
Typesetting: Małgorzata Czupryńska
Cover design: Beata Dębska

Information on submitting and reviewing papers is available on
the Publishing House's website
www.pracenaukowe.ue.wroc.pl
www.wydawnictwo.ue.wroc.pl

ISSN 1899-3192
e-ISSN 2392-0041

ISBN 978-83-7695-463-9

The original version: printed

Publication may be ordered in Publishing House
tel./fax 71 36-80-602; e-mail: econbook@ue.wroc.pl
www.ksiegarnia.ue.wroc.pl

Printing: TOTEM

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PRACE NAUKOWE UNIWERSYTETU EKONOMICZNEGO WE WROCŁAWIU
RESEARCH PAPERS OF WROCŁAW UNIVERSITY OF ECONOMICS nr 381 • 2015

Financial Investment and Insurance –
Global Trends and the Polish Market

ISSN 1899-3192
e-ISSN 2392-0041

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SELECTED METHODS OF THE DETERMINATION OF CORE INFLATION

Summary: Core inflation can be defined as the part of price change, which is used to assess the medium-and long-run growth trend in the prices of consumer goods and services in the economy. Usually it is assumed that core inflation is linked to expected inflation and demand pressure and is independent of supply shocks. The core inflation indicators allow for assessing the inflationary processes in the economy and therefore they are helpful in choosing investment and monetary decisions in the medium-run and long-run. We can distinguish many measures of core inflation. Therefore, the purpose of this article is use alternative measures of core inflation based on selected low pass filter, such as: exponentially weighted moving average, Holt's exponential smoothing, Hodrick-Prescott filter and Baxter-King filter. In the article we empirically compare these alternative measures with traditional measures of core inflation calculated by the NBP.

Keywords: Core inflation, trimmed mean, exponential smoothing, low-pass filter.

DOI: 10.15611/pn.2015.381.25

1. Introduction

The core inflation illustrates the tendency of price changes adjusted from the transient fluctuations. If the inflation rate is above the core inflation, we can predict that future inflation should decline because the transitional elements that cause high current level of inflation will expire.

Therefore, the core inflation measures allow a more accurate assessment of inflationary processes in the economy. Moreover, the core inflation measures have often lower variation over time than CPI inflation rates.

There are many measures of core inflation. Currently, the Polish National Bank calculates four core inflation measures: three are computed using mechanical methods, based on the exclusion of a basket of goods from the CPI basket, and one measure is calculated using a statistical method.

The purpose of this paper is the description and application alternative measures of core inflation based on the selected low-pass filters. We compare these alternative measures with traditional measures of core inflation calculated in the Polish National Bank.

When we calculate the traditional measures of core inflation, at the beginning we must exclude certain goods and services from basket used to calculate the CPI inflation rate. Here we have a problem: Price changes of which goods and services are transient? And therefore the exclusion of which goods and services will permit a more accurate assessment of inflationary processes in the economy? However, the presented alternative measures of core inflation, calculated on the basis of low pass filters permit the inclusion of permanent changes in the inflation rate without setting the group of goods or services that should be excluded from the basket, before calculating the core inflation measures. That is necessary for the calculation of the traditional measures of core inflation.

2. Core inflation

The core inflation we define as a part of the headline inflation, which is used to assess the medium and long-term trend of rising prices of consumer goods and services in the economy. Thus, the core inflation π_{bt} due to Bryan and Cecchetti [1994] is as follows:

$$\pi_{bt} = E_t \pi_{t+H}, \tag{1}$$

where: π_t – the actual inflation rate CPI; H – sufficiently long forecast horizon.

In the next parts we quote traditional measures of core inflation and we present measures of core inflation based on the low-pass filters.

3. Traditional measures of core inflation

The Polish National Bank (PNB) calculates the measures of core inflation since 1998. From March 2009 the Polish National Bank has been providing the following measures of core inflation [NBP 2014]:

1) measures calculated by using mechanical methods, such as:
- inflation excluding food and energy prices,
- inflation excluding administered prices,
- inflation excluding the most volatile prices,

2) measure calculated by using statistical methods.

Used mechanical methods rely on the elimination of certain elementary price indices from general index of good prices and services and then the calculation of the aggregate price index on a cut off set of goods and services. Most often there are excluded those goods and services whose prices are characterized by strong fluctuations derived from the impact of supply shocks or those goods and services whose information about their changes is limited. The disadvantage of this group of methods is the predetermination of the group of excluded goods.

For example, inflation excluding food and energy prices eliminates the prices of goods that are particularly sensitive to internal and external supply shocks. Thus, this excluded group includes prices of food and non-alcoholic drinks and energy prices. The share of food and energy prices is 42.9% of the CPI basket in 2014.

Inflation rate that is excluding administered prices is aggregate price index calculated on the cut off set. It is formed by the elimination of the prices that are not subject to market forces, but are subject to various types of administrative regulation. Therefore, the distribution of these prices may not reflect the long-term inflation trends Administered prices include goods and services of which final prices are influenced fully or largely by government institutions, local government institutions and regulators, and also goods and services whose price changes are legally limited.

The inflation rate excluding most volatile prices is formed by excluding the goods and services whose prices are most disturbed, namely the goods and services whose prices are particularly sensitive to various types of demand and supply shocks or characterized by significant and time-varying seasonality. Strong variability of certain prices can cause the CPI inflation rate does not indicate correctly a long-term trend in the general price level, at least in the short term. Therefore, we calculate the measure of core inflation, which excludes the goods and services whose have the most volatile prices. When the Polish National Bank calculates the measures of core inflation measures, the basket of most variable prices is determined by empirical method and then this basket is determined by using the standard deviation criterion from the sample at the level of elementary price indices. Every year the most variable price basket includes goods and services that are selected as long as their total weight achieves 20% of the CPI basket. The goods and services whose prices are the most variable are most often a significant part of foods, mainly unprocessed and low-processed fruits, vegetables, meat and also energy products, such as fuel, gas as well as Internet access services, administration services state and legal services.

There are considered the measures calculated by using statistical methods, such as (α, β) – trimmed mean. This mean is calculated from the formula

$$\bar{x}_{\alpha,\beta} = \frac{1}{r-m} \sum_{j=m+1}^{r} x_j ,$$

where:

$$0 \le \alpha, \beta \le 0{,}5, \quad m = [\alpha n], r = n - [\beta n].$$

When we calculate the trimmed mean we need to order the observations from smallest to largest, and then we reject the ($\alpha \cdot 100\%$) of the smallest values of observation and ($\beta \cdot 100\%$) of the largest values of observation.

When we calculate this measure of core inflation we often take equal values α and β.

The use of trimmed mean as the measure of core inflation was also proposed by Bryan and Cecchetti [1994].

The Polish National Bank calculates the 15% trimmed mean and it assumes $\alpha = \beta = 0.15$. Then this measure of core inflation is a weighted average calculated on a set of good prices whose cumulative weights correspond to the previously ascending ordering of price indices that are greater than 15% and less than 85%. The cutting off is done symmetrically on both sides of the distribution of price changes. Thus, we reject the group of goods with a total weight of 30%, which prices have been the biggest change compared to the base period.

The traditional measures of core inflation are less variable than CPI but they retain a substantial amount of high frequency variation. Therefore below we present the alternative measures of core inflation received as a result of the low pass filters applied to CPI inflation.

4. Measures based on the low-pass filters

Measures of core inflation based on the filters allow the inclusion of these measures of permanent changes in inflation.

Low-pass filters are one of the types of linear filters. At the beginning we present some basic notions about filters. The linear filter converts a time series x_t called the input vector into another time series y_t called the output vector by the following linear transformation:

$$y_t = \sum_{k=-\infty}^{\infty} w_k \cdot x_{t-k}, \tag{2}$$

where w_k are called filter coefficients. We assume that the filter coefficients are symmetrical, $\bigwedge_k w_{-k} = w_k$. If we use the linear filters to transformation of variables that are characterized by a trend, then desirable property of the filter is the elimination of this trend. Then the sum of the filter coefficients must be equal to zero,

$$\sum_{k=-\infty}^{\infty} w_k = 0.$$

Input vector x_t is also called the signal. In order to analyze filters in the frequency domain, we shall consider a signal x_t with a known frequency f and $x_t = e^{i2\pi ft}$.

A useful tool for describing and classifying linear filters is the frequency response function $H(f)$ which, in discrete time setting, is defined by:

$$H(f) = \sum_{k=-\infty}^{\infty} w_k \cdot e^{-i2\pi f k}, \tag{3}$$

where: f – frequency; w_k – impulse response function.

Therefore, frequency response function is the Fourier transform of the impulse response.

The frequency response function can also be written in the following form:

$$H(f) = G(f) \cdot e^{i \cdot \theta(f)}, \tag{4}$$

where: $G(f)$ – gain function; $\theta(f)$ – chase function.

We can now present the definition of low-pass filter. If the value of the gain function is large at low frequencies and small at higher frequencies, the filter is called a low-pass filter. Then the low-frequency dynamics of the inputs are preserved during the filtering, while the high-frequency components are discarded.

The ideal low-pass filter would have a well-defined cutoff frequency with the frequency response function given by the following formula (see [Gençay, Selçuk, Whitcher 2001]:

$$H(f) = \begin{cases} 1 & \text{for } 0 < f < f_U \\ 0 & \text{otherwise} \end{cases}, \tag{5}$$

where f_U is the upper cutoff frequency of the filter, $f_U < ½$.

However, the ideal low-pass filter is not computationally realizable because it requires infinitely many coefficients and an infinite number of data points. Thus, in practical application we use filters containing finitely many coefficients. These filters are only an approximation of the ideal filter.

As filters approximating the ideal low-pass filter we propose to use:

1) exponentially weighted moving average (EWMA),
2) Holt's exponential smoothing,
3) Hodrick-Prescott filter (HP filter),
4) Baxter-King filter (BK filter),

which are presented below.

Moreover, since the calculation of the alternative measures of core inflation used overall CPI inflation, it is sufficient to forecast the core inflation rate based on the low-pass filter the knowledge of CPI or C-CPI forecasts.

4.1. Exponentially Weighted Moving Average (EWMA)

Exponentially Weighted Moving Average EWMA (see: [Zeliaś, Pawełek, Wanat 2003]), called also exponential smoothing we calculate from the following formula:

$$\pi_{ct} = \alpha \cdot \pi_t + (1-\alpha) \cdot \pi_{c\ t-1} \text{ for } t > 1, \tag{6}$$

where: π_{ct} – the exponential smoother value, estimate of the average inflation rate, representing the core inflation rate at the period t; π_t – inflation rate at the period t; α – smoothing constant called also the gain parameter, which is assumed to lie between 0 and 1. Parameter gain is chosen most often a priori. This parameter can be fixed experimentally on the basis of initial sample. Then we calculate the smoothed values for different values α and we choose the value α for which mean error is smallest.

As π_{c1} we take frequently the value of the initial inflation rate π_1 or the arithmetic mean of the actual values of the initial sample of real inflation rates (e.g. mean of the first four values).

The rule described by formula (6) can also be written in the following form (see: [Cogley 2002]):

$$\pi_{ct} = \alpha \cdot [1-(1-\alpha)L]^{-1} \cdot \pi_t = \alpha \cdot \sum_{k=0}^{\infty} (1-\alpha)^k \cdot \pi_{t-k},$$

where L is lag operator. Thus, formula (6) showing exponential smoothing is a one-sided low-pass filter with exponential weights $w_k = \alpha(1-\alpha)^k$. In practice, when we calculate the exponential moving average we take into account a finite number of data values M. Then we often assume $\alpha = \frac{2}{1+M}$.

4.2. Holt's Exponential Smoothing

Equation (6) can be modified and written in the form of Holt's exponential smoothing as following:

$$\pi_{ct} = \alpha \cdot \pi_t + (1-\alpha) \cdot (\pi_{c\ t-1} + C_{t-1}) \text{ for } t > 1, \tag{7}$$

where:

$$C_t = \beta \cdot (\pi_{ct} - \pi_{c\,t-1}) + (1-\beta) \cdot C_{t-1} \quad \text{for } t > 1 \tag{8}$$

and π_{ct} – the smoother value, estimate of the average inflation rate, representing the core inflation rate at the period t, π_t – the inflation rate at period t, α, β – smoothing constant, $\alpha \in (0,1)$, $\beta \in (0,1)$, C_t – smoother value of difference in estimated trend value at period t.

As an initial values π_{c1} and C_1 we can take $\pi_{c1} = \pi_1$ and $C_1 = y_2 - y_1$ or the constant term and the slope coefficient of the linear trend function, respectively.

4.3. Hodrick-Prescott Filter

Hodrick-Prescot filter (see: [Rubaszek 2012]) we define as the additive decomposition procedure of the time series, in our analysis the CPI inflation rate π_t, on the cyclical component c_t and the smoother component representing the core inflation π_{ct}. Therefore

$$\pi_t = \pi_{ct} + c_t, \quad \text{for } t = 1, 2, \dots n. \tag{9}$$

King and Rebelo [1993] showed that the cyclical component c_t of the HP filter has the following frequency response function (see: [Gençay, Selçuk, Whitcher 2001]):

$$H(f,\lambda) = \frac{4 \cdot \lambda \cdot [1-\cos(2\pi f)]^2}{1+4 \cdot \lambda \cdot [1-\cos(2\pi f)]^2}. \tag{10}$$

They also showed that the smooth component of the HP filter is given by the following formula (see: [King, Rebelo 1993]):

$$\pi_{ct} = \tfrac{\theta_1 \cdot \theta_2}{\lambda} \cdot \left[\sum_{k=0}^{\infty} (A_1 \cdot \theta_1^k + A_2 \cdot \theta_2^k) \cdot \pi_{t-k} + \right. \\ \left. + \sum_{k=0}^{\infty} (A_1 \cdot \theta_1^k + A_2 \cdot \theta_2^k) \cdot \pi_{t+k} \right] \tag{11}$$

where: θ_1, θ_2 – complex conjugates whose values depend on λ; A_1, A_2 – the function of θ_1, θ_2.

Hence, the filter written in the above form is an infinite order moving average. Therefore, it cannot be implemented in practice without making some assumptions about the lag length.

Thus, in practice, the core inflation component π_{ct} is determined using the HP filter as a solution of the following minimization problem [Gençay, Selçuk, Whitcher 2001]:

$$\sum_{t=1}^{n} (\pi_t - \pi_{ct})^2 + \lambda \sum_{t=2}^{n-1} [(\pi_{c\,t+1} - \pi_{ct}) - (\pi_{ct} - \pi_{c\,t-1})]^2 \to \min, \tag{12}$$

where λ – smoothing parameter, $\lambda \geq 0$.

A problem in the use of the HP filter is appropriate choice of the smoothing parameter. The larger is the value of λ, the less fluctuation is present in the smooth component. When $\lambda = 0$ the smooth component is the data itself $\pi_{ct} = \pi_t$ and smoothing does not occur. When $\lambda \to \infty$ the smoother component π_{ct} resulting from the application of HP filter is the value of the deterministic linear trend estimated ordinary least squares method.

In application, λ is set to 1600 for quarterly data as suggested in 1997 by Holdrick and Prescott. That provides separation between trend and cycle for about 10 years.

The minimizing problem (12) can be written equivalently in matrix form as follows:

$$(\Pi - \Pi_c)\cdot(\Pi - \Pi_c)^T + \lambda \cdot \Pi_c \cdot K \cdot K^T \cdot (\Pi_c)^T \to \min \tag{13}$$

where: $\Pi = \begin{bmatrix} \pi_1 & \pi_2 & \dots & \pi_n \end{bmatrix}$, $\Pi_c = \begin{bmatrix} \pi_{c\,1} & \pi_{c\,2} & \dots & \pi_{c\,n} \end{bmatrix}$,

$$K = \begin{bmatrix} -2 & 1 & 0 & \dots & 0 & 0 & 0 \\ 1 & -2 & 1 & \dots & 0 & 0 & 0 \\ 0 & 1 & -2 & \dots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \dots & -2 & 1 & 0 \\ 0 & 0 & 0 & \dots & 1 & -2 & 1 \\ 0 & 0 & 0 & \dots & 0 & 1 & -2 \end{bmatrix}.$$

Solving the minimizing problem, that is the vector of core inflation rates we can calculate by the formula:

$$\Pi_c = \Pi \cdot (I_n + \lambda \cdot K \cdot K^T)^{-1}. \tag{14}$$

In the formula (14) I_n is the identity matrix of order n.

4.4. Baxter-King Filter

Baxter and King (1999) proposed the following estimator of the ideal filter for a finite number of observations:

$$\pi_{ct} = \sum_{k=-N}^{N} w_k \cdot \pi_{t-k}, \tag{15}$$

N is a parameter that must be determined before the calculation of the filter coefficients. For example, Baxter and King suggested that value of N be set at three years.

Thus, the Baxter-King filter shows a centered moving average with symmetric weights. If we consider the low-pass filter when the sum of the coefficients w_k is equal to 1, then $\sum_{k=-N}^{N} w_k = 1$.

The optimal values of the filter coefficients w_i we calculate from the formulas [Baxter, King 1999]:

$$w_k = v_k + \frac{1}{2N+1} \cdot \left(1 - \sum_{j=-N}^{N} v_j \right), \tag{16}$$

where: $v_k = \begin{cases} \frac{1}{\pi k} \sin(k \cdot f) & \text{for } k \neq 0 \\ \frac{f}{\pi} & \text{for } k = 0 \end{cases}$,

f – established value of frequency.

Using the low-pass Baxter-King filter the core inflation rates expressed by the formula (15) are calculated on the basis of observations of inflation rates π_t for $t = 1, 2, \ldots, n$ and the value of the core inflation rate can be calculated only at the periods $t = N+1, N+2, \ldots, n-N$.

Then a number of core inflation rates is smaller than number of initial inflation rates. The number of core inflation rates is less about the N initial and N final words.

Therefore, in practical applications to analysis of the current situation or predict future values of the variable, Baxter-King filter is used less frequently than the other filters.

5. Empirical analysis

In our analysis we have into account the monthly CPI inflation in Poland during the period January 2001 – July 2014.

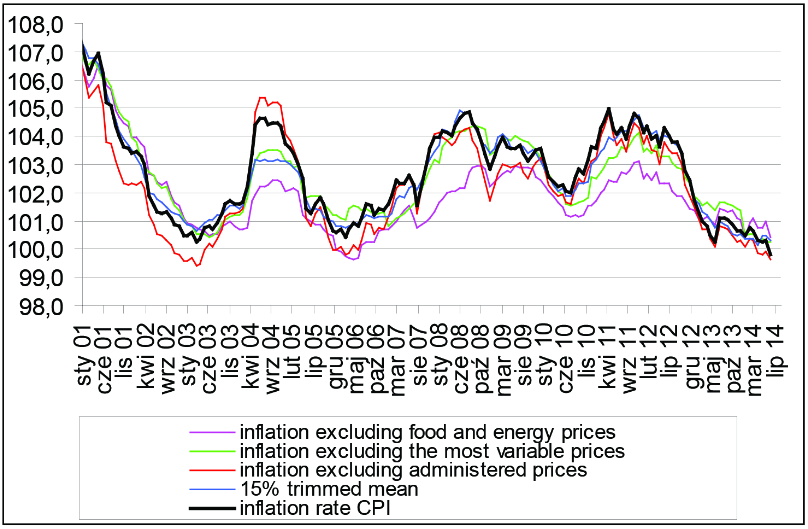

Figure 1. Traditional measures of core inflation

Source: own calculations based on NBP data.

Figure 1 presents the traditional measures of core inflation determined by the Polish National Bank: inflation excluding food and energy prices, inflation excluding the most variable prices, inflation excluding administered prices and 15% trimmed mean ((0.15, 0.15) – trimmed mean).

Figures 2a and b present the alternative measures of core inflation calculated on the basis of selected low-pass filters: exponentially weighted moving average, Holt's exponential smoothing, Hodrick-Prescott filter and Baxter-King filter. We assume gain parameters equal to 0.5 and for the BK filter $N = 36$.

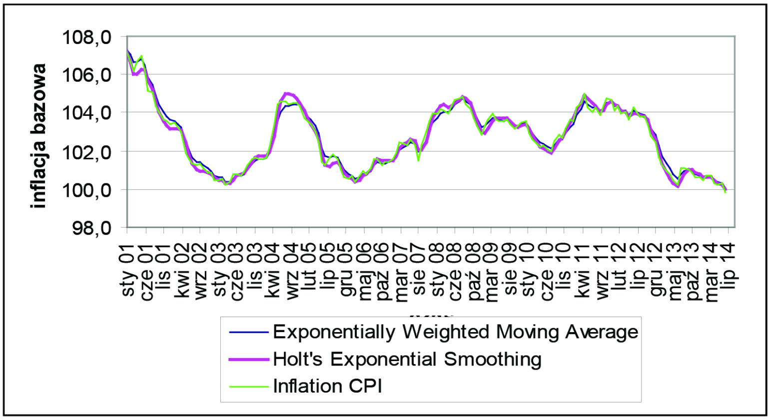

Figure 2a. Alternative measures of core inflation

Source: own calculations.

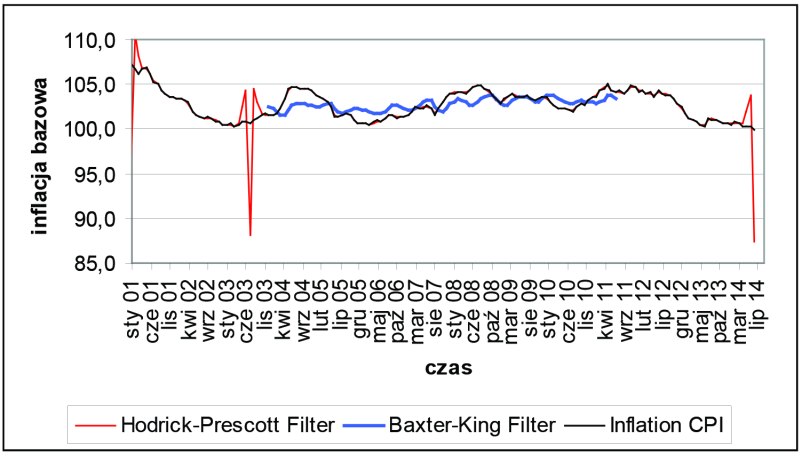

Figure 2b. Alternative measures of core inflation (cont)

Source: own calculations.

In order to assess the determined measures of core inflation we calculated the absolute errors – the difference between CPI inflation rate and various measures of core inflation, which are summarized in the figure below.

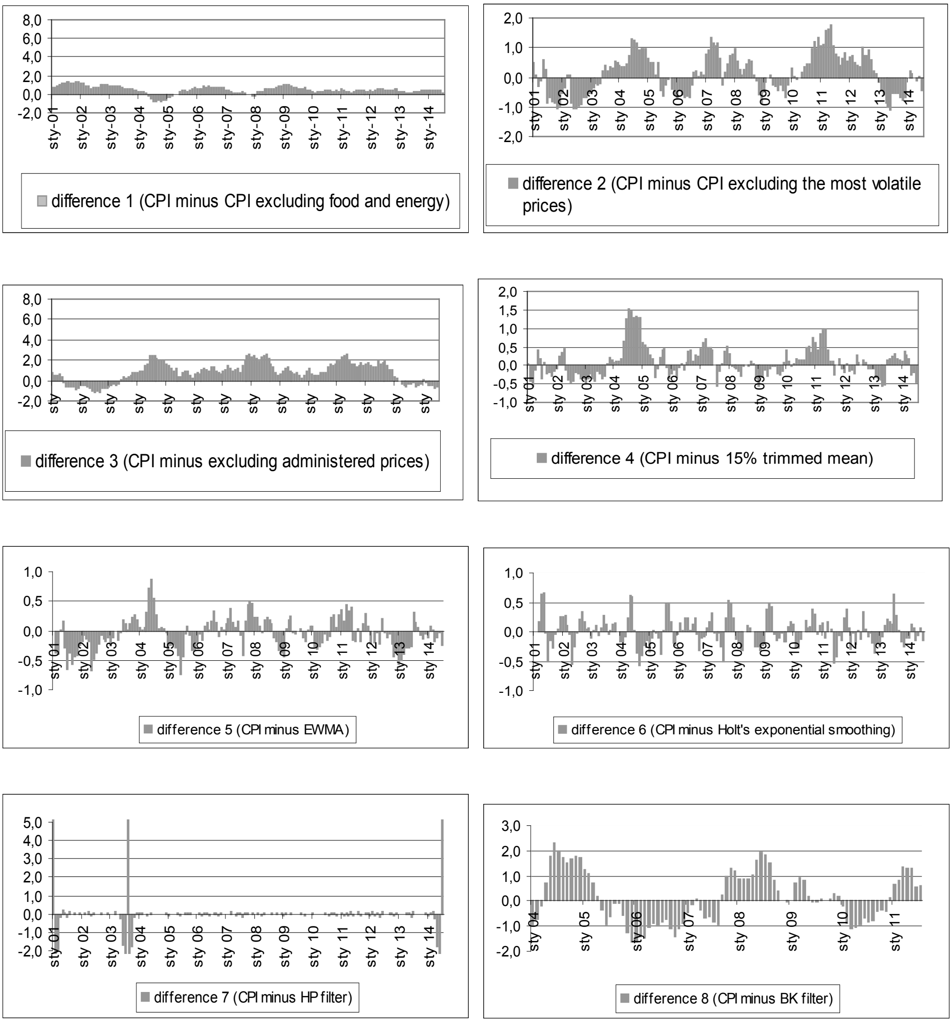

Figure 3. The absolute errors

Source: own calculations.

We note that throughout the period considered the smallest differences were obtained for core inflation calculated by alternative methods: the exponentially weighted moving average, Holt's exponential smoothing and Hodrick-Prescott filter. Other results we obtained for the measure of core inflation determined on base the Baxter-King filter.

At the end of the evaluated period, the exact results give also the selected classical measures of core inflation: inflation excluding food and energy prices, inflation excluding administered prices and the 15% trimmed mean.

6. Conclusions

For different economic conditions considered measures of core inflation approximate unobservable upward trend in the general price level with different accuracy. The usefulness of these measures largely depends on the nature of shocks which yield price categories excluded from the various core inflation measures.

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WYBRANE METODY WYZNACZANIA INFLACJI BAZOWEJ

Streszczenie: Inflację bazową można definiować jako część inflacji rejestrowanej, która służy do oceny średnio- i długookresowego trendu wzrostu cen towarów i usług konsumpcyjnych w gospodarce. Zazwyczaj przyjmuje się, że inflacja bazowa jest związana z oczekiwaniami inflacyjnymi i presją popytową oraz jest niezależna od szoków podażowych. Wskaźniki inflacji bazowej umożliwiają pogłębioną ocenę procesów inflacyjnych w gospodarce, a zatem są pomocne w podejmowaniu decyzji inwestycyjnych i monetarnych w średnim i długim okresie. Można wyróżnić wiele miar inflacji bazowej. W związku z tym w artykule zostały zaprezentowane wybrane metody wyznaczania inflacji bazowej.

Słowa kluczowe: inflacja bazowa, średnia obcięta, wygładzenie wykładnicze, filtr dolnoprzepustowy.