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SVAR APPROACH FOR EXTRACTING INFLATION EXPECTATIONS GIVEN SEVERE MONETARY SHOCKS: EVIDENCE FROM BELARUS

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SVAR Approach for Extracting Inflation Expectations Given Severe Monetary Shocks: Evidence from Belarus

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Inflation expectations play a crucial role for macroeconomic dynamics and more specifically for monetary environment. However, inflation expectations is an unobservable variable. So, the quality of the correspondent measure in a great extent predetermines its feasibility for macroeconomic analysis. Today, survey-based measures of inflation expectations prevail in macroeconomic analysis. However, the drawbacks and/or unavailability of such measures give a rise to other identification strategies. Extracting inflation expectations from the actual data (e.g. series of interest rate and actual inflation) basing on SVAR identification approach has become a valuable alternative/supplement for measuring inflation expectations. In this paper I show that the existing strategy of inflation expectations identification through SVAR approach is very sensitive to the state of monetary environment. When a monetary environment is unstable (e.g. high and volatile inflation), the assumptions of the baseline approach are not hold, and it produces biased estimations. I emphasize two sources of this bias in estimations and suggest procedure for obtaining unbiased estimates. My identification strategy includes a number of steps. I suggest applying Markov regime-switching framework for extracting an unbiased mean for ex ante real interest rate. Further, I use two-stage SVAR identification strategy. First, I identify an unexpected shock to actual inflation, which is crucial for obtaining a proper measure of inflation expectations. Further, I net the series of ex post interest rate from this 'noise'. Second, I run a baseline SVAR procedure, for which I use the data adjusted at the first step. Finally I obtain an unbiased and informatively rich series of inflation expectations[2].

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[2] The code for the procedure reported in this paper is available from the author upon request.

1. Introduction

Inflation expectations (hereinafter, IE) play an important role in macroeconomic dynamics through affecting the decisions of economic agents. For instance, households' IE have an effect on their consumption choice and through this affect the aggregate demand in the economy. Firms' IE affect the supply side of the economy and directly drive their price-setting decisions. Hence, the most important economic indicators – output and prices – are driven in this or that extent by expectations.

In applied research, IE are most widely studied as the driver for actual inflation. Through this, the studies dealing with IE mainly belong to the fields of monetary policy and monetary economics. During two last decades focusing on IE have become especially popular, as more and more central banks in the world tend to introduce inflation targeting (IT, hereinafter) as their monetary policy regime.

By definition, studying IE faces with the issue of its proper identification, as expected inflation is an unobservable variable. This challenge was addressed in different manners depending on the prior objectives of quantifying IE, available data and other circumstances. Until recently, survey-based measures prevailed in research, especially in those dealing with monetary policy issues. However, the measure of IE based on financial market data has been a rival identification strategy. In recent years, a kind of unification trend has matured, and new mixed measures (i.e. those combining both survey and market-based measures) have got increasing popularity.

In Belarus, proper quantification of IE has actually not been addressed thoroughly, as the country's monetary policy was definitely backward-looking. So, IE have almost been out of the agenda of monetary issues for a long time. A scarce mention of IE in the research context of Belarusian monetary environment took place in Mironchik (2010). Since recently, National bank of Belarus (hereinafter, NBB) began to compute and present a survey-based indicator of IE stemming from the poll of firms. However, this indicator is far from being a full-fledged IE measure. First, it measures the expectations of firms, while for the IE context the survey of households is more meaningful. Second, a number of characteristics of the survey (for instance, there is a selection bias towards state-owned and large firms) cause doubts in respect to the informational content of the indicator. Third, the indicator is presented only in the form of 'balance of responses', which narrows its applied utilization.

At the same time, quantifying and studying IE for the Belarusian case seems to be promising in many respects. First, the informative content of monetary data in Belarus is extremely rich. In its recent history the country has experienced periods of relative price stability interchanging with currency crises and episodes of huge inflation jumps. Second, Belarusian case contains evidence of IE formation under different monetary policy frameworks. The country has experienced a number of shifts in monetary policy framework: from pure discretion in the beginning of 2000s via different forms of currency peg during 2003-2014 to monetary targeting as of today (with the plans to introduce IT since 2020). Third, IE in Belarus might be the case of 'unexplored wilderness', as there were roughly no attempt to anchor expectations from the side of monetary authorities. So, Belarus may be a good background for studying IE in the context of unstable monetary environment.

Just instability of monetary environment gave a rise to most novelties in this paper. While adequate survey-based measures of IE are unavailable for Belarus, extracting it from financial market data becomes the first choice. In turn, tenuity of Belarusian financial market in terms of number of instruments, determines the choice in favor of methodology relying upon extracting data from nominal interest rates. Hence, I treat the approach developed by St-Amant (1996) and Gottschalk (2001a) as the baseline methodology for extracting IE for Belarus. However, this methodology cannot be applied to the Belarusian case in directly, as a number of explicit and implicit assumptions in it do not hold vs. the context of unstable monetary environment.

I show that in case of huge jumps and large volatility in inflation rate, the assumption about mean zero inflation forecast error does not hold. In respect to the baseline methodology, the outcome is the biased mean of the IE estimate. Further, inflation shocks automatically leads to a significant difference between real ex ante and ex post interest rates. The latter leads to violated assumption about data generation process (hereinafter, DGP), which produces additional bias in IE estimates during the periods of monetary instability. In this paper, I propose a framework to cushion the pitfalls of baseline methodology and to get rid of its sensitivity to the stance of monetary environment. I show that this methodology produces unbiased estimates for IR even in case of huge shocks in monetary environment. Finally, I apply this methodology to Belarusian data and construct the measure of IE with a rich informational contents and high predictive power for actual inflation rate.

The rest of the paper is organized as follows. In Section 2 I provide literature review and visualize the place of this study within the broad context of researches dealing with IE. Section 3 is devoted to the description of the baseline methodology and its pitfalls in case of unstable monetary environment. In Section 4 I formulate my adjustments to the baseline methodology, which allows generating unbiased estimates that are also not sensitive to monetary shocks. Section 5 deals with Belarusian data and reports the results of IE extraction procedure for the country. Section 6 summarizes the results of the study and reports main conclusions.

2. The importance of inflation expectations and their proper measurement

Since seminal papers of Muth (1961) and Lucas (1972) expectations of economic agents, and more specifically inflation expectations, has become one of the central pillar in macroeconomic analysis. Within the new Keynesian framework, which today plays a role of the main work-horse for monetary policy analysis, expected inflation plays a crucial role in actual inflation dynamics, coming straightforwardly into inflation equation (e.g. New Keynesian Philips curve equation in Clarida, Gali and Gertler, 1999 or Gali, 2008). This forms a kind of academic consensus about the role of IE in macroeconomic dynamics.

Nevertheless, some elements of conceptual discussion about the role of expectations still appear on the agenda. For instance, Palley (2012) focuses on the distinction between "formation" of inflation expectations and "incorporation" of inflation expectations within the Philips curve theory and argues about too much emphasis on the former, which may narrow the boundaries of the analysis. But majority of other 'conceptual' papers mainly provide new evidence about the role IE in macroeconomic dynamics. For instance, Brissimis and Migiakis (2016) test rational expectations hypothesis. They support it holds in the long-run, while in the short-run forecasters adjust their expectations slowly. Their finding supports the view that the persistence of inflation comes from the dynamics of expectations. Gabriel (2010) provides an empirical evidence of the significant effect of IE of households on prices and wages in the economy. Boneva et al. (2016) provide micro-foundations for the macro view at the IE, by having showed that firms' expectations play a crucial role for their price-setting behavior.

A huge portion of studies dealing with IE focuses on expectations and their role within IT framework. This reflects and stresses the emphasis of IT regime on anchored IE.

Correspondingly, the issue of anchoring IE and measuring the degree of anchoring are most popular in such kind of studies. For instance, Kelly (2008) provides evidence that anchored inflation expectations enhance price stability and is crucial for the effective monetary policy under IT regime. Strohsal and Winkelmann (2014) suggest a methodological framework for testing the degree of anchoring of IE. Nautz and Strohsal (2015) deal with the issue of long-term anchoring of IE. They assume that well-anchored IE should be sensitive to news and also suggest a framework for testing the degree of anchoring of IE.

Pretty often IE and IT context provides individual country-based evidence. For instance, Lyziak (2006) shows some success in anchoring IE by the central bank through introduction of IT. Holub and Hurnik (2008) provide evidence of successful anchoring of inflation expectations due to the introduction of IT in Czech Republic. Aguilar et al. (2014) provides evidence about importance of anchoring expectations in medium and long-term perspective basing on the example of Mexico. Gabriel (2010) broadens individual country analysis and projects it on emerging-developed country framework. He argues that IE in transition economies (Hungary as an example) are much less anchored, and correspondingly higher and more volatile than in developed economy (UK as the example)

A range of researches touches upon an issue of IE being subject to effect of adverse shocks. Aguilar et al. (2014) show that supply shocks may disturb IE, making them volatile and unanchored. Lyziak (2016) deals with the impact of shocks (global crisis and low inflation environment) on IE for Poland. He shows that during shocks IE in Poland become more sensitive to interest rate changes and development in real economy. Moreover, he shows that unstable environment also leads to less control of IE by the National bank of Poland. The issue of the IE sensitivity to adverse shocks seems to be important in many respects. First, it challenges the dominating view about the ability of central bank to unconditionally anchor IE. Second, it gives a rise to the analysis of monetary environment in a regime-switching manner. A similar idea, for instance, has been expressed in Viren (2006), who considers a regime-switching monetary environment, which is predetermined by more broadly understood macroeconomic regime-switching.

The bulk of mentioned researches actually visualize the importance of IE in macroeconomic analysis. But there is one more important issue about IE – this variable is unobservable. So, one cannot measure in a straightforward manner and correspondingly statistical offices cannot provide it on a regular basis. Hence, developing a proper measure of IE becomes a 'value for its own sake', as the quality of solving all the applied tasks interlinked with IE correspondingly depend on the feasibility of IE measure. This conceptual challenge has got two types of responses. The first one aims at reproducing actual IE by means of studying its formation (data generating) process. The second one develops approaches to proper measurement of IE.

The most influential pieces of research about IE formation process base on experimental design. For instance, Odries and Rodriguez (2013) conduct a number of experiments for studying the process of forming of IE. They conclude that IE (i) are seldom rational, (ii) a large piece of available information is ignored by forecasters, (iii) but introduction of inflation targeting makes forecasting more rational, (iv) while the periods of recessions reduce the degree of rationality by forecasters. A collection of some other stylized facts about IE formation was gathered by Curtin (2010) basing on the dataset from the Michigan consumer survey. He admits that: (i) there is considerable heterogeneity in inflation expectations, (ii) inflation expectations are forward looking; (iii) consumers do not efficiently utilize all available information; (iv) negative changes in the inflation rate have about twice the impact as positive changes, (v) there is evidence of staggered updating; (vi) all these findings do not result from offsetting errors across demographic groups. The outcome about heterogeneity on IE formation has been admitted in Frizler and Rumler (2015), who show the dependence of IE on social economic and demographic characteristics of households, and by Ballantynea et al. (2015) who mainly associate the issue of heterogeneity with demographic factors. Some country specific drivers of IE formation were detected in studies for Latin America countries. Licandro and Mello (2015) provide some ground of rationality in IE using the case Uruguay, showing that news affect IE by economic agents. Pincheira (2013) consider the case of Chile and provides an evidence of a meaningful role of exchange rate interventions as the driver for IE for this country.

Another strand of research put the IE formation process out of the boundaries of the analysis and focuses just on proper measurement of IE. Within this strand one can stress studies dealing with (i) survey-based measures, (ii) measures of IE extracted from financial market data; (iii) 'theoretical' measures of IE (this approach overlaps with IE DGP more thoroughly), (iv) mixed measures.

Survey-based measures have become the most widespread ones in respect to IE. The most evident reasons for domination of such measures are: (i) direct approach to measurement[3], (ii) simplicity and clearness for understanding and interpreting; (iii) availability in any economy[4]. A major traditional objection against survey-based measures – bad scaling, i.e. adjusting it to actual inflation scale requires additional assumptions and leads to deteriorating quality of the indicator. However, during last couple of decades, a meaningful response has been, which although have not removed such objections from the agenda, but mitigated them considerably. For instance, Curtin (1996) developed a methodology to construct the estimates of IE from Michigan household survey data. This quantifying strategy, the list of advantage of survey-based measure alongside with a high credibility and authority of Michigan consumer survey, has secured a corresponding IE measure to be the most popular in the US. This measure of IE became dominating in FED's analysis of monetary policy and in academic researches as well. Having this experience in mind, survey-based IE measures has got leading positions among central banks and academic communities in majority of other countries.

However, during the last decade survey-based measures began to lose its popularity somehow, as researchers have shown a number of inconsistencies peculiar to such measures. For instance, Fukac (2005) showed that on the one hand, survey-based measures of IE are informative in terms of predictive power for the interest rate and statistically does not differ from the market expectations. On the other hand, he witnessed that it did not have any predictive power for the actual inflation. De Bruin et al. (2010) have shown more evidently a number of inconsistencies embedded into survey-based measures by default. For instance, they provided evidence that in plenty of cases respondents vary in their interpretation of a question, which automatically leads to misinterpretation of the results. Moreover, they admit that the disagreement between respondents captured by the dispersion in their point forecasts is not always a good proxy for uncertainty about future inflation. So, they concluded that these drawbacks may squeeze the informative contents of the correspondent measure. Ehrmann, Pfajfar and Santoro (2015) showed that social and

[3] A frequent objection in respect to financial data – it may include 'noise' that has nothing to do with expected inflation. In turn, in case of survey-based measures respondents are assumed to answer directly about their expectations of price dynamics in future, which intended to prevent any 'noise' of such kind in the data.
[4] This argument assumes that no special conditions are needed for measuring IE. Consumer survey with a correspondent set of questions may be conducted in any economy.

economic characteristics of households affect the forecast accuracy, which also may give a rise to doubts to a survey-based measure.

'Theoretical' measurement of IE has become a partial alternative to a survey based measurement. Carrol (2003) gave a rise to 'theoretical' approach to identifying expectations. Carrol (2003) shows that although empirical household expectations are not rational in the usual sense, expectational dynamics are well captured by a model in which households' views derive from news reports of the views of professional forecasters, which in turn may be rational. This model born by this approach generates 'sticky' expectations that are consistent with actual available date. The latter enhance using the model as the expectations generator in case when the other measures of it are unavailable For instance, Dopke et al (2006) show that for four major European economies Carrol's model reproduces data on inflation expectations feasibly.

A similar approach may be used in respect to the models by Christiano, Eichenbaum and Evans (2005) and Smets and Woters (2003, 2007). Their DSGE model for monetary policy analysis, may supplementary be used for generating 'theoretical' measure of IE. However, Del Negro and Eusepi (2011) show that these measures are not informatively sufficient to be treated as full-fledged measures of IE. Moreover, the variant of 'theoretical measure', which assumes that agents have imperfect information, is strongly rejected by the data.

Doubts of reliability, the necessity to rely upon a specific monetary policy model, and relative complexity of a strategy suppressed the development of theoretical management. Under these circumstances the measures of IE extracted from financial data have become a major alternative to survey-based measures. St-Amant (1996) suggested a clear and theoretically consistent approach for extracting IE expectations series from the data on nominal interest rate. Technically, he employs Blanchard and Quah (1989) identification strategy, and applies an identification condition for structural vector autoregression (hereinafter, SVAR) from theoretical considerations. This framework was broadened and systemized by Gottschalk (2001a), who applied it to the analysis of IE in the Euro area. This pioneering strategy of extracting the IE series from actual data has got numerous gains such as: (i) direct, clear and theoretically consistent sense of measurement; (ii) the measure has got the same scale as actual inflation; (iii) the approach can easily be run for any economy and requires just the date on nominal interest rates and actual inflation, which are roughly always available. These gains gave a rise to other numerous strategies pf extracting IE from financial data. For instance, Kajanoja (2004) suggest a framework for extracting inflation expectations (along with long-run GDP growth) from stock and bond market data. Alonso, Blanco and del Rio (2011) focus on proper techniques that allow to extract the unbiased estimates on IE from the data on inflation-indexed bonds. However, possible pitfalls might be a problem for market-based measures as well (as in case of survey-based measures). For instance, Kajuth and Watzka (2011) admit the issue that liquidity and inflation-risk premiums affect the quality of IE indicators being extracted from index-linked bonds. They propose a methodology to cushion the problem and derive a measure with a higher predictive power for annual inflation rate than 'raw' measures. Casiraghi and Miccoli (2015) propose a way to compute market-based risk-adjusted measures of inflation expectations. They deal with the ex-post excess return on inflation swap contracts – the difference between the swap rate at a given maturity and the realized inflation rate over the same horizon – which is considered as an unbiased proxy of risk premia under the rational expectations hypothesis. Using it, further they construct a measure of risk-adjusted inflation expectations so as to assess the role of risk premia in determining inflation swap rates. Miccoli and Neri (2015) show that the information contents of market-based IE measure may be somehow misleading. They provide evidence for Euro area that measures based on inflation swaps are affected 'over and above' the impact of changing macroeconomic conditions and oil prices.

During last couple of years, one can admit a trend towards a 'compromise' among the measures of IE. One the one hand, there is plenty of accumulated evidence about drawbacks of both survey and market-based measures. On the other hand, there is also plenty of evidence that both groups of measures contain useful information for the purposes of monetary policy. For instance, Bauer (2014) provides evidence that both market-based and survey-based measures of IE are interrelated and are meaningful in terms of explaining nominal interest rates variation. Moore (2016) compares survey-based and market-based measures of IE for Austria. He concludes that in a low inflation environment there is a divergent trend between these measures and market-based measures have moved lower than survey-based measures. The main explanation for these changes according to Moore (2016) is the inflation risk premium. Also, he argues that the bond-based measure is likely to have been affected by a time-varying liquidity premium. However, these conclusions does not transform into prioritizing this or that measure, still assuming that both groups are informatively valuable for monetary policy.

An elaboration of mixed measures of IE may be considered as the outcome of this ‘unification’ tendency and the freshest trend in IE measurement. For instance, Kapetanios, Maule and Young (2016) emphasize the importance of considering information contained in different measures of IE and correspondingly elaborate a new summary measure of the term structure of IE. But another mixed IE measure – the one developed by the Federal Reserve Bank of Cleveland (Haubrich, Pennacchi, and Ritchken, 2011 and Haubrich, 2009)– seem to have become a new trendsetter in the branch. This measure combines the data from nominal interest rates, inflation swaps and two survey measures of IE (including those from Michagan survey). It is argued to be ‘cleaner’ and more useful in terms of information contents for monetary policy and predictive power for actual inflation.

3. Baseline methodology and its limitations

3.1 The summary of baseline methodology

The strategy developed by St-Amant (1996) and Gottschalk (2001a) starts from theoretical foundations. Nominal interest rate is viewed as consisting of ex ante real interest rate and expected inflation (1).

$$i_t = rea_t + \pi_t^e \qquad (1)$$

where i_t – nominal interest rate, rea_t – ex ante real interest rate, π_t^e – expected inflation.

It should be also emphasized that both rea_t and π_t^e are unobservable variables, while i_t is an observable one. This view of nominal return may be applied to any financial instrument with any term, and which determines the interpretation of the correspondent decomposition. For instance, if one deals with an interest rate on 6 months deposits, a correspondent decomposition will include ex ante real rate for such deposits, and today’s expectation of inflation by deposit holders for *t+6* months ahead.

Further, a simplified version of Fischer equation (2) is used for the analysis:

$$rep_t = i_t - \pi_t \qquad (2)$$

where rep_t – ex post real interest rate, π_t– actual inflation.

Herewith, one must admit that for theoretical consistency π should enter the equation (2) with a sub-index of *t+1.* However, this emphasis on a strict matching between the periods is often skipped in applied analysis. Otherwise, it sophisticates computation of real ex post interest rate and makes this computation impossible on real-time basis. Moreover, just this approach is more consistent with the view that expected inflation for *k* periods ahead affects actual inflation rate today, but not the actual rate in *k* periods ahead. In this paper, I follow this widely used simplification and treat rep_t directly in the manner of (2).

A next variable of interest is the inflation forecast error, which is introduced according to (3):

$$\Delta_t = \pi_t^e - \pi_t \qquad (3)$$

where Δ_t – inflation forecast error.

Combining (1) and (2) one can derive the relationship between real ex ante and ex post real rates using inflation forecast error (4):

$$rep_t = rea_t + \pi_t^e - \pi_t = rea_t + \Delta_t \qquad (4)$$

The next step is focusing on dynamic characteristics of individual variables engaged into the analysis. It is expected that: $i_t \sim I(1)$, $\pi_t^e \sim I(1)$, $\pi_t \sim I(1)$, while $rea_t \sim I(0)$, $rep_t \sim I(0)$, and $\Delta_t \sim I(0)$ [5]. This combination of dynamic characteristics causes a number of important conclusions for the variables of interest.

First, one may argue that in (1) π_t^e is the only source of non-stationarity of i_t. The latter also may be interpreted as rea_t having no permanent effect on the level of i_t, or equivalently, causing a zero long-run effect on the first difference of i_t.

Second, the condition of $\Delta_t \sim I(0)$ actually assumes that π_t^e and π_t are cointegrated. The statement that π_t^e and π_t share common trend allows treating Δ_t as being driven by just one type of shock (not two different shocks according to 3), which may be treated as the shock to inflation expectations. Hence, (4) may be interpreted as: rep_t (which is a stationary variable) is driven by two types of shocks – those to ex ante real interest rate and those to inflation expectations. Having said this, one may consider i_t and rep_t as variables being driven by two same shocks, i.e. shocks to rea_t and π_t^e.

[5] The procedure also assumes testing whether these assumption hold in reality. For the datasets in St-Amant (1996) and Gottschalk (2001a) these assumptions are supported by tests.

Having both conditions in mind, we can consider the DGPs for Δi_t[6] and rep_t according to (5):

$$\begin{cases} \Delta i_t = \mu_t^{\Delta i} + \sum_{i=0}^{n} \alpha_i^{rea} * v_{t-i}^{rea} + \sum_{i=0}^{n} \alpha_i^{\pi^e} * v_{t-i}^{\pi^e} \\ rep_t = \mu_t^{rep} + \sum_{i=0}^{n} \beta_i^{rea} * v_{t-i}^{rea} + \sum_{i=0}^{n} \beta_i^{\pi^e} * v_{t-i}^{\pi^e} \end{cases} \qquad (5)$$

where $\mu_t^{\Delta i}$ and μ_t^{rep} are expected values of Δi and rep; v^{rea} and v^{π^e} are shocks to rea and π^{ε} correspondingly; α_i^{rea}, $\alpha_i^{\pi^e}$, β_i^{rea}, $\beta_i^{\pi^e}$ are coefficients.

According to this notation, the condition of zero long-run response of Δi_t to v^{rea}means that:

$$\sum_{i=0}^{n} \alpha_i^{rea} = 0 \qquad (6)$$

Together (5) and (6) forms a framework similar to those in Blanchard and Quah (1989), or in a more general manner it may be treated as a structural system with permanent and transitory shocks (Pagan and Pesaran, 2008). The strategy for identifying these shocks assumes the following steps:

A). Estimation of a reduced VAR consisting of the variables driven by the same shocks. A variable with a non-stationary component enters into the VAR as the first difference. In respect to the current study the VAR to be estimated looks like:

$$\begin{bmatrix} \Delta i_t \\ rep_t \end{bmatrix} = \begin{bmatrix} c_i \\ c_{rep} \end{bmatrix} + C(L) * \begin{bmatrix} \Delta i_t \\ rep_t \end{bmatrix} + \begin{bmatrix} \varepsilon_t^i \\ \varepsilon_t^{rep} \end{bmatrix} \qquad (7)$$

where c_i and c_{rep} - constants, $C(L) = \begin{bmatrix} C_{i,i}(L) & C_{i,rep}(L) \\ C_{rep,i}(L) & C_{rep,rep}(L) \end{bmatrix}$, $C_{i,i}(L)$, $C_{i,rep}(L)$, $C_{rep,i}(L)$, $C_{rep,rep}(L)$ – polynomials in the lag operator L, ε_t^i, ε_t^{rep} –reduced form innovations.

B). Identification of the structural form of the reduced VAR (7), using (6) as the long-run identification condition. This allows estimating corresponding structural innovations that are uncorrelated to each other according to (8):

$$\begin{bmatrix} u_t^i \\ u_t^{rep} \end{bmatrix} = B^{-1} \begin{bmatrix} \varepsilon_t^i \\ \varepsilon_t^{rep} \end{bmatrix} \qquad (8)$$

where B – is the matrix of structural factorization, u_t^i, u_t^{rep} – structural innovations.

[6] One may equivalently consider the date generation process for i_t in levels (consisting of the same shocks). But using the 1st difference here is more convenient for a further move towards SVAR context.

Alongside, structural factorization allows identifying correspondent impulse response function $\Phi_{m,n}$, which measures the responses of variable *m* to innovation in variable *n* in period between 0 and t. A correspondent polynomial representing cumulative impulse response I denote as $\Phi_{m,n}(L)$.

C). Identification of structural innovations and structural impulse responses allows representing SVAR in a moving average form:

$$\begin{bmatrix} \Delta i_t \\ rep_t \end{bmatrix} = \begin{bmatrix} \overline{\Delta \iota} \\ \overline{rep} \end{bmatrix} + \Phi(L) * \begin{bmatrix} u_t^i \\ u_t^{rep} \end{bmatrix} \qquad (9)$$

where $\Phi(L) = \begin{bmatrix} \Phi_{i,i}(L) & \Phi_{i,rep}(L) \\ \Phi_{rep,i}(L) & \Phi_{rep,rep}(L) \end{bmatrix}$

The system (9) is interpreted as the estimation of the system (5), and u_t^i is interpreted as estimated $v_t^{\pi^e}$, while u_t^{rep} as estimated v_t^{rea}.

A term $\Phi_{rep,rep}(L) * u_t^{rep}$ in the 2nd equation of (9) may be interpreted as the transitory component of rea_t (i.e. its deviation from a correspondent mean). Hence, once knowing $\overline{rea}$ one can estimate rea_t.

D). St-Amant (1996) does not show explicitly his assumption in respect to $\overline{rea}$, but from indirect considerations it might be assumed that $\overline{rea} = \overline{rep}$. Gottschalk (2001a) employs the band-pass filter by Baxter and King (1995). So, finally having an estimate in respect to $\overline{rea}$, one can estimate:

$$rea_t = \overline{rea} + \Phi_{rep,rep}(L) * u_t^{rep} \qquad (10)$$

$$\pi_t^e = i_t - rea_t \qquad (11)$$

3.2 The pitfalls of the baseline methodology

A first and the most evident pitfall of the baseline methodology stems from the *assumptions* about $\overline{rea}$. The simplest assumption of $\overline{rea} = \overline{rep}$ equivalently means that $\overline{\Delta} = 0$. The latter is usually justified by the rational expectations hypothesis. However, one can refer to numerous evidences of rational expectations hypothesis empirical rejection (Faik, 2001; Conte et al., 2007). More than this, even if the rational expectation hypothesis holds, it does not guarantee the condition of $\overline{\Delta} = 0$ in respect to the whole sample if a huge monetary shock took place within the sample. For instance, even if the cointegration vector of π_t^e and

π_t has got coefficients (1,-1)', huge short-term shocks (either to actual inflation, or to inflation expectations) would cause a substantial difference between π_t^e and π_t t through a number of periods. If this difference is huge enough, while the restoration of equilibrium is pretty long enough, it would secure $\overline{\Delta} \neq 0$ for the whole sample[7]. If there is a number of periods of monetary instability, which are unidirectional (e.g. unexpected shocks in actual inflation secures prolonged periods of $\overline{\Delta} < 0$ or $\overline{\Delta} > 0$), $\overline{\Delta}$ may deviate from zero substantially. The latter equivalently means that assumption $\overline{rea} = \overline{rep}$ produces bias, and the estimate of rea_t according to (10) will include this bias.

A more advanced approach is used in Gottschalk (2001a) and assumes applying Baxter-King band-pass filter for estimating $\overline{rea}$. Employing the band-pass filter is justified by the assumption that DGP for rea_t includes a constant subject to a level shift according to (12):

$$rea_t = c^{rea} + Shift + \rho * rea_{t-1} + \varepsilon_t^{rea} \qquad (12)$$

where c^{rea} – constant term, $Shift$ – a term indicating either time trend or level shift, ρ – coefficient, ε_t^{rea} – residual term.

In this case, a measure $(c^{rea} + Shift)$ is considered to be the equilibrium level for rea_t, and should be used instead of (or as the measure of) $\overline{rea}$ in (10). In turn, Baxter-King band-pass filter is effective in extracting a measure like $(c^{rea} + Shift)$.

It must be stressed that a choice in favor of Baxter-King band-pass filter and assumed DGP according to (12) in Gottschalk (2001a) is highly motivated by the data on real interest rate used for the Euro area, which was expected to contain structural breaks leading to lowering equilibrium interest rate. In this case "the equilibrium real interest rate is approximated with the underlying trend in the real interest rate, which is estimated with the band-pass filter… this methodology ensures by construction that the deviations of the ex-ante real short-term rate from the trend path are stationary".

However, for a general case treating DGP for rea_t according to (12) contradicts to the expected DGP in (5). The latter assumes 'normal' stationarity of rea_t, not stationarity around the trend. Hence, straightforward employment of Baxter-King filter in a general case, unless there is a strong support for the DGP according to (12), will lead to capturing of a

[7] For this kind of situation I use the term monetary instability and correspondingly a term monetary stability if there is no signs of such situation.

fraction of fluctuations that are to be captured during the SVAR identification (steps A, B, and C) within a Baxter-King underlying trend, i.e. within the estimate of $\overline{rea}$ in (10). So for a general case, the estimate of $\overline{rea}$ by Baxter-King band-pass filter will be biased as well, causing the bias of rea_t estimate in (10).

If a data set considered includes relatively long periods of monetary instability, the bias produced by Baxter-King band-pass filter might expand, as swings in Δ_t will not be properly captured as the noise, but partially as a level shift according to $(c^{rea} + Shift)$ view. The size of such kind of bias also depends on the assumed parameters of Baxter-King filter. However, adjusting parameters to capture the periods of monetary instability properly might result in improper capturing of the underlying trend value throughout 'normal' periods. The latter forms one more disadvantage of applying Baxter-King band-pass filter as the device for estimating $\overline{rea}$.

A second – less evident, but more substantial – failure of the baseline methodology stems from simplifying assumptions about (4) that allow interpreting the DGP for the variables of interest as (5). As shown above, the statement that $\Delta_t \sim I(0)$ and π_t^e and π_t gives a rise to interpretation of rep_t as being driven by two, not three types of shocks. However, such an assumption would be correct if and only if the cointegration vector of π_t^e and π_t has got coefficients (1,-1)'. The latter would also mean (in case there are no periods of monetary instability) that not just $\Delta_t \sim I(0)$, but also $\overline{\Delta} = 0$, and $\overline{rea} = \overline{rep}$.

However, even in general case there is no theoretical grounds to peremptory statement that the cointegration vector is (1,-1)'. Moreover, if one deals with a situation when periods of huge monetary shocks are present in the sample, it might be even more common that $\overline{\Delta} \neq 0$, and $\overline{rea} \neq \overline{rep}$. The latter means that in a general case dealing with (4), one must consider rep_t as being driven not by two, but by three types shocks. Hence, one must distinct among: v^{rea} – a stationary shock to rea_t, v^{π^e} – a shock to IE (with a permanent component) that is shared with actual inflation, and v^{π} – an unexpected shock to actual inflation. Also v^{π} might be interpreted as the residual term in cointegrating equation between π_t^e and π_t:

$$\pi_t = c^{\pi} + \gamma * \pi_t^e + v_t^{\pi} \qquad (13)$$

where c^{π} – constant term, γ – coefficient, v_t^{π} – residual term.

In case of monetary stability ignoring v^{π} does not produce a systematic bias, as $\overline{v^{\pi}} = 0$. But in case of monetary instability, $\overline{v^{\pi}} \neq 0$ (moreover, the condition of $v_t^{\pi} \sim I(0)$ might not hold for the whole sample, and might hold only if controlling the breakpoints). Hence, ignoring v^{π} and dealing with a specification (5) during the periods of monetary instability will not be consistent with the reality. A variation associated with v^{π} which is not anticipated by the specification in (5) will be assigned to v^{rea} and v^{π^e}. More than this, while v^{π} is defined in a way to have only a transitory component, it means that a huge fraction of the correspondent variation will be assigned to another shock that is constructed to have only transitory component, i.e. v^{rea} in terms of (5). In SVAR estimation framework it means that it will be assigned to the transitory term $\Phi_{rep,rep}(L) * u_t^{rep}$ of rea_t in (10). Hence, one may expect that during the periods resulting in $\overline{\Delta} > 0$, the baseline methodology will overestimate rea_t and underestimate π_t^e, and on the contrary, during period of $\overline{\Delta} < 0$, the baseline methodology will underestimate rea_t and overestimate π_t^e.

4. Fine-tuning SVAR strategy of IE identification

4.1 Estimating the mean of ex ante real interest rate

As shown above, I argue that specification (12) might be a special case for rea_t. As a general DGP for rea_t I consider (14):

$$rea_t = c^{rea} + \sum_{i=1}^{k} \delta_i * T * D_i + \sum_{j=1}^{l} LS_j * D_j + \varepsilon_t^{rea} \qquad (14)$$

where c^{rea} – constant, T – time-trend, LS – constant term indicating level shift, i and j - time periods corresponding to structural breaks (periods of trend growth and/or level shifts) in rea_t, D_i, D_j – dummy variables corresponding to the periods i and j ($D_i = 1$ if $t \in i$ and $D_i = 0$ otherwise, $D_j = 1$ if $t \in j$ and $D_j = 0$ otherwise), $\varepsilon_t^{rea} \sim N(0, \sigma)$ – residual term.

Specification (14) allows capturing roughly any path for rea_t including the periods of trend growth or decline[8]. However, the trend component as a rule may be skipped and a more parsimonious version DGP for rea_t may be considered, if treating very long time horizon[9] or just on the contrary relatively short one:

$$rea_t = c^{rea} + \sum_{j=1}^{l} LS_j * D_j + \varepsilon_t^{rea} \qquad (15)$$

[8] Such periods might reflect structural changes in the economy like savings glut, changing demographic trends, etc.

[9] For instance, there is a famous stylized Kaldor's fact that the rate of return on investment is roughly constant over long periods of time.

However, (15) cannot be estimated, as rea_t is an unobservable variable. But the latter is rather closely connected with rep_t (through (4)), and the term Δ_t that connects them may be treated as the another mechanism for temporary level shift. So, we can combine (4) and (15) as:

$$rep_t = c^{rea} + \sum_{j=1}^{l} LS_j * D_j + \Delta_t + \varepsilon_t^{rea} = c^{rea} + \sum_{j=1}^{l} LS_j * D_j + \sum_{i=1}^{k} LS_i * D_i + \varepsilon_t^{rea} \quad (16)$$

where $\sum_{j=1}^{l} LS_j * D_j$ – 'normal' level shifts (i.e. reflecting fundamental changes), and $\sum_{i=1}^{k} LS_i * D_i$– level shifts due to monetary instability.

Both mechanisms of a temporary level shift are actual analogies of regime-switching mechanism, i.e. they generate periods with different values of a constant term. Hence, the specification (16) can be properly estimated through the regime-switching framework, which for a general case looks like:

$$y_t = X_t' * \varphi_m + Z_t' * \psi + \sigma(m) * \varepsilon_t \quad (17)$$

Where y_t- the dependent variable, X_t, Z_t- vectors of exogenous variables, φ_m- the vector of coefficients indexed by regime, ψ – regime invariant coefficients, ε_t – residual term ($\sigma(m) * \varepsilon_t$ – denotes regime dependent σ of a residual term).

For a specific case of rep_t it will include only regime specific constant term, which should reflect $\sum_{j=1}^{l} LS_j * D_j$ and $\sum_{i=1}^{k} LS_i * D_i$ in it. So, the next specification is to be estimated:

$$rep_t = c_m^{rea} + \sigma(m) * \varepsilon_t \quad (18)$$

The prior objective of estimating (18) is not getting the estimates of c_m^{rea}, but detecting and segregating among regimes. The overall number of regimes in (18) is $(k + l)$. The objective for the researcher herewith is to dissect between the types of regimes, i.e. between those corresponding to 'normal' level shift and those associated with the periods of monetary instability. Constants c_m^{rea} corresponding to the former might be captured in $\overline{rea}$ term of (10), while those corresponding to the latter must be skipped, as it denotes shifts Δ_t not in $\overline{rea}$. However, this intermediary challenge of dissecting the regimes in majority of cases is likely to be skipped as well, as usually (16) does not include 'normal' level shifts (i.e. $\sum_{j=1}^{l} LS_j * D_j$) and swings in mean are associated just with the periods of monetary instability. So, in this case:

$$\overline{rea} = c_0^{rea} \quad (19)$$

where $c_0^{rea} - c^{rea}$ corresponding to regime 0, i.e. to the regime of monetary stability (hence 1, 2,… will mean types of monetary instability).

The probability of being in regime m at time t $P(s_t = m)$ may be treated as predetermined, which refers to the case of simple switching, or may be dependent on the previous state (at time $t-1$) which refers to Markov-switching framework. For a general case, there are no grounds to argue that any of these switching mechanisms is the best by default in capturing (16). So the solution might be testing both and selecting the best specification according to Akaike and Schwarz informational criterions.

4.2 Estimating a transitory component of ex ante real interest rate

As shown in Section 3.2 a large fraction of the bias in the estimate of π_t^e stems from ignoring v^π in (5). So the main idea for solving the problem comprises of the following steps: (i) identifying v^π, (ii) adjusting rep_t to v^π, (iii) running the steps A-D and (7)-(11) in respect to this adjusted measure of ex post real interest, not the 'raw' one.

Hence, there is an intermediary task to identify v^π. The identification procedure for v^π may rely on the similar SVAR strategy. Herewith, one might consider two variables driven by two same shocks one of which is v^π. To match the concept of the system with permanent and transitory shocks, one of the variables of interest should be $\sim I(1)$ and enter the SVAR in first difference, while the second one should be $\sim I(0)$ and enter the SVAR in level. As for the second (stationary) variable the choice is predetermined by scaling. The shock v^π is needed for adjusting rep_t, hence we need the measure of v^π corresponding to the scale of rep_t. So, I consider v^π – unexpected transitory shock to actual inflation – as one of the driving forces for rep_t. Correspondingly, the second type of innovation that drives rep_t is expected to capture the rest of effects, including a permanent one. Qualitatively the second type of shock may be treated as the kind of aggregate monetary shock with a permanent component (hereinafter, denoted as η^π[10]).

The rest of the task is to select an $\sim I(1)$ variable that theoretically may be considered as the combination of two types of shocks: v^π and η^π. Actual inflation rate π_t seems to be the best solution herewith. There are no theoretical obstacles for treating it as the combination of a

[10] The shock u^π must be somehow similar to v^{π^e} in (5), but nevertheless they should be differentiated. The latter is associated with IE only, while the nature of the former is broader.

monetary shock with a permanent component that characterizes the stance of the monetary environment (η^{π}) and unexpected shock to the actual rate of inflation v^{π}.

So, I consider DGP for π_t and rep_t to be as follows:

$$\begin{cases} \Delta\pi_t = \mu_t^{\Delta\pi} + \sum_{i=0}^{n} \gamma_i^{\eta} * \eta_{t-i}^{\pi} + \sum_{i=0}^{n} \gamma_i^{v} * v_{t-i}^{\pi} \\ rep_t = \mu_t^{rep} + \sum_{i=0}^{n} \zeta_i^{\eta} * \eta_{t-i}^{\pi} + \sum_{i=0}^{n} \zeta_i^{v} * v_{t-i}^{\pi} \end{cases} \quad (20)$$

where $\mu_t^{\Delta\pi}$ and μ_t^{rep} are expected values of $\Delta\pi$ and rep; η^{π} and v^{π} are permanent monetary shock and unexpected transitory monetary shock correspondingly; γ_i^{η}, γ_i^{v}, ζ_i^{η}, ζ_i^{v} are coefficients.

The shocks in (20) may be estimated through SVAR identification scheme similar to the one in A-C and (7)-(9). Herewith, the SVAR includes variables $\Delta\pi_t$ and rep_t. Similarly to (9) I get vector moving average representation of the system:

$$\begin{bmatrix} \Delta\pi_t \\ rep_t \end{bmatrix} = \begin{bmatrix} \overline{\Delta\pi} \\ \overline{rep} \end{bmatrix} + \Psi(L) * \begin{bmatrix} \epsilon_t^{\pi} \\ \epsilon_t^{rep} \end{bmatrix} \quad (20)$$

where $\Phi(L) = \begin{bmatrix} \Psi_{\pi,\pi}(L) & \Psi_{\pi,rep}(L) \\ \Psi_{rep,\pi}(L) & \Psi_{rep,rep}(L) \end{bmatrix}$

The mean of the transitory shock is expected to be zero. Hence, the estimate only of a transitory component (i.e. $\sum_{i=0}^{n} \zeta_i^{v} * v_{t-i}^{\pi}$) is needed. Hereinafter, a correspondent estimate is denoted as $tshock$ (i.e. transitory shock), which is obtained according to (21):

$$tshock = \Psi_{rep,rep}(L) * \epsilon_t^{rep} \quad (21)$$

A newly introduced variable $tshock$ itself is interesting for the analysis. It signals about the stance of the monetary environment and huge swings in it reflect any systemic abnormalities in monetary mechanisms.

Within the context of IE identification $tshock$ is needed for adjustment of rep_t. So, I introduce a new variable rep_adj_t according to (22):

$$rep\_adj_t = rep_t - tshock \quad (22)$$

Finally, inserting rep_adj_t instead of rep_t into A-D and (7)-(11) (and estimating $\overline{rea}$ according to the scheme in Section 4.2) allows obtaining unbiased estimates for $\pi_t$and rea_t.

4.3 Numerical illustration with a predetermined data generation process

The objective of the numerical exercise is to visualize advantages of the proposed improvements to the baseline methodology. As show above, substantial monetary shocks is the major reason for biased estimates according to the baseline methodology. So, I construct the data set in a way to secure visible substantial monetary shocks. The data set is simulated for 500 observations.

Firstly, I generate inflation series just as the random walk process. In order the inflation rate to be similar to reality, I choose a random walk process for which positive values prevail. While generated as the random walk $\pi_t \sim I(1)$ by definition.

Second, I generate rea_t according to (23):

$$rea_t = 3 + wn \qquad (23)$$

where wn is the white noise term.

After that I deal with the series of the expected inflation π_t^e. Conceptually I treat the series to be cointegrated with π_t and in a large extent to be driven by the latter. However, in order to introduce monetary shocks, I secure this kind of relationship indirectly through a number of steps. First, I introduce a binary state variable r, which refers to the regime of the monetary environment: 0 – denotes normal monetary regime, 1 – denotes the abnormal stance, when the link between π_t and π_t^e experiences huge swings. In this numerical example, I generate r depending π_t[11] in a following manner: if the mean value of last 10 observations of π_t was more than 10%, and a sustainable growth during last 10 observations took place (i.e. each observation was more than the previous one) than $r = 1$, and $r = 0$ otherwise.

Second, I introduce the following rule for Δ_t:

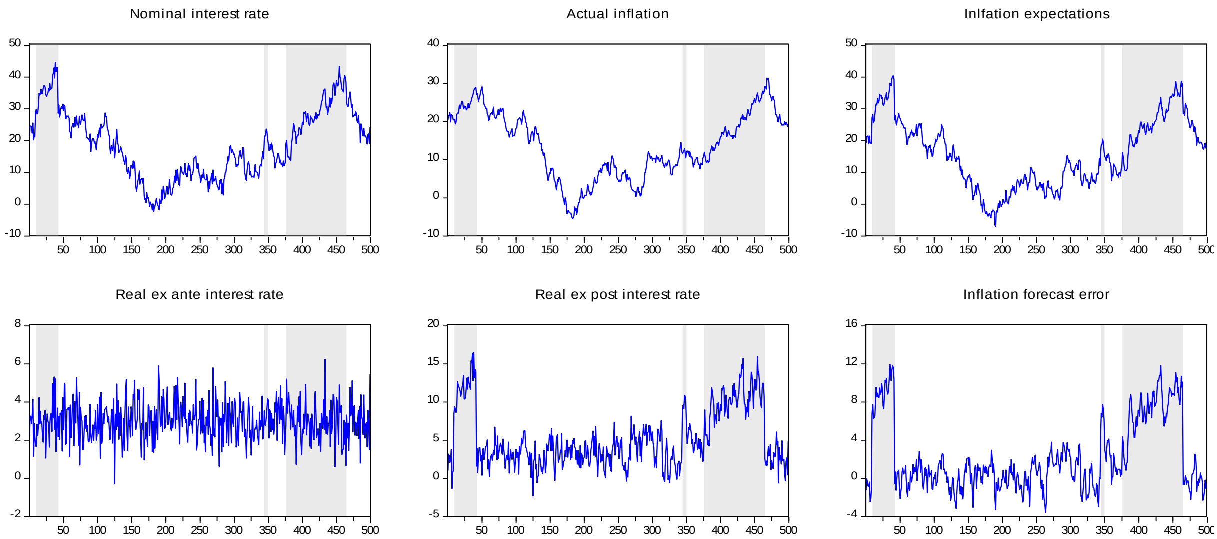
$$\begin{cases} \Delta_t = ar(1), if\ r = 0 \\ \Delta_t = 0.4 * \left(\frac{\pi_t + \pi_{t-1} + \pi_{t-2}}{3}\right) + ar(1), if\ r = 1 \end{cases} \qquad (24)$$

where $ar(1)$ – is the first order autoregressive term with zero mean.

[11] More precisely, r depends on the smoothed value (by HP filter) of π_t. as otherwise it would be too dependent on high frequency fluctuations within the random walk process of π_t.

Third, I get π_t^e as the sum of π_t and Δ_t. Nominal interest rate and ex post interest rate are calculated through identities according to (1) and (2).

Figure 1 provides visual representation for the simulated data set.



Note: Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$

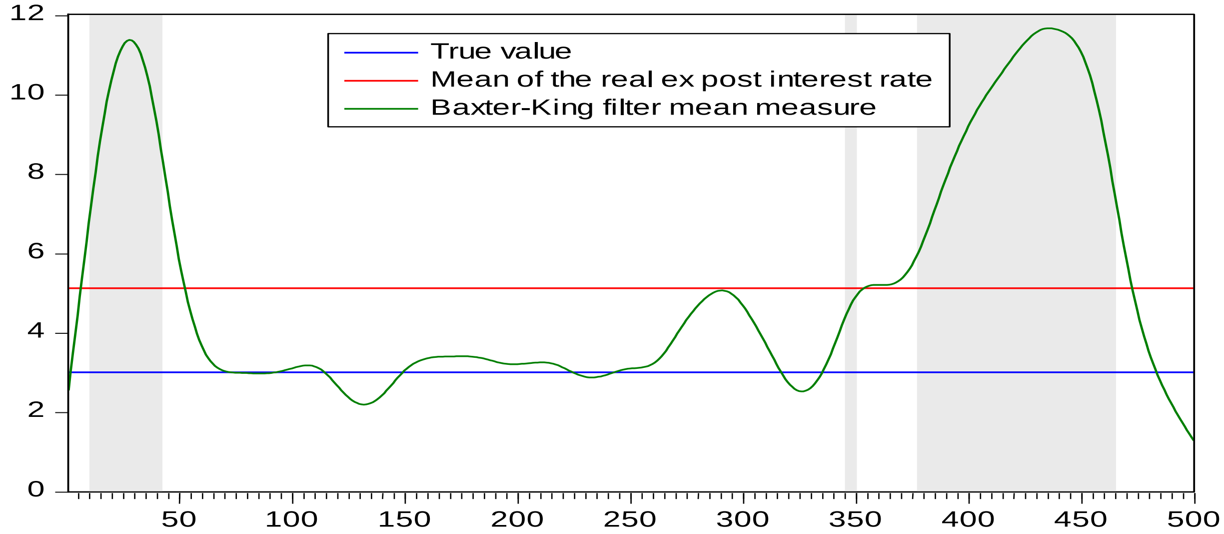
Figure 1. Simulated Dataset.

As one may see from Figure 1, monetary instability leads to substantial deviations of rep_t from rea_t. Just these periods are responsible for significant different in mean and other statistical properties of these two measures of real returns (see Table 1).

Table 1. Descriptive Statistics for Real Ex Ante and Ex Post Interest Rates

Indicator	Variable notation	Variable name
Mean	2.966055	5.118528
Median	2.911281	4.067038
Maximum	6.210191	16.44314
Minimum	-0.31443	-2.40943
Standard Deviation	1.013969	3.822014
Skewness	0.168745	0.875279
Kurtosis	3.00048	2.918925

Table 1 clearly demonstrates why the approach $\overline{rea} = \overline{rep}$ (for using this $\overline{rea}$ in (10)) fails. The measure of $\overline{rea}$ through Baxter and King band-pass filter also cannot capture correctly the mean distorted by the periods of monetary instability. Figure 2 provides comparison among the measures for $\overline{rea}$.



Note: Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 2. The Estimates of the Mean of Ex Ante Real Interest Rates.

However, the approach of employing the regime-switching framework (according to (18)) demonstrates pretty good results. I run the models according to both simple switching and Markov switching framework, allowing either common error variance for both regimes or regime specific variance. Basing on information criterions for the current case I select Markov type model with the common error variance for both regimes (see Table 2).

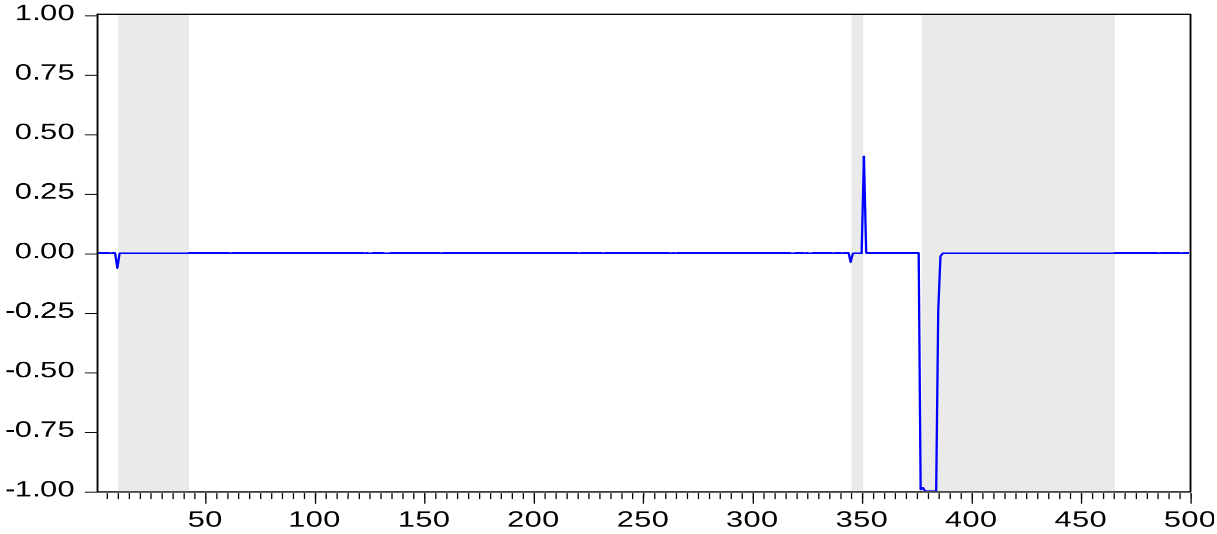
Table 2. The Results of Regime-Switching Models Estimation

Indicator	SS-1σ	SS-2σ	MS-1σ	MS-2σ
Coefficient for regime 1	11.050	10.753	*11.002*	10.996
Coefficient for regime 2	3.299	3.211	***3.259***	3.257
Standard error of the regression	3.830	3.833	*2.072*	2.068
Akaike information criterion	5.171	5.167	*4.269*	4.268
Schwarz information criterion	5.204	5.209	*4.311*	4.318

Note: SS denotes simple switching framework, MS denotes Markov switching framework; 1σ denotes error variance common for both regimes, 2σ denotes regime specific error variance.

The model captures the changing stance of the monetary environment pretty good (see Figure 3). It captures 118 out of 128 observations corresponding to the periods of monetary instability and correspondingly fails in correct classification of 10 observations.

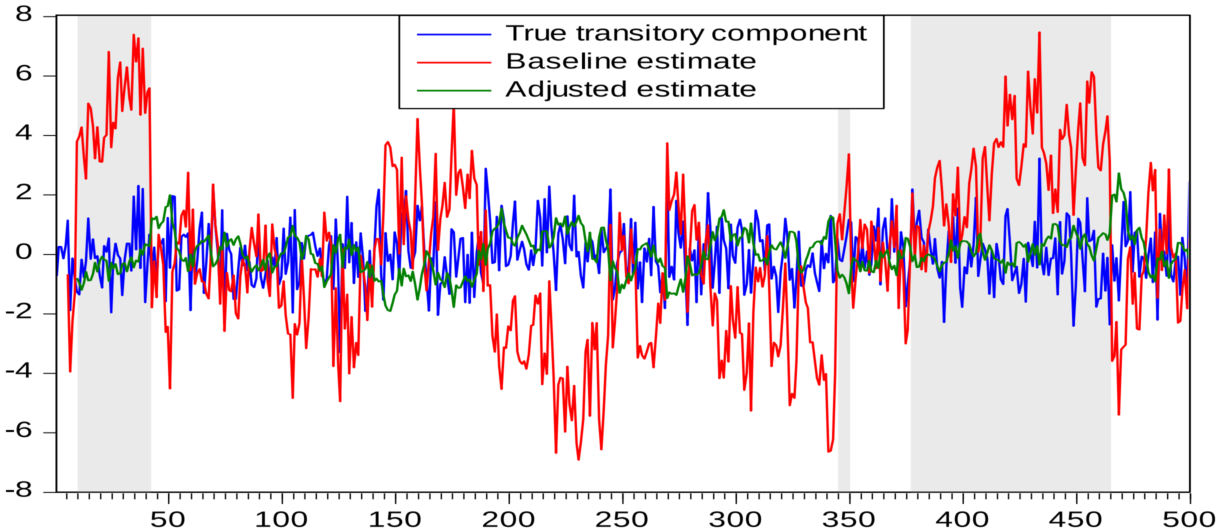
So, finally I extract the estimate of the constant term from the Markov switching framework (with error variance common for both regimes), which is *3.259* and use it the estimate for $\overline{rea}$. This approach provides the best estimate in comparison to those presented in Figure 2.



Note: The Figure uses the difference between the probability of being in regime 1 (abnormal) and r (binary variable, where 0 is 'normal' regime and 1 is monetary instability) as the measure of goodness of fit. Zero value means perfect capturing, the values close to 1 or -1 mean the failure in regime capturing. Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 3. The Goodness of Capturing Regime Switching.

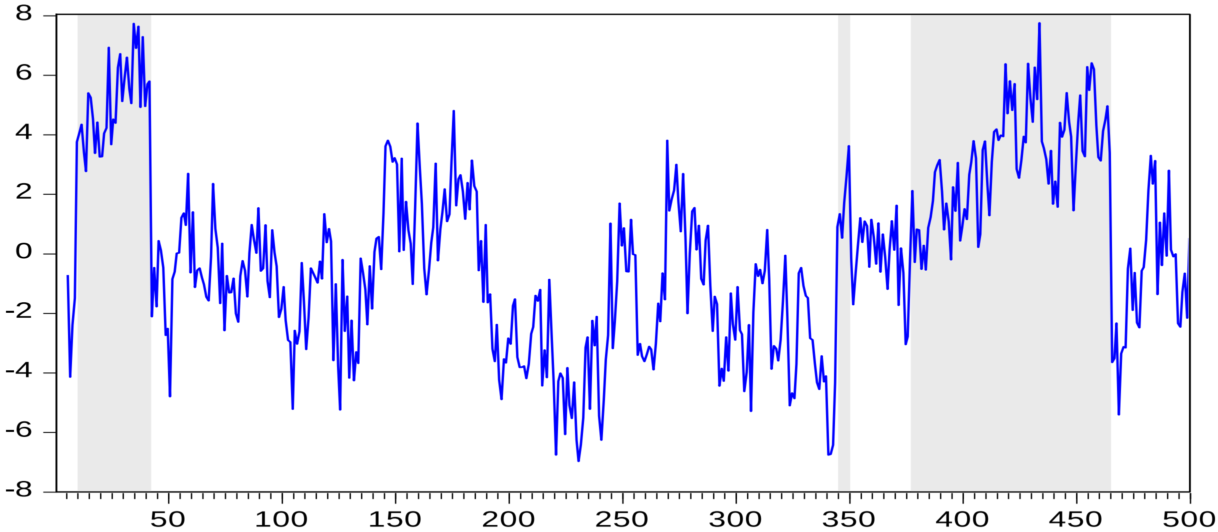
Further, I deal with the transitory component or rea_t. First I run a baseline approach for it, and afterwards adjusted approach. Figure 4 reports the comparison between two measure of transitory component for rea_t and its true series.



Note: Baseline estimate corresponds to the estimate obtained based on the baseline methodology, adjusted estimate correspond to the adjusted methodology according to the Section 4.2. Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 4. The Estimates of the Transitory Component of Ex Ante Real Interest Rates.

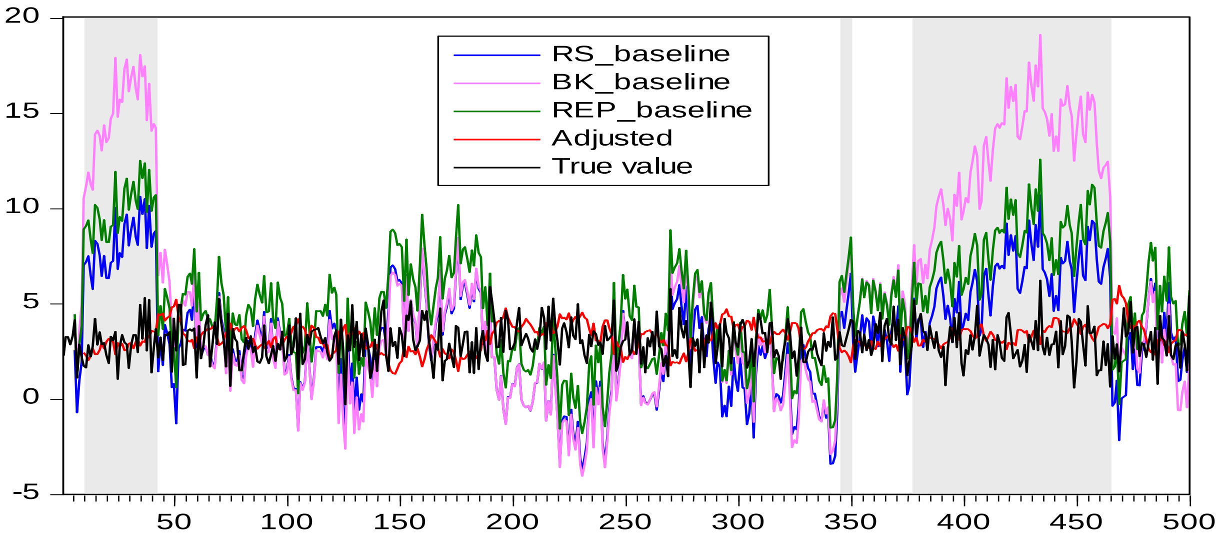
A newly introduced variable $tshock$ displays close connection with the periods of monetary instability. However, its economic sense seems to be broader and accords to the preliminary design of the unexpected shock to actual inflation. Figure 5 provides the comparison of $tshock$ with the periods of monetary instability.



Note: Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 5. Unexpected Shock to Actual Inflation ($tshock$).

The sum of mean estimate for rea_t and its transitory component produces the estimate for rea_t itself according to (10). The comparison of corresponding estimates between baseline methodology and the adjusted one is presented at Figure 6.

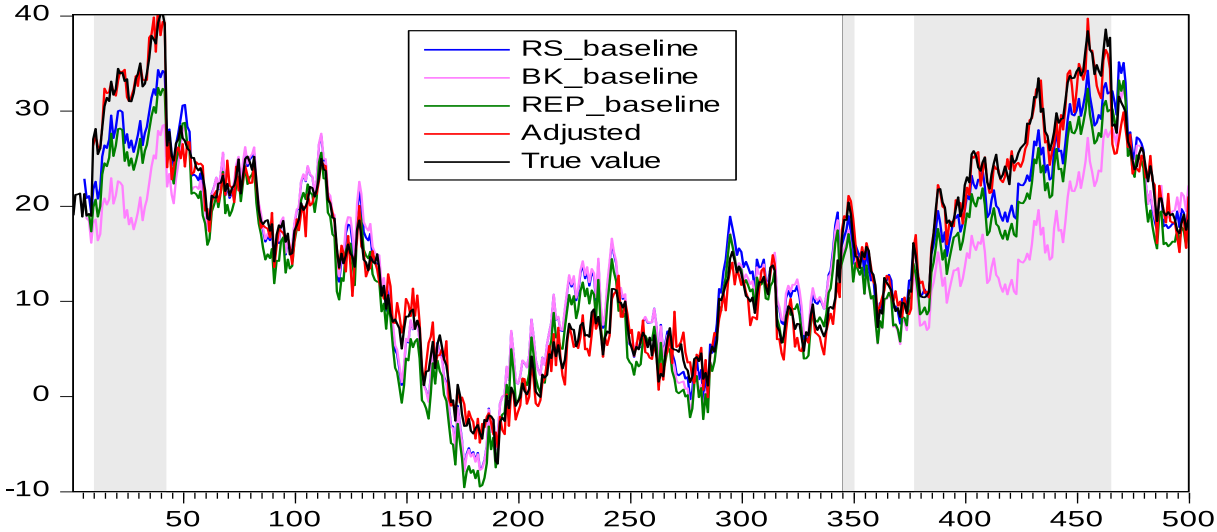


Note: RS-baseline corresponds to the mean estimate according regime switching framework, while the transitory component is estimated according to the baseline methodology; BK_baseline - corresponds to the mean estimate basing on Baxter-King filter and the transitory component is estimated according to the baseline methodology; REP_baseline corresponds to the mean estimate equal to the mean of real ex post interest rate and the transitory component is estimated according to the baseline methodology; Adjusted – corresponds to the adjusted methodology at both steps. Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 6. Estimates of Real Ex Ante Real Rate

From Figure 6 one may see that for the current dataset, the error stemming from the estimate of the mean is comparable with the one stemming from the estimating of the transitory component. Both kinds of errors substantially progress during the periods of monetary instability.

Having the estimates for ex ante real rates at disposal, one may pass to the ultimate step of estimating IE. Figure 7 provides estimates of IE basing on different variations in methodology.



Note: RS-baseline corresponds to the mean estimate according regime switching framework, while the transitory component is estimated according to the baseline methodology; BK_baseline - corresponds to the mean estimate basing on Baxter-King filter and the transitory component is estimated according to the baseline methodology; REP_baseline corresponds to the mean estimate equal to the mean of real ex post interest rate and the transitory component is estimated according to the baseline methodology; Adjusted – corresponds to the adjusted methodology at both steps. Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$.

Figure 7. Estimates of Inflation Expectations

Figure 7 visually demonstrates that all the measures of IE except the adjusted one are subject to the impact of the monetary environment. Hence, during the periods of monetary instability these approaches tend to underestimate the actual value of IE.

Table 3 summarizes descriptive statistics of the error of different estimates for IE.

Table 3. Descriptive Statistics for Error of IE Estimates

Indicator	RS_baseline	BK_baseline	REP_baseline	Adjusted
Mean	-0.27358	-2.17667	-2.16021	-0.26766
Median	-0.00819	-0.63254	-1.89482	-0.29248
Maximum	7.681516	7.454266	5.794888	4.026287
Minimum	-6.83772	-14.9691	-8.72434	-4.51898
Standard Deviation	2.94083	5.388049	2.94083	1.28942
Skewness	-0.08763	-0.80629	-0.08763	0.083635
Kurtosis	2.431154	2.599367	2.431154	3.192217

Note: RS-baseline corresponds to the mean estimate according regime switching framework, while the transitory component is estimated according to the baseline methodology; BK_baseline - corresponds to the mean estimate basing on Baxter-King filter and the transitory component is estimated according to the baseline methodology; REP_baseline corresponds to the mean estimate equal to the mean of real ex post interest rate and the transitory component is estimated according to the baseline methodology; Adjusted – corresponds to the adjusted methodology at both steps.

So, adjusted measure is the only one which demonstrates no bias, insensitivity to monetary environment, minimum dispersion and the distribution of error that cannot be rejected to be normal.

5. Estimating IE in Belarus

Belarusian case is peculiar by its high inflation volatility and periods of extremely huge inflation jumps. For instance, in 2011 annualized monthly inflation overreached the level of 300%. Moreover, the periods of 3-digit inflation took place in the beginning of 2000s. In case of such huge monetary shocks, the issues of proper data handling can have critical impact on the results.

Rather often huge swings in the data are intended to be smoothed somehow or even ignored as outliers, as they 'spoil' dynamics characteristics of the date. On the other hand, such periods contain useful information and ignoring them or 'hiding and/or stretching' within the sample through smoothing might lead to loss of valuable information.

Technically the latter problem in the context of the current paper vitalizes the questions about the frequency of the data and the time horizon for measuring actual inflation. Dealing with quarterly data allows automatically smooth some inflation series and treat it as less volatile. Monthly data from this view provides 'purer' information, but sometime overloaded with an unneeded noise. In terms of time horizon, one can deal with purely 'contemporary' measure of inflation, say with annualized monthly rate or, on the contrary, with a two much backward oriented rate, say average annual measure of inflation.

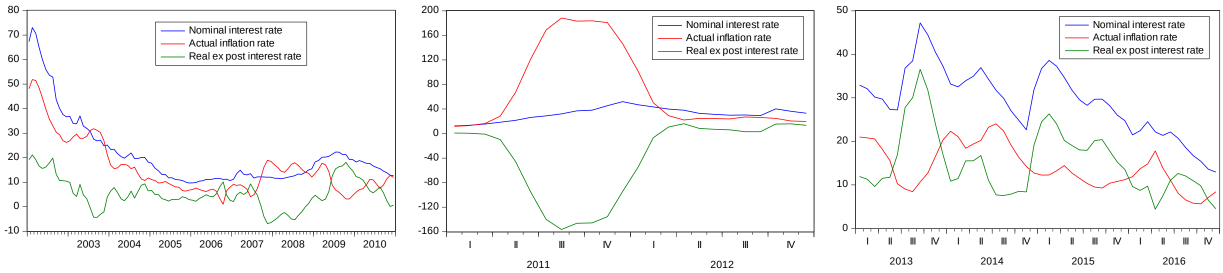
Having in mind plenty of pros and cons in respect two different choices within the two dimensions, as a kind of compromise for the current paper I deal with a monthly data, and at the same time measure inflation as annualized quarterly (i.e. during last three months) average. The sample considered includes 180 observations between 2002:1 and 2016:12.

One more important issue that may have a critical impact on results is choosing a proper interest rate, which may be representative in terms of IE. However, due to some specific features of Belarusian financial market, there is no evident first choice in respect to mostly informatively rich interest rate. For instance, interbank interest rate is the most 'free[12]' one

[12] In terms of directive impact on it (by administrative instruments) by authorities. Plenty of other interest rates, especially ones on ruble loans (via loans to state-owned enterprises), are substantially distorted by direct government interventions.

in the economy, but it experiences volatility due to changes in monetary regulations or liquidity shocks in the banking system, which have nothing to do with the considerations of inflation expectations. Another group of relatively ‘free’ interest rates are the ones at the market of households deposits. However, some noise beside the point touches these rates as well. So, in this respect as a kind of compromise I deal with the aggregate measure of interest rate that is the simple average of three interest rates: (i) interbank interest rate, (ii) interest rate on households savings deposits with the term of less than one year, and (iii) those with a term of more than one year[13].

Visual representation of the Belarusian dataset is provided at Figure 8. The data is divided for three subsamples, in order to emphasize huge monetary shocks that took place over 2011-2012, and trace the evolvement of the indicators during other periods ‘unshaded’.



Note: Shaded areas correspond to the periods of monetary instability, i.e. $r = 1$

Figure 8. Belarusian Dataset.

The impact of monetary shocks and high inflation volatility results in extremely volatile and ‘strangely’ distributed observations for the real ex post interest rate. Figure 9 reports the histogram and descriptive statistics for this rate.

An attempt to extract $\overline{rea}$ from this data by means of statistical filtering results in extremely volatile underlying trend (Figure 10). One can expect, that similarly to the numerical example with a simulated data, this volatility in rea estimate is due to the changing monetary environment, rather than actual changes in rea_t. Moreover, during the period of the currency crisis the Baxter-King estimate assumes huge shock of $\overline{rea}$, determining a low of about 150%, which can hardly be interpreted (see Figure 10).

[13] In this paper I report just these ‘average’ results. However, using different data input for the methodology in terms of frequency, inflation measuring, and selecting different indicators of interest rate produce relatively similar results.

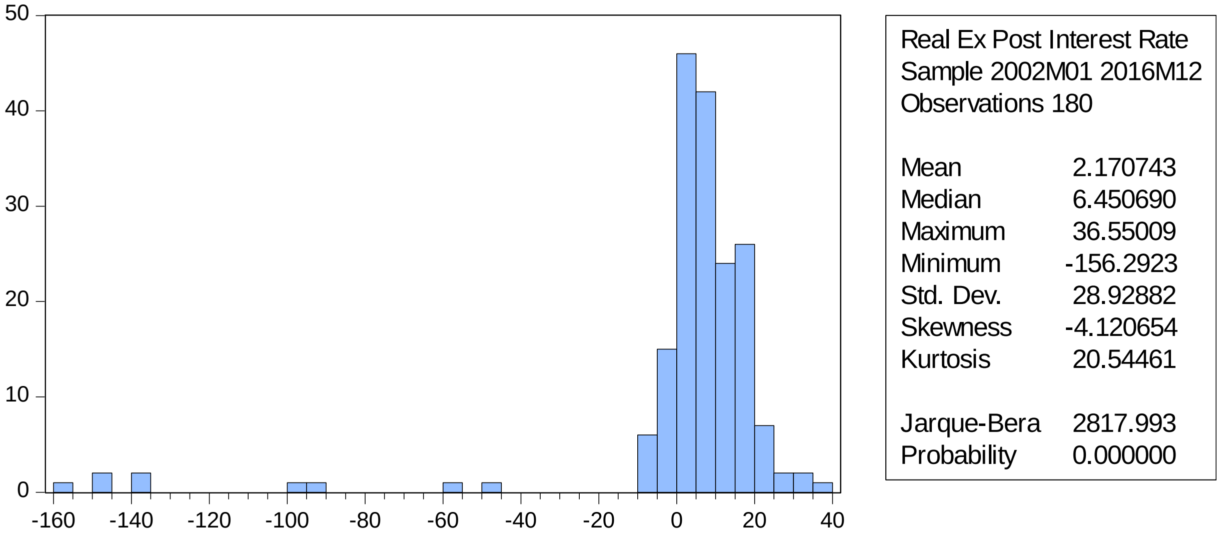


Figure 9. Histogram and Descriptive Statistics for the Real Ex Post Interest Rate

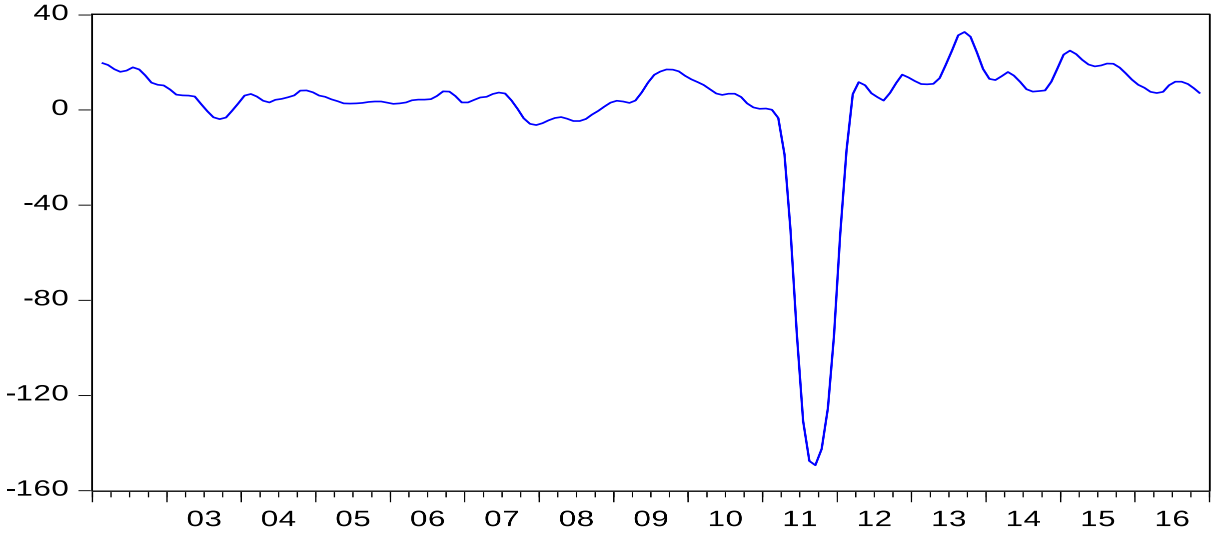


Figure 10. The Estimate of the Mean of Ex Ante Real Rate by Baxter-King Band-Pass Filter

Given the contradictions with employing frequency filter, further I employ the approach of estimating $\overline{rea}$ according to regime switching framework. Herewith, all models specifications assuming 3 regimes strongly outperform models with 2 regimes (except simple switching with common error variance, which captures only 2 regimes). Table 4 reports main parameters and characteristics from regime switching framework models.

For Belarusian data, the model with Markov type of switching, assuming 3 regimes and regime specific error variance demonstrates best performance according to Akaike and Schwarz information criterions. Hence, I use the estimate from this model for the subsequent steps of the procedure.

Table 4. The Results of Regime-Switching Models Estimation

Indicator	SS-1σ	SS-2σ	MS-1σ	MS-2σ
Coefficient for regime 1	7.541	13.796	1.838	*14.124*
Coefficient for regime 2	7.541	-112.017	14.484	***2.963***
Coefficient for regime 3	-130.552	5.352	-130.552	*-63.102*
Standard error of the regression	29.174	29.341	12.385	*20.761*
Akaike information criterion	8.016	7.591	7.559	*6.744*
Schwarz information criterion	8.122	7.533	7.736	*6.957*

Note: SS denotes simple switching framework, MS denotes Markov switching framework; 1σ denotes error variance common for both regimes, 2σ denotes regime specific error variance.

Three regimes that the model emphasizes may be treated as 'normal' (regime 2 according to model classification), 'subnormal' (regime 1) and 'abnormal (regime 3) ones. Such a classification becomes intuitively acceptable when dating the regimes. Figure 11 reports the probabilities of the monetary environment of being in a particular regime.

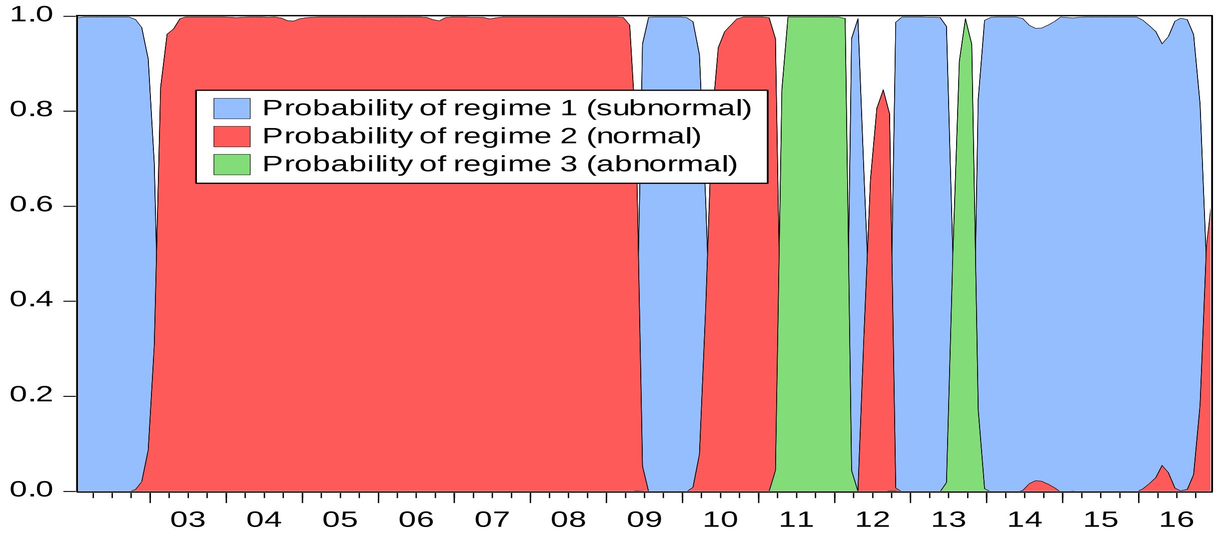


Figure 11. Probabilities of Individual Regimes of Monetary Environment in Retrospective

This classification and dating strongly corresponds with anecdotal evidence and known stylized facts about Belarusian monetary environment. It signals that monetary environment existed in 'normal' regime just for a relatively short period in a recent history. Such kind of interpretation allows ignoring 'subnormal' and 'abnormal' regimes for estimating $\overline{rea}$. Hence, I treat the estimate just for a 'normal' regime as a proper estimate of $\overline{rea}$ for (10). So, I use the value of 2.963 as the medium-term equilibrium one for ex ante real interest rate[14].

[14] One may note that this value is relatively similar to the mean of the ex post interest rate (see Figure 9). However, this must be just a happenstance. For instance, if one deals with the sample between January 2004

The next step is the identification of $tshock$ and adjusting real ex post interest rate to it according to (22). Figure 12 visualizes estimated $tshock$ and its impact on the measure of real ex post interest rate.

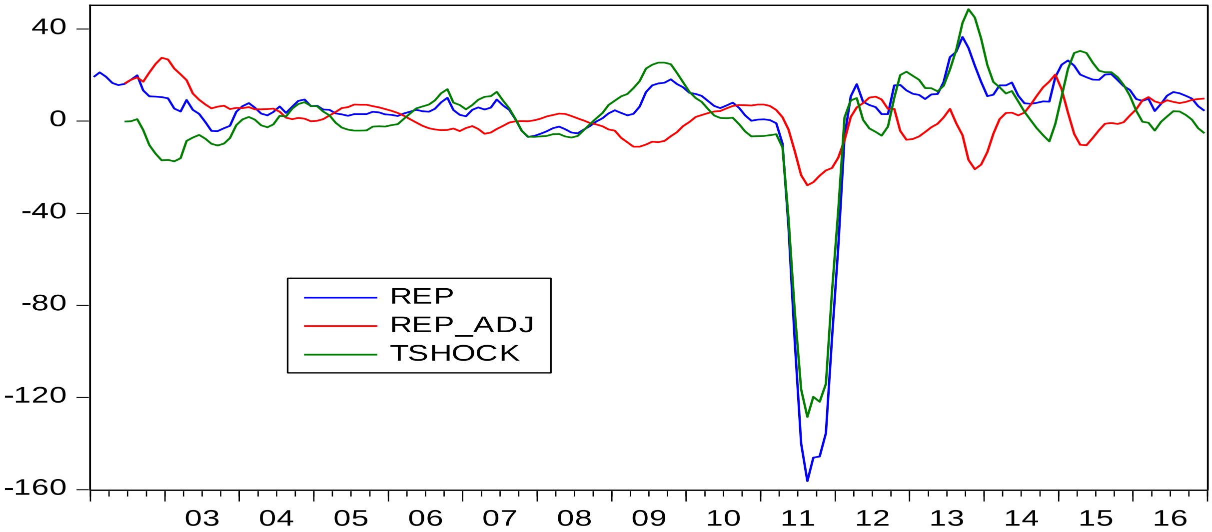
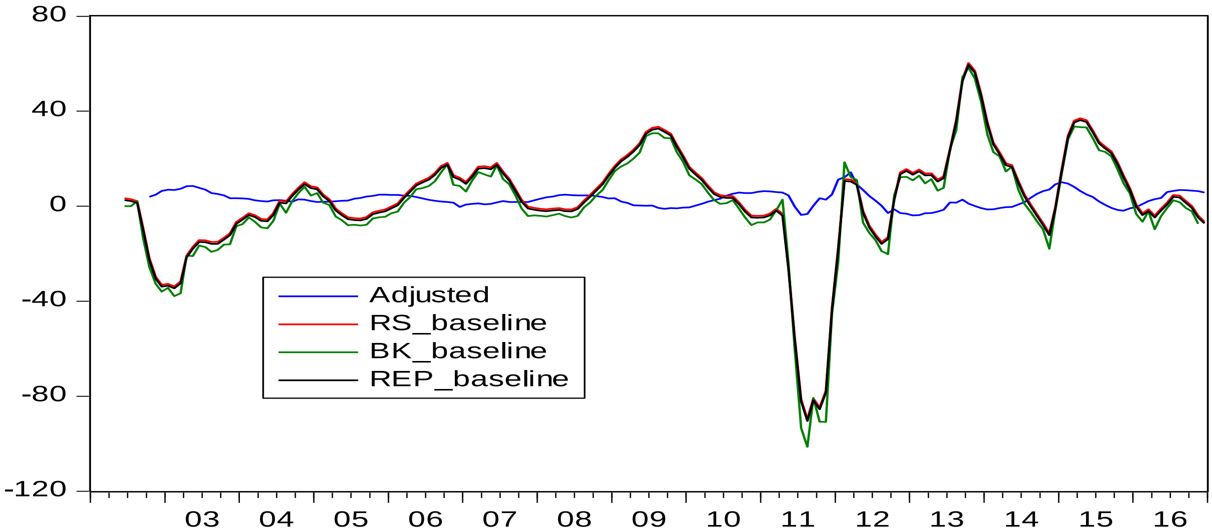


Figure 12. The Measures for Real Interest Rates and Unexpected Shock to Inflation.

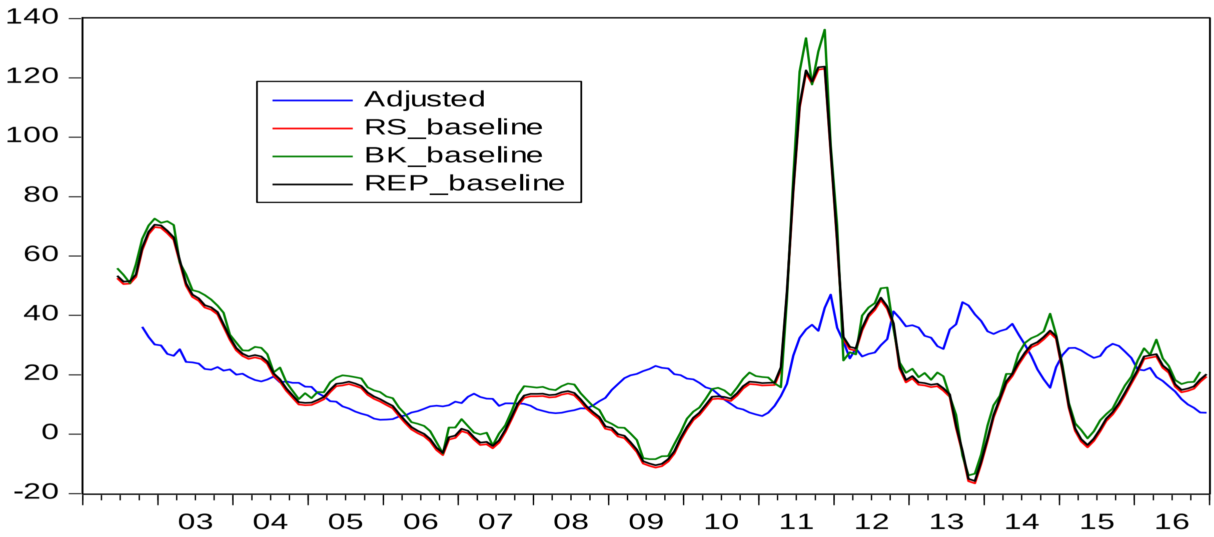
Having got rep_adj_t, I use it instead of rep_t in procedure A-D and (7)-(11) and get the estimates for rea_t and π_t. Figure 13 and 14 report this measure in comparison to those baseline ones.



Note: RS-baseline corresponds to the mean estimate according regime switching framework, while the transitory component is estimated according to the baseline methodology; BK_baseline - corresponds to the mean estimate basing on Baxter-King filter and the transitory component is estimated according to the baseline methodology; REP_baseline corresponds to the mean estimate equal to the mean of real ex post interest rate and the transitory component is estimated according to the baseline methodology; Adjusted – corresponds to the adjusted methodology at both steps.

Figure 13. Estimates of Real Ex Ante Real Rate

and December 2014, the estimates according to the regime switching models will still be roughly the same. However, the mean of the ex post interest rate for this sample is negative and amounts to -1.298.



Note: RS-baseline corresponds to the mean estimate according regime switching framework, while the transitory component is estimated according to the baseline methodology; BK_baseline - corresponds to the mean estimate basing on Baxter-King filter and the transitory component is estimated according to the baseline methodology; REP_baseline corresponds to the mean estimate equal to the mean of real ex post interest rate and the transitory component is estimated according to the baseline methodology; Adjusted – corresponds to the adjusted methodology at both steps.

Figure 14. Estimates of Inflation Expectations

One may see from Figures 13 and 14 that for Belarusian case a reasonable estimation of the transitory component of ex ante real interest rate is much more crucial for feasible estimate of IE. All the measures except the adjusted one perform rather strange and extremely volatile dynamics that contradicts to anecdotal evidence, stylized facts about IE and conventional wisdom about it.

Together both measures – those of ex ante real rate and IE – may be used for the decomposition of variance of nominal interest rate. Figure 15 provides such a representation. It demonstrates that the variance in nominal interest rate in Belarus retrospectively was dominantly driven IE, while the contribution of ex ante real rate was much lower.

The relationship between IE and actual inflation traditionally is one of the main points of interest within the monetary policy analysis. Figure 16 provides visual representation of this relationship. It demonstrates clearly difference stances of this relationship according to time-line. Throughout the period 2003-2008 expectations were roughly anchored and evolved pretty close to actual inflation. In 2009-2010 rather substantial divergence took place that could be associated with a reduced credibility of the currency peg and the global crisis. Later on in 2011, actual inflation outran IE enormously, which gives grounds to characterize inflation spike of 2011 as unexpected. But this unexpected spike later on resulted in a persistently higher IE than actual inflation. The latter might demonstrate the distrust to monetary policy and the lack of credibility to it.

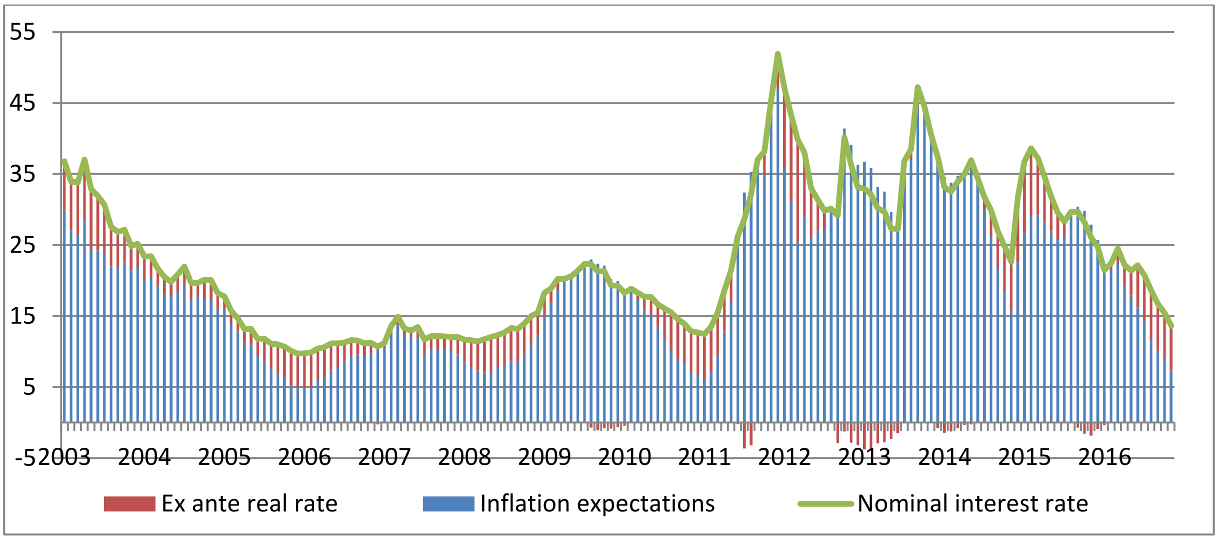


Figure 15. Decomposition of Nominal Interest Rate

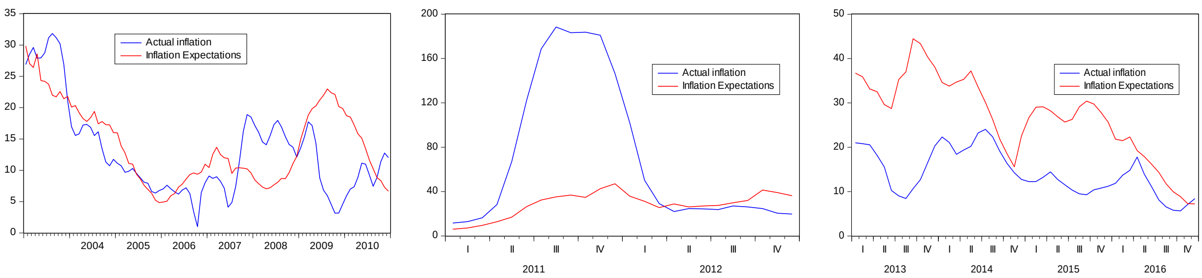


Figure 16. Actual Inflation and Inflation Expectations

One more view at the relationship between actual inflation and IE is a prognostic one. More precisely, the IE measure might be considered the more influential, the more it is powerful for explaining actual inflation. Herewith, reformulate the latter in a rather general way: can the measure of IE improve the simple first order autoregressive model of actual inflation. Table reports correspondent results.

Table 4. Testing Predictive Power of IE

Indicator	AR(1) model	AR(1) and IE model
AR(1) coefficient	0.973 (0.006)	0.960 (0.011)
IE coefficient	-	1.508 (0.134)
Standard Error of the Regression	8.919	8.189
Adjusted R-squared	0.922	0.936
Akaike Info Criterion	7.241	7.076
Schwarz Criterion	7.277	7.098

Note: Standard errors are given in parenthesis.

So, the obtained measure of IE in Belarus may be treated as containing predictive power for actual inflation.

6. Conclusions

Extracting inflation expectations from the actual data (e.g. series of interest rate and actual inflation) basing on SVAR identification approach has become a valuable alternative/supplement for measuring inflation expectations. In this paper I show that the existing strategy of inflation expectations identification through SVAR approach is very sensitive to the state of monetary environment. When a monetary environment is unstable (e.g. high and volatile inflation), the assumptions of the baseline approach are not hold, and it produces biased estimations. I emphasize two sources of this bias in estimations and suggest procedure for obtaining unbiased estimates. My identification strategy includes a number of steps. I suggest applying Markov regime-switching framework for extracting an unbiased mean for ex ante real interest rate. Further, I use two-stage SVAR identification strategy. First, I identify an unexpected shock to actual inflation, which is crucial for obtaining a proper measure of inflation expectations. Further, I net the series of ex post interest rate from this ‘noise’. Second, I run a baseline SVAR procedure, for which I use the data adjusted at the first step. Finally I obtain an unbiased and informatively rich series of inflation expectations. Such a measure extracted from Belarusian data conforms to anecdotal evidence on Belarusian monetary environment and possess predictive power for actual inflation. For the context of monetary policy analysis it demonstrates that Belarusian monetary environment has been functioning in the situation of unanchored IE during last couple of year and just IE was the driving force responsible for high and volatile nominal interest rates.

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