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Elena Deryugina, Alexey Ponomarenko,
Andrey Sinyakov and Constantine Sorokin

Evaluating underlying inflation measures for Russia

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Abstract

We apply several tests to the underlying inflation measures used in practice by central banks and/or proposed in the scientific literature, in an attempt to find the best-performing indica-tors. We find that although there is no single best measure of underlying inflation, indicators calculated on the basis of dynamic factor models are generally among the best performers. These best performers not only outdid the simpler traditional underlying indicators (trimmed and exclusion-based measures) but also proved to be economically meaningful and inter-pretable.

Keywords: underlying inflation, core inflation, monetary inflation, dynamic factor model, Russia.

JEL classification: E31, E32, E52, C32.

Elena Deryugina, Bank of Russia. Email: DeryuginaEB@cbr.ru.
Alexey Ponomarenko, Bank of Russia. Email: PonomarenkoAA@cbr.ru.
Andrey Sinyakov, Bank of Russia. Email: SinyakovAA@cbr.ru.
Constantine Sorokin, NRU-HSE. Email: csorokin@hse.ru.

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Introduction

Headline inflation rates can be volatile. Such volatility in a key price index can make it difficult for policymakers to accurately judge the underlying state of, and prospects for, inflation. In Russia this volatility is often connected with changes in relative prices arising from exchange rate fluctuations and one-off changes in regulated prices. Therefore, it is crucial for the central bank to separate the inflation dynamics from those changes in relative prices and inflation that do not provide information useful for understanding future inflation. The importance of separating relative prices and inflation is noted, for example, in Reis and Watson (2010) and Fisher (1981). Theoretically, one-off changes in relative prices do not affect inflation in the medium term and thus do not require any response from monetary authorities (see Nessen and Soderstrom (2001)). Therefore, a measure of underlying inflation that is useful for monetary policy decisions should help to identify the headline inflation shocks that are relevant for monetary policy and should be designed to inform policymakers of the dynamics of future headline inflation or current medium-term inflation expectations.

Different approaches are described in the literature for constructing measures of underlying inflation, not only and not so much as a statistical measure but as an analytical instrument (Amstad et al. (2014); Meyer et al. (2014); Bilke and Stracca (2008); Wynne (2008, 1999); Lafleche and Armour (2006); Aucremanne and Wouters (1999)). Dementiev and Bessonov (2012) and Tsyplakov (2004) estimate underlying inflation measures for Russia. Considering that underlying inflation is not observable and that there are many approaches to measuring it, a task that emerges is to test which of the underlying inflation measures is best in terms of the definition of underlying inflation. These tests are given in Amstad et al. (2014), Mankikar and Paisley (2004) and Silver (2006). In practice, it may turn out that some underlying inflation measures perform well according to some of the criteria and badly according to others. That is why, for practical purposes, the above studies recommend the use of a set of underlying inflation indicators. With this approach, the probability of a monetary policy error is only reduced, and confidence in the central bank’s decisions increases when the range of underlying inflation numbers is narrow, whereas if the range is wide enough, monetary policymakers get the opportunity to analyse the causes of the mixed signals of indicators.

In Section 1, we provide a description of the underlying inflation measures, with a focus on dynamic factor models that ultimately have turned out to be the best performers. In

Section 2, we describe the formal evaluation tests and their results. We also demonstrate the practical application of the best performing underlying inflation indicators as exemplified by our inflation dynamics analysis of the past decade in Russia. Section 3 concludes.

1 Underlying inflation measures

1.1 Data

We use monthly statistics compiled by Rosstat or the Bank of Russia from January 2002 to September 2014. We use Rosstat's consumer price inflation (CPI) and the core inflation index as price indicators, as well as 43 CPI components of the highest aggregation level. Because there are no pre-2006 data on CPI components of the lower aggregation level, we chose to work only with the most aggregated CPI categories. Accordingly, we combined the aggregated categories 'other foodstuffs', 'other non-food products' and 'other services' into a single CPI category, despite their heterogeneous nature. Seasonal smoothing is done with TRAMO/SEATS.

All our calculations are conducted in pseudo-real time. Calculating our underlying inflation measures in pseudo-real time means that the underlying inflation number for any month is based solely on real-time information available to the researcher during that month. The pseudo-real time format aims to obtain a measure of underlying inflation that a central bank could have calculated in the past. Precisely that level of underlying inflation (with parameterisation of models based on information available as of that time) is information that is crucial for the central bank to take monetary policy decisions.

Below, we describe the 20 indicators of underlying inflation that we tested.[1] These include eight exclusion-based indicators, one based on the re-weighing method, four trimmed measures and seven indicators based on dynamic factor models and models with unobserved trend. We also added to this selection Rosstat's core CPI calculated by the exclusion method.

[1] In our work we considered 40 indicators of underlying inflation but later limited those presented here to 20 owing to their similarity. The dynamics of all calculated underlying inflation indicators (recursive and final evaluations) are available on request.

1.2 Underlying inflation measures based on dynamic factor models

1.2.1 Standard model

Dynamic factor models use information contained in a wide set of indicators and are designed to decompose inflation into two stationary, orthogonal unobservable components – the common χ_{jt} and the idiosyncratic ε_{jt}:

$$\pi_{jt} = \chi_{jt} + \varepsilon_{jt},$$

where the common component is driven by a small number of common factors (shocks).

The common component can be decomposed into long-term (x_{jt}^{L}) and short-term (x_{jt}^{S}) constituents by identifying low-frequency fluctuations with periodicity above the designated threshold h (Cristadoro et al. (2005)):

$$\pi_{jt} = x_{jt}^{L} + x_{jt}^{S} + \varepsilon_{jt}$$

The smoothed (long-term) common component can be obtained by summing up the waves with periodicity [−π/h, π/h] using spectral decomposition. This long-term component will measure underlying inflation. This measure will not contain idiosyncratic shocks that are not common to all CPI components, or short-term fluctuations, which are not relevant for monetary policy. We do calculations for two alternative threshold periods, h=12 and h=24, and calculate the indicator based on a dynamic factor model without using band-pass filters.

The basic model can be written as

$$\pi_{jt} = b_j(L)f_t + \varepsilon_{jt},$$

where: $f_t = (f_{1t}, \ldots, f_{qt})'$ is a vector of q dynamic factors and $b_j(L)$ is a lag operator of order s. If $F_t = (f'_t, f'_{t-1}, \ldots, f'_{t-s})'$. Thus the static representation of the model is

$$\pi_{jt} = \lambda_j F_t + \varepsilon_{jt},$$

where: $b_j(L)f_t = \lambda_j F_t$.

We select the number of dynamic factors so as to ensure that each subsequent factor increases the share of variance explained by the common component by no less than 10% (Forni et al. (2000)). As a result, we use q=3 and assume[2] s=12.

Our data set consists of the seasonally adjusted monthly increases in 44 price indicators (CPI and its components).[3] The econometric estimation procedure was replicated in accordance with Cristadoro et al. (2005).

As a result, we obtained three alternative measures of underlying inflation, depending on the threshold frequency. We also tested simple indicators of underlying inflation, calculated solely on the basis of band-pass filters.

1.2.2 Pure inflation model

The 'pure' inflation concept (Reis and Watson (2010)) is an alternative approach to the specification of a dynamic factor model. It is assumed under this approach that the price growth is decomposed into three components:

$$\pi_t = \nu_t + \rho_t + \varepsilon_t$$

Pure inflation (v), reflecting price growth under the impact of monetary factors should be both present in the dynamics of all goods and services, and equiproportional. This growth should be separated from changes in relative prices (ρ_t) and idiosyncratic fluctuations (ε_t). We used the same set of data, which we applied to standard dynamic factor models. The econometric procedure was replicated in accordance with Reis and Watson (2010). The model included three common factors and two[4] lags in autoregressive models.

1.2.3 Monetary inflation model

We use the monetary approach to underlying inflation measurement as another alternative model (for details, see Deryugina and Ponomarenko (2013)). Here, we attempt to evaluate

[2] We found that using a smaller number of lags would worsen the properties of the obtained results.
[3] We used here only price indices, such as Giannone and Matheson (2007), Khan et al. (2013). The use of a wider range of macroeconomic indices as in Cristadoro et al. (2005) and Amstadt et al. (2014) does not lead to improved results.
[4] Including more lags destabilizes real-time estimates obtained from models presented in Sections 1.2.3 and 1.2.4.

the information content of money with regard to inflation developments in the spirit of Nobili (2009), i.e. by applying the dynamic factor model approach to a cross-section of variables comprising the broad monetary aggregates (as well as their components) and the collection of different price indices. Our statistical approach aims at extracting the underlying monetary process that is most relevant for inflation by weighting the monetary aggregates according to their signal-to-noise ratio, namely, down-weighting those with large idiosyncratic variances. It is presumed that our approach will downplay those monetary instruments whose behavour is affected by financial innovation as well as portfolio considerations. This parsimonious approach is similar to that of Bruggeman et al. (2005), who identify underlying money growth as a component of money that feeds into inflation movements with certain periodicity. And, given that we rely on a range of price indicators to reflect inflation developments, we expect to filter out the volatile component of CPI growth that might otherwise distort the relationship with money growth.

We formulate the dynamic factor model in a state-space representation (for details, see Stock and Watson (2011)):

$$X_{it} = a_i F_t + v_{it}$$

$$F_t = \mu + \sum_{j=1}^{L} D_j F_{t-j} + e_t$$

$$e_t = R\, u_t$$

The ‘measurement’ equations represent the dependence of the set of price and monetary variables (X_{it}) on static unobservable factors (F_t) (for details, see Appendix 1). The explained part ($a_i F_t$) represents the common component, while the unexplained part (v_{it}) is the idiosyncratic component. The ‘transition’ equations represent a VAR model of static factors. Structural shocks (u_t) can be subsequently derived from the residuals of the VAR model (e_t). Therefore, as with structural VAR models, we can calculate impulse response functions related to these shocks, and historical decompositions for static factors (and, correspondingly, for observable indicators). We estimate the model using Bayesian methods as proposed in Blake and Mumtaz (2012). The numbers of static factors and their lags are selected on the same criterion as was applied for standard models. As a result, the number of static factors (F_t) was 2 as was the number of lags, L=2.

The structural interpretation of dynamic factor models is rare but hardly unprecedented (Forni et al. (2009); Forni and Gambetti (2010)). We believe that analysis of the macroeconomic properties of structural shocks can be useful for identifying the part of inflation that we can consider as underlying inflation. For this purpose, we decompose the residuals e_t into independent shocks $\boldsymbol{u_t}$ with the help of the principal components approach[5] (Forni et al. (2009)). The function of impulse responses to one of the two identified shocks (see Appendix 1) is considered economically substantive. A monetary shock leads to the instant acceleration of the monetary indicators' growth, which persists during the next five quarters. The accelerated growth of price indicators begins later and reaches its peak in six to eight quarters (four quarters for real estate prices) and ends in ten to twelve quarters. These dynamics are in line with the theoretical lag structure of the relationship between rates of growth of money supply and inflation (see, for example, Nicoletti-Altimari (2001)). At the same time, impulse responses to the second structural shock do not possess such properties.

On these grounds, we exclude both the idiosyncratic part (v_t) and fluctuations caused by 'non-monetary' structural shocks from the underlying inflation measure.

1.3 Other underlying inflation measures

1.3.1 Exclusion method

In order to calculate the CPI by the exclusion method, certain components which fail to comply with the underlying inflation definition by some criteria are excluded from the consumer goods basket. The weights of the CPI components remaining in the basket are adjusted to represent a total of 100% of a new basket, and the weighted average value calculated from the components' indices will represent the underlying inflation index.[6]

The underlying inflation calculation usually excludes CPI components characterized by high historical volatility (such as energy or fuel prices), the expressly seasonal nature (such as vegetable and fruit prices) or administered nature (such as alcohol

[5] The use of the Cholesky decomposition for this purpose does not lead to any considerable change in the results.
[6] For calculations using the exclusion method on the basis of Russian data; see e.g. Dementiev and Bessonov (2012).

prices or the prices of certain social services). The volatility (seasonal or administered) of these prices indicates that a change occurs precisely in relative prices.[7]

We calculated the following underlying inflation measures:

- Three standard and widely used measures of underlying inflation: a) CPI net of vegetables and fruits, energy and administered prices (namely, housing and utility charges), representing 84% of the CPI in Russia; b) 'Non-food goods excluding energy and fuel' representing 33% of the CPI; c) Rosstat's core CPI, representing 80.5% of the CPI (December 2014) was also included in this group.
- The CPI net of the eight most volatile components (Lafleche and Armour (2006)), where volatility is measured by the standard deviation of the monthly inflation of certain CPI components in the moving 24-month window. Appendix 3 presents CPI components (the most volatile ones) that are most frequently excluded from the underlying inflation index for Russia, using the methodology of the Bank of Canada.
- We calculated underlying inflation excluding certain specified components, as well as 50% and 75% of the most volatile components, using their weights in the consumer goods basket. As before, our volatility metric was the standard deviation of monthly inflation in the moving 24-month window.
- The inflation indicators representing 50% of the CPI basket were characterized by the lowest sensitivity concurrently (on the average) to three types of shocks that are frequently sources of change in relative prices: world oil price shocks, world food price shocks and exchange rate shocks. The sensitivity of certain CPI components to the above shocks was determined via the structural VAR model (see Davis (2012); Fukac (2011); Bicchal (2010); for criticism, see Lenza (2011)). An alternative approach was realized using the Local Projection Method; see Jordà (2005)8. A detailed description of the calculation algorithm

[7] This approach to the exclusion of relative prices is criticized, for example, in Bullard (2011). In particular, it is noted that energy price inflation changed permanently in the 2000s due to the growing demand in Asian countries and, therefore, the exclusion of fuel prices from underlying inflation systematically understates the trend inflation, as inflation retains components that were subjected to downward pressure from demand due to growth in the share of expenditures on fuel in the budget of US households. That is why the exclusion of energy prices from the US underlying CPI is not justified.

[8] A detailed description of the calculation algorithm and its results are available upon request.

and the results, namely, the most frequently excluded CPI components, is given in Appendix 3.

- Selection of components representing 50% of the CPI based on their ability to forecast future inflation (12 months ahead). A similar index is reported in Bilke and Stracca (2008). This approach boils down to the following: considering that a change in relative prices should not be reflected in future inflation, the components exposed to frequent changes in relative prices (whose inflation reflects a change in relative prices) should be characterized by poor forecasting ability for future headline inflation.

1.3.2 Re-weighing CPI components

The approach to an underlying inflation index on the basis of re-weighing of CPI components is similar to the exclusion method (see, for example, Macklem (2001)). This approach uses weights inversely proportional to the historical volatility of the monthly inflation of certain CPI components, where volatility is calculated in the moving 24-month window.

1.3.3 Underlying inflation measures based on the trimming method

The trimming method selects only a part of the empirical distribution of the monthly inflation of certain CPI components for the underlying inflation index (normally, the tails of the distributions are cut off) (see, for example, Meyer and Venkatu (2012)). The trimmed distribution, like the exclusion method, aims at eliminating those price changes in the CPI which may be related to changes in relative prices (see, for example, the theoretical model in Bryan and Cecchetti (1993)).

We calculated four underlying inflation indicators using this approach.

Following Meyer and Venkatu (2012), we calculated optimal thresholds for Russian data. Trimming thresholds were selected to minimize the deviation of the current underlying inflation level from either the realized 24-month centred moving averages of monthly inflation or the realized future (over the next 24 months) monthly inflation. We have also constructed the real-time trimmed measure of underlying inflation (using future inflation over the next 24 months as a criterion) based on monthly re-optimisation based solely on data available in pseudo-real time, which is a more accurate measure available to the policymaker. We allowed for asymmetrical lower and higher thresholds. We found that threshold percentiles from 20th to 25th (depending on the sample and optimization criteria) were optimal.

Along with optimal trimmed measures, we calculated the standard underlying inflation indicator as a weighted median (instead of the average as represented by the CPI).

2 Evaluating the properties of underlying inflation measures

There is a set of criteria that can be used to assess the relevance of alternative underlying inflation measures. In principle, these tests can be divided into three broad categories (see, for example, Wynne (1999)).

2.1 Technical properties

The first category of criteria helps to assess the technical properties of underlying inflation measures:

- **Volatility**: We measure volatility as the average absolute deviation of the annual inflation growth rate from the average value over the moving 25-month period.
- **Bias:** We measure the cumulative deviation of underlying inflation from actual inflation for the period 2003–2014.
- **Stability of real-time estimates**. We measure the deviation of ex-post estimates of annual underlying inflation rates from real-time recursive estimates.

These results, which were not determinative for assessing the quality of underlying inflation measures, are presented for reference in Appendix 4.

2.2 Forward-looking properties

The most widespread criterion for assessing the quality of underlying inflation measures is their ability to forecast actual inflation. We use the standard model (see, for example, Lafleche and Armour (2006)) for assessing this property for the 12-month horizon (a temporary horizon relevant for monetary policy):

$$(\pi_{t+12} - \pi_t) = \alpha + \beta\,(\pi^U_t - \pi_t) + u_{t+12} \qquad (1)$$

where π_t is annual CPI growth rates and the π^U_t are annual underlying inflation growth rates.

We use recursive estimates of underlying inflation rates to take into account the model's possible instability. The model is estimated using the sample from July 2006 to September 2014. We use R^2 as an indicator of the model's fit. We also conduct the Wald test for $\alpha=0$ and $\beta=1$. If this test is passed, we can say that the current level of underlying inflation is a good benchmark for expected actual inflation.[9]

We also conduct a test for exogeneity of the future value of underlying inflation relative to current actual inflation. If this test is not passed, it may be presumed that the model's latest estimations are unstable, or it may be that fluctuations relevant for further dynamics of other inflation components have been erroneously excluded from the underlying indicator. For this purpose, we estimate[10] an equation of the following type:

$$(\pi^U_{t+12} - \pi^U_t) = \delta + \gamma\,(\pi^U_t - \pi_t) + \varepsilon_{t+12} \qquad (2)$$

The test for exogeneity is deemed passed if γ is not a statistically significant positive coefficient.

The test results are presented in Table 1. In terms of R^2 for equation (1), three underlying inflation indicators based on DFM were top ranked in five of seven cases and also passed the Wald and exogeneity tests (with the exception of 'pure' inflation).

[9] This type of test is conventionally used as the main criterion for forward-looking properties. We found, however, that in the case of Russia this test is easily passed by most models, including those with very low goodness of fit. We therefore augment our analysis by examining R^2.
[10] The significance of the coefficients in equations (1) and (2) was estimated with Newey-West adjustment.

Table 1 Results of assessing forward-looking properties of underlying inflation measures

Measure	***R^2 of equation (1)***	Measures that passed Wald test (α=0 and β=1 in equation (1)) at 5% level of significance	Measures that passed exogeneity test (t-statistics < 1.96 for γ in equation (2))
DFM (monetary inflation)	0.44	*	*
Band-pass filter (h=12)	0.41		*
DFM (h=12)	0.33	*	*
DFM (h= 24)	0.32	*	*
DFM (all frequencies)	0.22	*	*
CPI ex. 75% of the most volatile components	0.22	*	
DFM (pure inflation)	0.14	*	
CPI ex. 50% of most volatile components	0.14	*	
Band-pass filter (h=24)	0.11	*	*
Non-food products CPI ex. gasoline	0.08		
CPI ex. 50% of the worst forecasters of future inflation	0.05	*	*
Optimal trimmed CPI, optimality criterion: future inflation	0.05	*	*
Optimal trimmed-mean CPI, optimality criterion: moving average inflation	0.04	*	*
CPI ex. vegetables and fruits, gasoline, utilities	0.04	*	*
Volatility-weighted CPI	0.03	*	
CPI ex. 50% of the most sensitive components to shocks in SVAR	0.03	*	*
Core CPI (Rosstat)	0.03	*	
CPI ex.the eight most volatile components	0.02	*	
CPI ex. 50% of the most sensitive components to shocks in LPM	0.01	*	*
Weighted median	0.01	*	
Optimal trimmed inflation (real-time optimization)	0.01	*	*

2.3 Economic relevance of underlying inflation measures

Correlation with fundamental inflation indicators is presumably another property that a measure of underlying inflation should possess. This primarily relates to factors that reflect aggregate demand. Specifically, Bryan and Cecchetti (1993) test the relationship of underlying inflation measures with money supply, while Andrle et al. (2013) and Khan et al. (2013) test it with business cycle indicators.

In order to test this property, we estimate the standard equation (Filardo et al. (2014)):

$$\pi_t = \mu + \sum_{j=1}^{L} \Theta_j X_{t-j} + e_t \ , \qquad (3)$$

where π is the annual underlying inflation growth rate, X is the vector of explanatory variables (annual broad money supply growth rates and output gap[11]).

The estimation was conducted using quarterly data for the period 2002–2014. The number of lags equals L=4. We used R^2 as an indicator of correlation.

Apart from aggregate demand indicators, the relationship of underlying inflation measures with secondary effects (i.e. changes in inflation expectations, wage indexing) that follow price-level increases can characterize their macroeconomic content. Thus, we assume that irrelevant inflation fluctuations will not be reflected in the growth of nominal variables. Correspondingly, inflation measures net of such fluctuations will possess better characteristics as an explanatory factor for wage dynamics. In order to test this property, we estimate the standard equation (Zhang and Law (2010)):

$$w_t = \mu + \lambda \pi_{t-1} + \sum_{j=1}^{L} \Theta_j X_{t-j} + \sum_{j=1}^{L} \Omega_j w_{t-j} + e_t \qquad (4)$$

where w represents the quarterly rate of growth in the average nominal wage, π is the annual underlying inflation growth rate, X is the vector of other explanatory variables (unemployment and quarterly productivity growth[12]).

The estimation was accomplished using quarterly data for the period 2002–2014. The number of lags is L=4. The informative nature of the inflation indicator for wage dynamics is characterized by the significance of the (positive) coefficient λ.

The test results are given in Table 2. Most underlying inflation measures exceed the CPI in terms of R2 in equation (3), while the three best measures are indicators based on dynamic factor models. Two of these proved to be statistically significant as explanatory indicators for nominal wage dynamics.

[11] Based on the HP-filter
[12] The ratio of real GDP to the number of employed

Table 2 Results of assessing economic relevance of underlying inflation measures

Measure	***R^2 of equation (3)***
DFM (h=24)*	0.80
DFM (monetary inflation)*	0.79
DFM (h=12)	0.77
CPI ex. 75% of most volatile components*	0.76
Optimal trimmed CPI, optimality criterion: future inflation	0.76
Optimal trimmed CPI, optimality criterion: moving average inflation	0.75
CPI ex. 50% of the most shock-sensitive components in SVAR	0.74
Rosstat’s Core CPI	0.73
Weighted median	0.72
Optimal trimmed CPI (real-time optimization)	0.70
CPI ex. vegetables and fruits, gasoline, utilities	0.68
DFM (all frequencies)	0.68
CPI ex. 50% of the most volatile components	0.67
Volatility-weighted CPI	0.67
CPI ex. the eight most volatile components	0.64
CPI (for reference)	0.61
Band-pass filter (h=24)	0.60
Band-pass filter (h=12)	0.60
Non-food products CPI ex. gasoline	0.58
CPI ex. 50% of the most shock-sensitive components in LPM	0.56
DFM (pure inflation)	0.48
CPI ex. 50% of the worst forecasters of future inflation	0.34

* - indicators, for which t-statistics > 1.96 for λ in equation (4)

2.4 Overall assessment

The test results allow us to conclude that underlying inflation measures calculated on the basis of dynamic factor models (except for the ‘pure’ inflation indicator and indicator calculated with the help of the standard model without application of band-pass filter) possess the necessary properties as regards the requirements of underlying inflation measures. None of the other indicators (including Rosstat’s core CPI) possess the balance of properties required for obtaining satisfactory results in many-sided assessment. In this regard, we deem it expedient to use this methodology for the purposes of monetary policy. We therefore combine three measures of underlying inflation (Chart 1): indicators based on the standard dynamic factor model (with frequency thresholds of 12 and 24 months), and on 'monetary' inflation. Real-time estimates of this range and its median values are presented in Chart 2.[13]

We would assert that fluctuations of the magnitude we have obtained are economically interpretable and represent the main macroeconomic developments in the Russian economy in the past decade. In particular, we can see in the 2008-2009 period preceding the crisis of a clearly defined disinflation phase in 2003–2006 that gave way to the accelerated price growth in 2007–2008, which is consistent with the idea of the economy's overheating in the pre-crisis period. We also note that, for this period, underlying inflation measures would have served as more useful benchmarks for monetary policy than observed CPI and core CPI (their growth continued to slow down rapidly until the second half of 2007, which precluded the need for monetary tightening). In the post-crisis period, the dynamics of underlying inflation measures could also be considered as informative for monetary policy. Specifically, underlying inflation was observed to slow down along with the actual CPI in the period after the 2009 recession, reflecting the impact of aggregate demand fundamentals, whereas in the period 2010–2012, underlying inflation growth rates were sufficiently stable, despite sharp changes in CPI growth. Considering that these fluctuations were related to one-off short-term factors (the drought in 2010 and the changed procedure for indexing administered prices in 2012), the underlying inflation indices net of these factors were more useful for the purposes of monetary policy during this period as well. The presented indicators point to an increase in inflation rates in 2010–2011, which coincides with the period of recovery in economic activity, and the subsequent inflation slowdown in 2012–2013. Observing the sharp deviation of headline inflation from underlying inflation in 2015, one may conclude that it reflects the impact of temporary drivers of inflation related to adjustment of prices for imported goods due to the rouble's depreciation. The uncertainty surrounding the latest estimate has increased as the divergence among models has become larger.

[13] We present the latest data available (up to June 2015) although, as mentioned above, we conduct our assessment using the time sample from January 2002 to September 2014.

Figure 1 Range of underlying inflation measures based on dynamic factor models (annual growth rates, %)

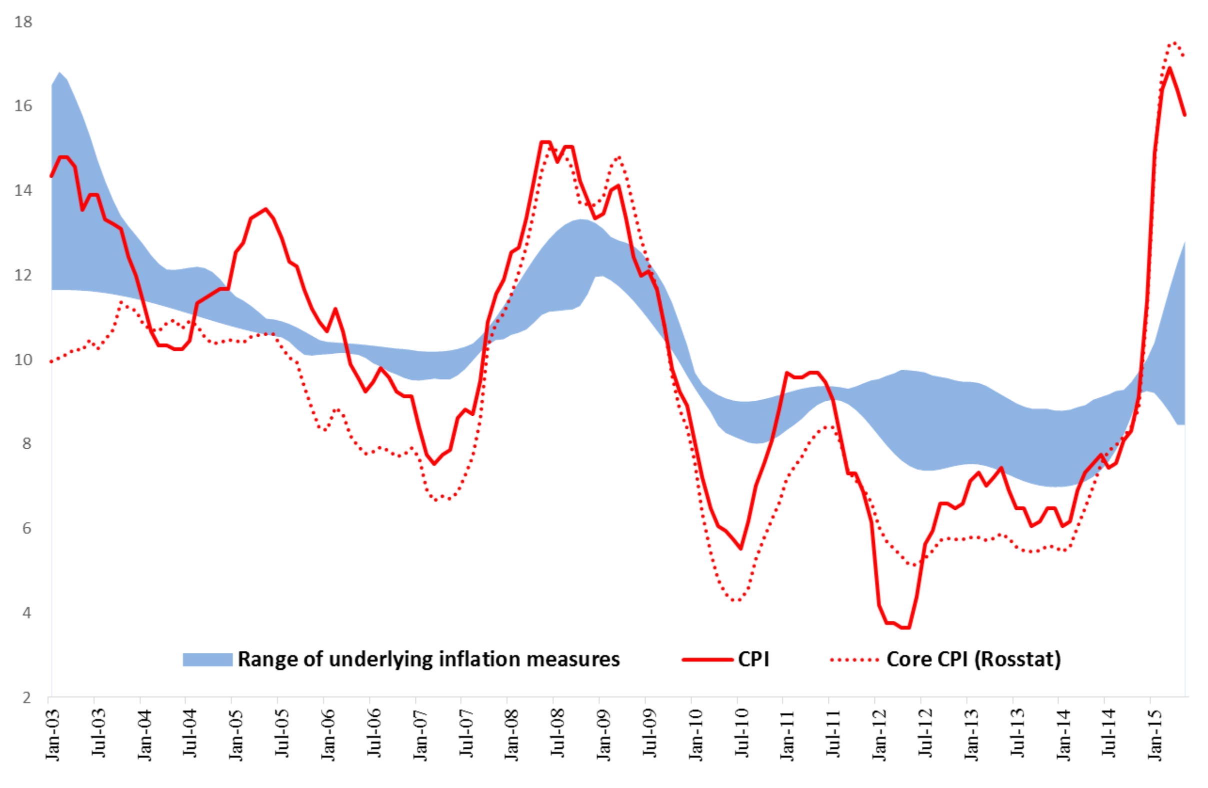
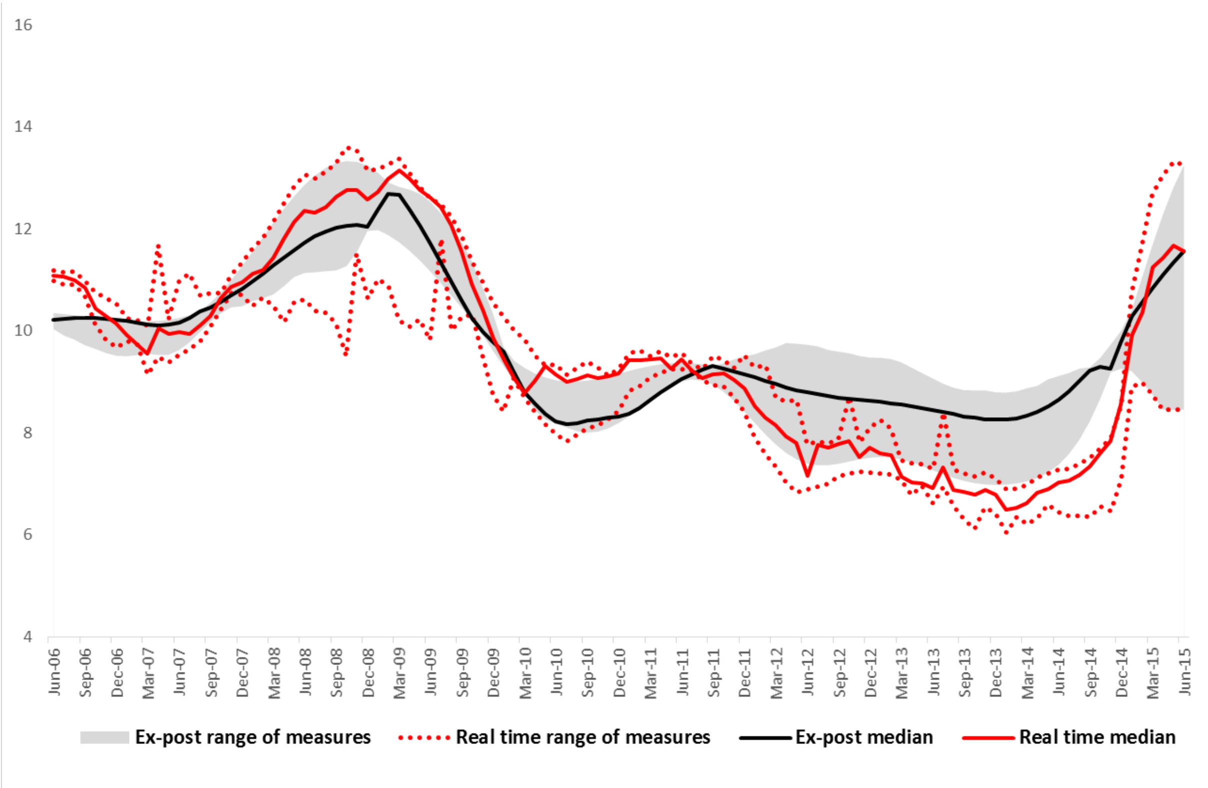


Figure 2 Range and medians of underlying inflation measures based on dynamic factor models (annual growth rates, %): final estimate and calculation in pseudo-real time



Conclusions

An underlying inflation measure, i.e. an inflation indicator that nets out shocks irrelevant for monetary policy, is a key indicator for a central bank whose main task is to maintain price stability. On the one hand, the use of such an indicator can help reveal inflation risks and, on the other hand, render monetary policy more balanced by preventing mechanistic responses to realized price changes irrespective of their nature. At the same time, there is no generally accepted method of determining which shocks are irrelevant for monetary policy. Instead, there are several methodologies for calculating underlying inflation and some criteria (which are not mutually exclusive but are not necessarily interrelated) that can be used to make an implicit estimation of the properties of the indicators obtained. Such methodologies were examined in this paper.

We calculated 20 underlying inflation measures, using four alternative approaches: exclusion, re-weighing, trimming, and estimation of an unobservable trend on the basis of dynamic factor models. We assessed the obtained indices with the help of tests characterizing three aspects of their properties: technical properties, usefulness for forecasting future inflation, and economic interpretability. We concluded that underlying inflation measures calculated with the help of dynamic factor models are the best performers according to formal tests. In particular, these indicators remained stable in the period of price shocks in 2010 and 2012 but reflected greater inflationary pressure in 2007–2008 and its decrease in 2009. As a result, these indicators remained informative in all the periods with regard to future inflation dynamics in the medium term and were closely related to aggregate demand fluctuations. We believe these indicators possess the necessary properties for the purposes of monetary policy.

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Appendix 1

Variables used in monetary dynamic factor model

Monetary indicators	***Price indicators***
M1, households (HH)	CPI
M1, non-financial corporations (NFC)	Core CPI
Term deposits in roubles, HH	Non-food prices
Term deposits in roubles, NFC	Food prices
Divisia M2	Services prices
M2Y	Fixed capital investment deflator
	Housing prices (primary market)
	Housing prices (secondary market)

Figure 1 Impulse response functions for the first (monetary) structural shock

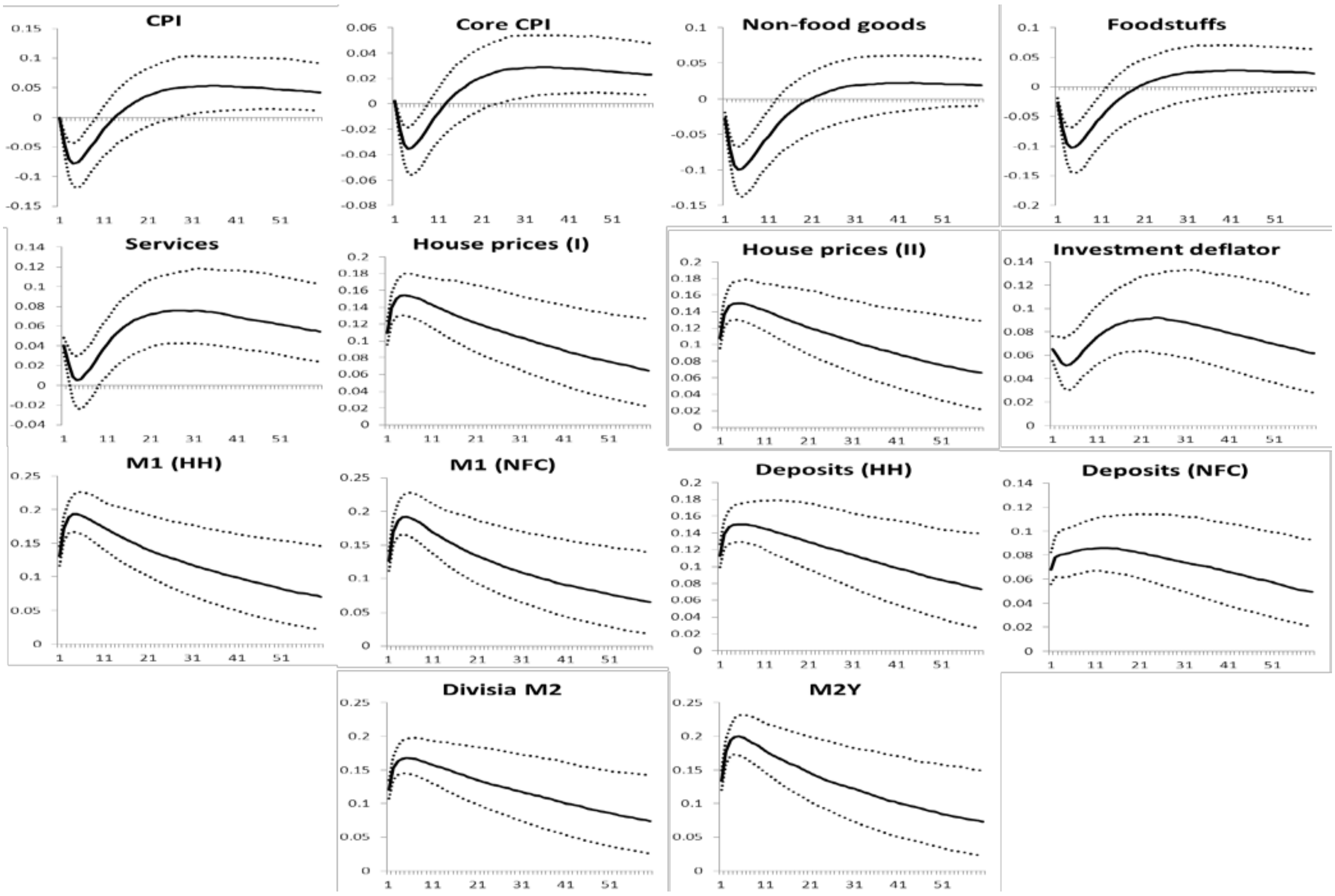
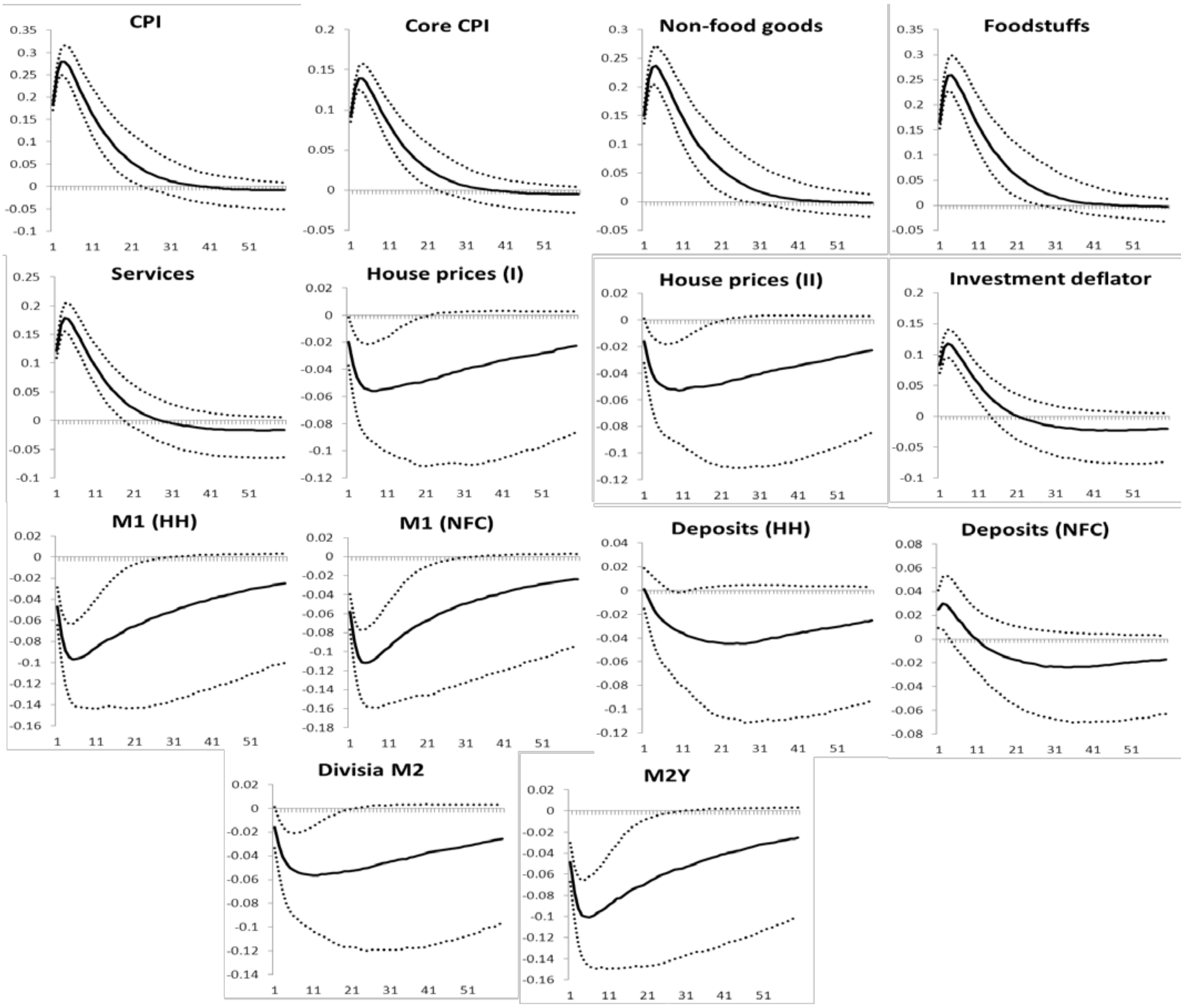


Figure 2 Impulse response functions for the second structural shock



Appendix 2

CPI components most frequently excluded from underlying CPI based on Lafleche and Armour's (2006) method in moving 24-month window. Percentage of all 132 samples.

Eggs	100
Sugar	100
Vegetables and fruits	100
Gasoline	99
Cheese	87
Pasta products	61
Communication services	54
Butter	46
Other services	45
Milk and dairy products	27
Passenger transport services	19
Other food products	19
Medicine	11
Bread and bakery products	10
Meat and Poultry	7
Alcoholic beverages	4
Phones	3
Tea and coffee	3
TV and radio sets	3
Fish and edible sea products	1
Personal computers	1
Housing and public utilities services	1
remaining components...	0

It follows from the table that historically the CPI components with the most unstable monthly inflation include eggs, sugar, vegetables and fruits, gasoline, cheese, communication services, pasta products – all of which were included in less than 50% of the underlying inflation indexes.

Appendix 3

Most frequently excluded CPI components, % of all pseudo-real time samples, i.e. the share of all parameterisations of the VAR model for determining sensitivity to shocks (overall, 120 observations from January 2005).

Meat and Poultry	100
Fish and edible sea products	100
Butter	100
Sugar	100
Tea and coffee	100
Bread and bakery products	100
Pasta products	100
Vegetables and fruits	100
Tobacco products	100
Electrical appliances	100
TV and radio sets	100
Personal computers	100
Phones	100
Gasoline	100
Medicine	100
Housing and public utilities services	100
Other food products	100
Other services	100
Confectionery	89
Furniture	73
Perfumery	43
Milk and dairy products	0
all remaining products and services...	0

Appendix 4

Table 1 Average absolute deviation of annual inflation growth rate from average level in moving 25-month period (p.p.)

Indicator	***Volatility***
DFM (h=24)	0.2
DFM (‘monetary’ inflation)	0.3
DFM (h=12)	0.4
DFM (‘pure’ inflation)	0.4
Inflation excluding 75% of the most volatile components	0.5
Non-food goods excluding energy and fuel	0.6
Shock-insensitive 50% CPI in LPM	0.6
Shock-insensitive 50% CPI in SVAR	0.6
Volatility-weighted inflation	0.7
Weighted median	0.8
Optimal trimmed CPI, criterion: future inflation	0.8
Inflation excluding 50% of the most volatile components	0.8
Exclusion of the eight most volatile components	0.8
Optimal trimmed CPI, criterion: moving average	0.8
DFM (all frequencies)	0.9
Optimal trimmed CPI (real time optimization)	0.9
CPI excluding vegetables and fruits, energy and housing, and utility services	1.0
Band-pass filter (h=24)	1.0
Band-pass filter (h=12)	1.3
50% CPI of the best future inflation predictors	1.3

Table 2 Cumulative deviation of underlying inflation from actual inflation 2003–2014 (%)

Indicator	***Deviation***
Inflation excluding 50% of the most volatile components	5.9
DFM (h=24)	2.1
DFM (h=12)	1.8
Exclusion of the eight most volatile components	0.9
Band-pass filter (h=24)	0.8
DFM (all frequencies)	0.4
Band-pass filter (h=12)	0.2
DFM (‘pure’ inflation)	–0.2
Optimal trimmed CPI (real time optimization)	–0.5
Volatility-weighted inflation	–1.6
Inflation excluding 75% of the most volatile components	–2.3
DFM (monetary inflation)	–3.0
Optimal trimmed CPI, criterion: moving average	–4.8
CPI excluding vegetables and fruits, energy and housing, and utility services	–5.2
Optimal trimmed CPI, criterion: future inflation	–9.1
Shock-insensitive 50% CPI in SVAR	–9.4
Shock-insensitive 50% CPI in LPM	–11.4
Weighted median	–11.8
50% CPI of the best future inflation predictors	–20.5
Non-food goods excluding energy and fuel	–29.1

Table 3 Deviation of final estimates of annual underlying inflation growth rates from real-time recursive estimates (p.p.)

Indicator	***Deviation***
Optimal trimmed CPI, criterion: moving average	0.0
Optimal trimmed CPI, criterion: future inflation	0.0
Weighted median	0.0
Optimal trimmed CPI(real time optimization)	0.0
Non-food goods excluding energy and fuel	0.0
CPI excluding vegetables and fruits, energy and housing, and utility services	0.0
Band-pass filter (h=12)	0.2
DFM (h=12)	0.4
DFM (h=24)	0.5
Band-pass filter (h=24)	0.5
Shock-insensitive 50% CPI in SVAR	0.9
Exclusion of the eight most volatile components	0.9
DFM (‘monetary’ inflation)	0.9
Volatility-weighted inflation	0.9
Shock-insensitive 50% CPI in LPM	1.2
DFM (all frequencies)	1.2
Inflation excluding 50% of the most volatile components	1.3
50% CPI of the best future inflation predictors	1.5
DFM (pure inflation)	1.6
Inflation excluding 75% of the most volatile components	1.7

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