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Money as a leading indicator of inflation in Belarus and its implications for monetary policy

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Executive Summary

High inflation is one of the most acute problems of the Belarusian economy in recent years. It undermines the foundations of macroeconomic stability, introduces a significant uncertainty in the activity of enterprises and households, and creates difficulties for private business development. Therefore, at the moment the reduction of inflation is a key issue for economic policy in Belarus. In order to stabilize high inflation and make monetary policy more effective, the National Bank of Belarus (NBB) in 2015 moved to a regime of monetary targeting. However, the usage of monetary targeting requires clear-cut and stable relationships between the variables used as the operational, intermediate and final target. The absence or weakness of such links makes a monetary targeting regime actually ineffective in reducing inflation.

In this paper we evaluate the empirical foundations of monetary targeting in Belarus using relevant comprehensive econometric techniques. We use econometric approaches based on the cointegrated vector autoregression model (cointegrated VAR) to analyze the relationships between the operating and the intermediate target and estimate the real money demand function. The obtained money demand function allows us to identify disequilibrium on the money market in the form of the real money gap. This estimated unobservable variable, along with the short-run dynamics of the money supply is used as the main explanatory variables in the P^*-model of inflation in order to assess the impact of monetary factors on its dynamics. Such an approach allows to consistently empirically testing the existence of necessary conditions for monetary targeting in Belarus.

There is econometric evidence that the operational target, intermediate target and final target are related in the right manner for monetary targeting in Belarus. Such relationships are confirmed for a rather long period: 1995Q–2014Q4. The monetary base and M3 are cointegrated. Monetary base is strongly exogenous related to M3. The intermediate target is controllable by the operational target. Thus, the first requirement for monetary targeting is fulfilled.

Money and prices are homogeneous, so the usage of real money is an appropriate option. In a nominal system, money and prices are interrelated, which is a good prerequisite for monetary targeting and P^*-modeling of inflation. There is quite a stable money demand function for real M3. Thus, the second requirement for monetary targeting is relatively fulfilled. However, the absence of relevant opportunity cost indicator (beside inflation) makes real money demand function for M3 less informative concerning the behavior of economic agents.

The cointegrating vector from the real money demand function is used for construction of the real money gap, reflecting disequilibrium on the money market. The real money gap (with one lag) and changes of M3 are statistically significant in a P^*-model of inflation. Thus, the third requirement for monetary targeting is equally fulfilled.

To sum up, monetary targeting in Belarus can be justified from an econometric point of view using relatively long historical data.

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1. Introduction and motivation

High inflation is one of the most acute problems of the Belarusian economy in recent years. It undermines the foundations of macroeconomic stability, introduces a significant uncertainty in the activity of enterprises and households, and creates difficulties for private business development. Therefore, at the moment the reduction of inflation is a key issue for economic policy in Belarus.

In order to stabilize high inflation and make monetary policy more effective, the National Bank of Belarus (NBB) in 2015 moved to a regime of monetary targeting. However, the usage of monetary targeting requires clear-cut and stable relationships between the variables used as the operational, intermediate and final target. The absence or weakness of such links makes a monetary targeting regime actually ineffective in reducing inflation.

The basic ideas of monetary targeting in Belarus are discussed in Mironchik, Bezborodova (2015) and Kalechits (2015). These authors presented the rationale for monetary targeting in Belarus and some quantitative justifications of its effectiveness for controlling inflation. We used those materials as a starting point of our analysis of monetary targeting feasibility in Belarus.

The following key points of monetary targeting in Belarus should be mentioned:

– the NBB choses an operational target and an intermediate target to control inflation;

– the NBB should be able to control the operational target;

– the NBB choses an appropriate monetary aggregate as an intermediate target.

This monetary aggregate chosen as an intermediate target has to meet the following three criteria:

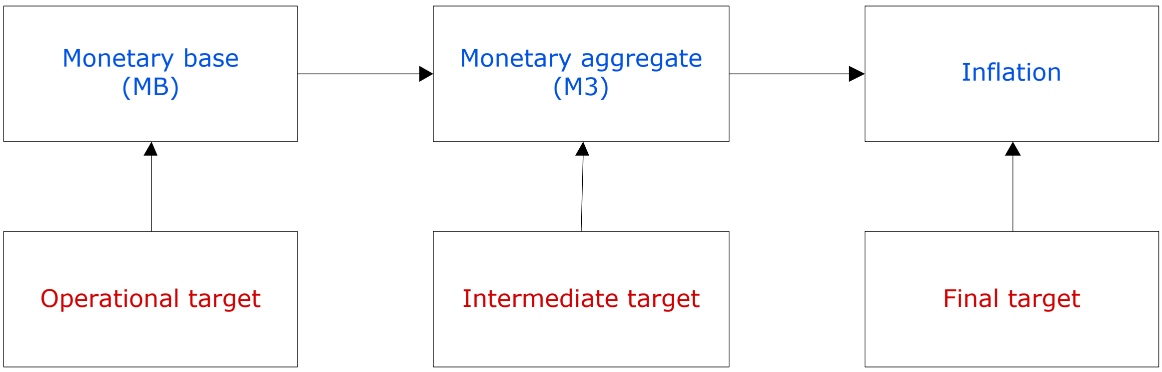
(1) stable relationship between operational and intermediate target;

(2) stable (real) money demand function for this aggregate;

(3) stable relationship between monetary aggregate and inflation.

Monetary aggregate M3 (broad money) had been chosen as an intermediate target (precisely, growth rates of M3). In its turn, ruble monetary base by implication controllable by the NBB was opted as an operational target (precisely, monthly and quarterly growth rates of monetary base). The general scheme of monetary targeting in Belarus is presented in Figure 1. In this way, ruble monetary base acts as an operational target, monetary aggregate M3 plays the role of an intermediate target and inflation, estimated on the basis of consumer price index, is a final target of monetary policy.

Figure 1. Monetary targeting in Belarus: The general concept



Source: compiled by the authors on the basis of Mironchik, Bezborodova (2015), Kalechits (2015).

Definitely, a necessary condition for such a scheme to be workable is the existence of well-established links between the considered variables. Furthermore, the directions of these linkages are crucial, namely an operational target should be cause for an intermediate target, but not vice versa; an intermediate target should be cause a final target, but not vice versa. The existence of these relationship and causality between them, in our view, is not a pure theoretical question. It is rather an empirical issue and these links can be analyzed econometrically.

As a starting point of our analysis, we estimated simple pair correlations between the growth rates of monetary base (Δmb), monetary aggregate M3 ($\Delta m3$) and inflation (Δcpi), expressing variables in natural logarithms without seasonal adjustment. Two samples were used: the first one is full sample (1995q1–2014q4); the second one is a sub-sample utilized in Mironchik, Bezborodova (2015) and usually applied in NBB research. As one can see from Table 1, the correlations between operational and intermediate target and intermediate and final target are statistically significant both for the full sample and the sub-sample, but for 2002Q1–2014Q4 they became essentially lower. At first glance, it is not a good sign for monetary targeting.

Table 1. Pair correlations between operational, intermediate and final target

	1995Q1–2014Q4			2002Q1–2014Q4		
	Δmb	$\Delta m3$	Δcpi	Δmb	$\Delta m3$	Δcpi
Δmb	1.00	-	-	1.00	-	-
$\Delta m3$	0.74 (9.64)	1.00	-	0.51 (4.17)	1.00	-
Δcpi	0.56 (5.89)	0.83 (13.4)	1.00	0.23 (1.67)	0.76 (8.18)	1.00

Note: variables are in natural logarithms, seasonally unadjusted. Sub-sample 2002q1–2014q4 corresponds to the time span used in Mironchik, Bezborodova (2015); t-statistics are in parentheses.
Source: own estimations.

Refining the analysis a bit, we tested for Granger causality between operational and intermediate target and intermediate and final target. In general a variable *x* Granger-causes variable *y*, if *y* can be better predicted using the histories of both *x* and *y* than using the history of *y* alone. Since the variables of interest can be potentially cointegrated, their logarithmic levels and testing procedure proposed in Toda, Yamamoto (1995) are applied. These authors showed that vector autoregression model (VAR) formulated in levels can be estimated and tested even if the variables are integrated or cointegrated of an arbitrary order. They suggested applying a usual lag selection procedure to a possibly integrated or cointegrated VAR since the standard asymptotic theory is valid as far as the order of integration of the process does not exceed the true lag length of the model. After the determination of a lag length, say *k*, VAR model with lag length $k+d_{max}$ is estimated, where d_{max} is the maximal order of integration of the variables that is suspected. Then the coefficients of the last d_{max} lagged variables in the model are regarded as zeros and ignored, and one can test linear or nonlinear restrictions on the first *k* coefficient using the standard asymptotic theory.

Table 2. Granger causality between operational, intermediate and final target

Granger	1995Q1–2014Q4		2002Q1–2014Q4	
test	Wald test (χ^2)	*p*-value	Wald test (χ^2)	*p*-value
$mb \nRightarrow m3$	3.58	0.1669	0.14	0.9328
$m3 \nRightarrow mb$	13.72	0.0011	9.32	0.0095
$m3 \nRightarrow cpi$	2.33	0.6753	26.42	0.0000
$cpi \nRightarrow m3$	26.20	0.0000	46.60	0.0000

Note: variables are in natural logarithms, seasonally unadjusted. Sub-sample 2002q1–2014q4 corresponds to the time span used in Mironchik, Bezborodova (2015). $x \nRightarrow y$ corresponds to null hypothesis (H_0) that a variable x dies not Granger cause a variable y. For (mb, m3) and (m3, cpi) lags length equal to 2 and 4 are chosen respectively. Additional lag is added to each test in accordance with Toda, Yamamoto procedure (1995). Seasonal dummies are also included. All equations are tested for serial correlation (H_0 that serial correlation is absent was not rejected).
Source: own estimations.

The results of Granger causality tests are presented in Table 2. As one can see, simple causality analysis does not speak in favor monetary targeting. Ruble monetary base does not cause the monetary aggregate M3. Instead, we observe a reverse causal link: M3 causes the monetary base. Moreover, for the full sample money does not causes prices, but vice versa prices affect money in a Granger sense. In the shorter sub-sample these variables are interrelated. Again, at first sight, these results are also not supportive for inflation targeting.

Thus, summarizing the results of this simple analysis, the following conclusions can be made:

- operational, intermediate and final target are moderately correlated, but over the last years these correlations became essentially lower;
- operational target does not Granger cause the intermediate target, instead one can see a reverse causality;
- over 1995q1–2014q4, monetary aggregate M3 did not cause CPI in a Granger sense, but the other way around prices cause money. Over 2002q1–2014q4, a bi-directional causality was observed. However, in accordance with additional analysis, the sum of the coefficients at *m*3 lags is not statistically different from zero;
- obviously, simple correlations and causalities presented above cannot justify or falsify monetary targeting in Belarus;
- it follows that a more comprehensive analysis of the monetary targeting prerequisites in Belarus is needed.

The aim of our study is to evaluate the empirical foundations of monetary targeting in Belarus using relevant comprehensive econometric techniques. It is necessary to make some important remarks here. First of all, a really workable mechanism of monetary targeting implies the existence of a stable long-run relationship between the operational and intermediate target of monetary policy. Furthermore, this linkage should be one-directional: from the operating target to the intermediate target, but not vice versa. Only in this case an effective control of the money supply in the economy is possible. Secondly, another essential element of monetary targeting is the existence of a stable money demand function. And stability is a key prerequisite here. Finally, the monetary aggregate, selected as an intermediate target should have a significant impact on the inflation dynamics in the long- and short-run. Accomplishment of these conditions allows rendering the projected impact on inflation in the framework of monetary targeting. All preconditions of monetary targeting mentioned above are testable empirical hypotheses and can be verified or rejected using appropriate econometric methods.

In this paper, we use econometric approaches based on the cointegrated vector autoregression model (cointegrated VAR) to analyze the relationships between the operating and the intermediate target and estimate the real money demand function. The obtained money demand function allows us to identify disequilibrium on the money market in the form of the real money gap. This estimated unobservable variable, along with the short-run dynamics of the money supply is used as the main explanatory variables in the P^*-model of inflation in order to assess the impact of monetary factors on its dynamics. Such an approach allows to consistently empirically testing the existence of necessary conditions for monetary targeting in Belarus.

In the next section of the paper we briefly discuss the usefulness of monetary aggregates in the conduct of monetary policy relying on relevant economic literature. Then, in the third section the research strategy and the main working hypotheses are formulated. The main fourth section presents and discusses the results of the econometric analysis. In particular, the long-run money supply and demand functions are estimated and analyzed; the possibility of using monetary variables as leading indicators of inflation in Belarus is tested. The sixth section concludes and provides several policy implications.

2. When can monetary aggregates be useful for monetary policy?

Despite the fact that the well-known dictum that inflation is always and everywhere a monetary phenomenon, in general, is supported by the academic community, in the last decades academic researcher often disregarded monetary aggregates in economic analysis and monetary policy. This is manifested especially clearly in the era of inflation targeting. Nevertheless, many practitioners and researchers continue to consider monetary aggregates as important indicators for monetary policy. The most striking real life example is the ECB, with its two pillars approach to the analysis of the risks to price stability, where monetary trends are taken explicitly into account.[1] Among the academic research it should be noted the recent paper of

[1] https://www.ecb.europa.eu/mopo/strategy/html/index.en.html

Thornton (2014) with the striking title “Monetary policy: Why money matters (and interest rates don’t)” where the author argues that money is essential for monetary policy because it is essential for controlling the price level, and the monetary authority’s ability to control interest rates is greatly exaggerated.

In the context of our research the empirical relationship between money and prices is of the main interest. Thus, we will focus further on the several relevant papers analyzing money demand and the impact of the monetary indicators on inflation.

Very often the analysis of the influence of money on inflation is carried out in the framework of a money demand function. However, in a stable money demand function where all explanatory variables are exogenous (weakly and super exogeneity), it is impossible to invert the money demand equation into a price (inflation) equation [Ericsson (1998)]. To analyze inflation in a money demand framework, it is necessary that prices (inflation) have to be endogenous in the system of examined variables.

There are several interesting papers demonstrating the existence of interrelation between money and inflation. Specifically, in Baltensperger, Jordan and Savioz (2001) the issues of money demand and inflation in Switzerland are examined. The authors argue that money should continue to play an important role in monetary policy even if a central bank pursues a strategy based on inflation forecasts. Within the context of an error correction model, this paper delivers empirical evidence that both the growth rate of the monetary aggregate M3 and appropriate monetary overhang contain useful information with regard to future inflation. This evidence strongly suggests that money should remain an important indicator for monetary policy.

Trecroci and Vega (2002) consider the information content of M3 for future inflation in the euro area. Their results confirm that a significant positive association exists between the real money gap and future inflation up to five to six quarters ahead. Nielsen (2007) analyzes UK money demand over a period of 130 years. The author performs a multivariate cointegration analysis and illustrates how a long-run time series analysis may be conducted on a data set characterized by turbulent episodes and institutional changes. It is interesting to note that the empirical analysis demonstrates a single equilibrium relationship relating velocity to opportunity costs, and a significant link between excess money and inflation. Dreger and Wolters (2014) present a stable money demand function for real M3 in the euro area despite the financial crisis. There are two long-run relationships in the model: the first one is for money demand and the second one is for inflation. Thus, money and inflation are interrelated. Disequilibrium on the money market impacts on the growth rate of inflation and makes its forecast better in comparison with a benchmark model.

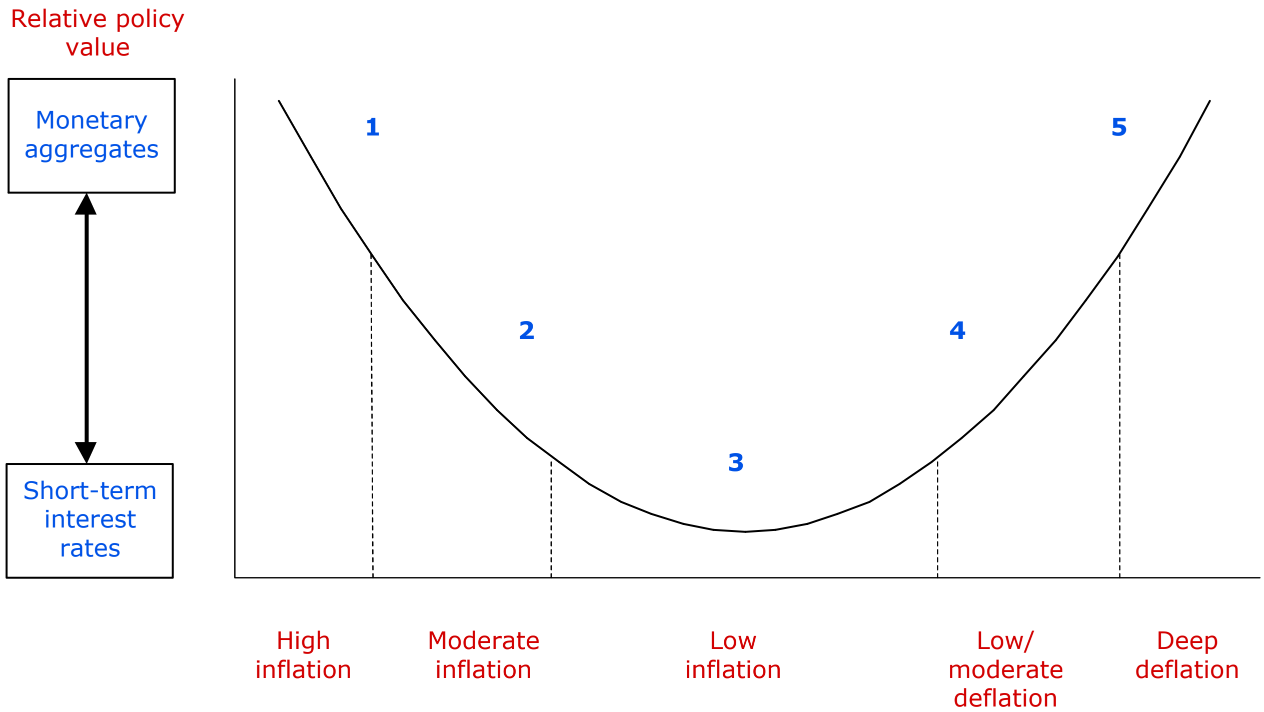
In Berger and Harjes (2009) monetary policy in the euro area is considered in the context of global liquidity, using a P^*-model. The paper shows that excess liquidity in the U.S. leads developments in euro area’s liquidity. Additionally, U.S. excess liquidity also enters consistently positive as a determinant of euro area inflation. The authors also point out on evidence that this conclusion may be related to a weakening of the effectiveness of monetary policy in the euro area during times of excessive U.S. liquidity.

For the US economy, the monetary overhang has a significant impact on the growth rate of inflation as demonstrated in Hossfeld (2010), where the author applies cointegrated VAR methodology while analyzing money demand, monetary overhang and inflation. In El-Shagi and Giesen (2013) the authors show the influence of monetary growth on inflation in the US without explicitly using a money demand function, applying multivariate state space model.

As one can see, the empirical evidence of the interrelationship between money and inflation in different countries and regions is quite wide. In our view, the results are heavily depending on the methodology used. An application of the cointegrated VAR technique permits the empirical verification or rejection of such relationships, allowing the data speak freely for themselves.

To finalize this brief review of the relevant literature, we would like to present some general considerations concerning the usefulness of monetary aggregates in the conduct of monetary policy. In Bordo and Filardo (2007) a promising and pragmatic zonal view on the relative importance of different instruments for monetary policy is discussed. The authors write: “Many monetary economists have come to regard the monetary aggregates as obsolete measures of the monetary policy stance. This critique has led some to view money as having lost its central role in the conduct of monetary policy. We say to those advocating excising money from monetary policy, “Not so fast”. To better understand the potential role for money, we develop a zonal view of monetary policy which reflects the historical regularity for the relative informativeness of the quantitative measures of monetary policy, such as the monetary aggregates, and real interest rates to depend on the inflation zone in which a central bank finds itself" (see figure 2).

Figure 2. Monetary policy: Zonal view



Source: Bordo, Filardo (2007).

In accordance with Bordo and Filardo (2007), there exists a U-shaped pattern between different zones and the usefulness of monetary aggregates relative to real short-term interest rates as measures of the stance of monetary policy. This U-shaped pattern is empirically validated. Thus, monetary aggregates are useful for monetary policy especially under high inflation (the Belarusian case) and deep deflation. Ultimately, the degree to which this is relevant is an empirical issue.

3. Research strategy and the main hypotheses

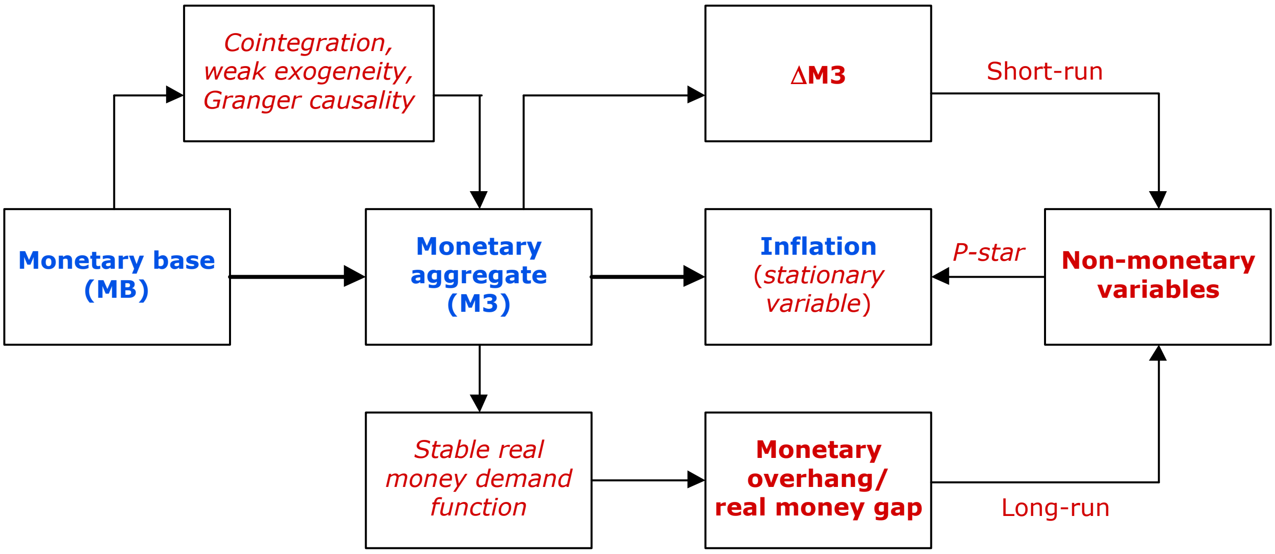
To denote the strategy of our empirical analysis, it is convenient to add the general concept of monetary targeting, depicted in Figure 1, with some important elements (see Figure 3). As we have mentioned earlier, effective monetary targeting supposes a uni-directional long-run relationship between operational and intermediate target. In econometric terms this means that the monetary base and the monetary aggregate M3 should be cointegrated. Additionally, the monetary base has to be at least weakly exogenous variable in the system. In this case, there will be a one-way long-run relationship between the levels of operational and intermediate target. Another prerequisite of monetary targeting is a unidirectional short-run relationship between the monetary base and M3. Econometrically, this means that between the monetary base and the monetary aggregate M3 a one-way Granger causality should exist. Thus, the operational target has to be strongly exogenous relative to the intermediate target. This insures the controllability of money supply by the NBB both in short- and long-run.

The next crucial condition for monetary targeting is a stable money demand function. Since the NBB uses the monetary aggregate M3 (broad money) as an intermediate target, the estimation of the money demand function is not a straightforward exercise. Theoretically, money may be demanded for at least two reasons: as an inventory to smooth differences between income and expenditure streams, and as one among several assets in a portfolio (Ericsson, 1998). Thus, long-run money demand function can be expressed as following:

$$M^d / P = f(I, \mathbf{R}), \qquad (1)$$

where M^d is nominal money demand; P is the price level; I is a scale variable; $\mathbf{R}$ is a vector of returns on various assets. The function $f(\cdot,\cdot)$ is increasing in I, decreasing in those elements of $\mathbf{R}$ associated with assets excluded from M, and increasing in those elements of $\mathbf{R}$ for assets included in M .Since in Belarus the financial markets are highly underdeveloped, it is practically impossible to find the appropriate time series representing the rates of return on assets outside the monetary aggregate M3. The only pragmatic solution here, in our view, is to use some kinds of smoothed (trend) inflation as a proxy of opportunity cost of holding broad money. In a highly inflationary environment, such a choice seems quite feasible. Real GDP is a natural candidate for scale variable in money demand function for real M3. Consumer price index (CPI) is used as a deflator to get real money balances.

Figure 3. The econometrics of monetary targeting



Source: compiled by the authors.

In many empirical studies, the real money demand function is immediately estimated without preliminary testing of price homogeneity (price homogeneity means that a 1% increase of nominal money corresponds to a 1% increase of prices, i.e. monetary illusion is absent). Such an approach seems inappropriate from an empirical viewpoint. For this reason, at first we estimate nominal money demand function, then testing for price homogeneity and (if price homogeneity is not rejected) only thereafter turn to the use of real money demand function. Additionally, within the nominal money demand system it is possible to analyze directly the relationship between money and prices and test important hypothesis concerning price exogeneity (endogeneity). Endogeneity of prices in nominal money demand system is an essential precondition for monetary targeting and *P**-model of inflation.

Estimating the real money demand function, it is not enough to get a long-run relationship (cointegrating vector) with variables having sensible values of the coefficients and theoretically expected signs. To be useful for monetary policy, the real money demand function has to be stable in terms of existing cointegrating vectors, long-run and short-run parameters over the examined period. Real money demand function stability is a testable hypothesis (to be more precise – a set of hypotheses) and it can be verified in the framework of cointegrated VAR.

A stable real money demand function is a key point of monetary targeting. Moreover, it serves as a basis of estimation of the important unobservable indicator – the monetary overhang and real money gap. These estimated variables reflect disequilibria on the money market and can be used as a measure of inflation pressure in the long-run due to monetary factors. Monetary overhang is defined as the difference between the actual real stock of money and the equilibrium stock of money calculated on the basis money demand function. The real money gap is a closely related concept and it can also be calculated using real money demand function where actual values of explanatory variables are substituted by their potential (or trend) counterparts (Belke and·Polleit, 2009). The real money gap is a key variable in the *P**-model of inflation.

The *P**-model of inflation needs inflation to be a stationary variable. If it is not so, the model of inflation will be unbalanced (mixture of stationary and non-stationary variables). Inflation in Belarus over the last decades is characterized by different structural breaks which can mask stationarity of this variable. Thus, these structural breaks (mean shifts) have to be taken into account when testing inflation for a unit root.

The relationship between intermediate and final target is analyzed in the framework of *P**-model with the real money gap as a key explanatory variable characterizing the long-run impact of monetary growth (reduction) on inflation. The short-run influence on money growth is accounted through inclusion of the growth rates of nominal monetary aggregate into the model of inflation. In general, the *P**-model of inflation is a monetary model. However, non-monetary variables can also be included into the model and tested for its significance. Among natural candidates for the role of non-monetary variables are the nominal exchange rate and the price index of the primary commodities on world markets.

Summing up the strategy of econometric analysis of monetary targeting in Belarus, depicted in Figure 3, we can emphasize three steps of our empirical study and the main working hypotheses to be tested:

(1) Analysis of money supply (testing for cointegration, exogeneity, Granger causality) using cointegrated VAR methodology (Johansen, 1998; 1991; 1995; Johansen and Juselius, 1990; Juselius, 2006). Analyzing the long-run money supply function, we took into account the suggestion of Baghestani and Mott (1997) in including an appropriate interest rate into money supply equation. In our case, perhaps, a nominal refinancing rate is the most obvious choice, however, eventually we used the refinance rate in real terms since this variable is more in line with broad money where foreign currency deposits expressed in Belarusian rubles contain an inflationary component.

The main working hypotheses on this step of analysis are:

- H_{11}: Operational target (ruble monetary base) and intermediate target (monetary aggregate M3) are cointegrated;
- H_{12}: There is a one-way long-run link between the ruble monetary base and the monetary aggregate M3, i.e. the monetary base is weakly exogenous variable, while M3 is the endogenous variable in the system;
- H_{13}: The growth of the ruble monetary base leads to an increase of M3, while the increase of real refinance rate reduces monetary aggregate M3;
- H_{14}: Money supply function is stable over the examined period, i.e. stability for cointegration test, the long-run parameters and short-run coefficients is not rejected;
- H_{15}: There is one-way short run Granger causality between the operational and the intermediate target, i.e. the monetary base is a strongly exogenous variable;
- H_{16}: The monetary aggregate M3 is controllable by the NBB by means of manipulating the operational target. In econometric terms, the controllability means that the shocks of base money have permanent impact on monetary aggregate M3, but not vice versa.

(2) Analysis of nominal and real money demand for M3, using cointegrated VAR methodology. We base our analysis on Ericsson (1998) considering the general approaches to money demand modeling and Juselius (2006) applying cointegrated VAR methodology.

The main working hypotheses on the second step are:

- H_{21}: There is a nominal money demand function in Belarus, i.e. nominal M3, CPI and real GDP are cointegrated with sensible values of the coefficient and expected signs;
- H_{22}: There is price homogeneity in this long-run relationship, i.e. the coefficient at CPI in cointegrated vector is equal to 1. Thus, we are able to analyses the real money demand function correctly without loss of information;
- H_{23}: There is an interrelationship between money and prices in a nominal money demand system, i.e. monetary aggregate M3 and CPI are weakly endogenous variables, while real GDP is a weakly exogenous variable;

- H_{24}: There is a real money demand function in Belarus, i.e. real M3, real GDP and smoothed (trend) are cointegrated with sensible values of the coefficient and expected signs;
- H_{25}: The real money demand function is stable over the examined period, i.e. stability for cointegration test, the long-run parameters and short-run coefficients is not rejected.

(3) Determination of the role of money in inflation dynamics using a *P**-model. We use the *P**-model of inflation with real money gap as proposed in Gerlach and Svensson (2003) and additionally include nominal growth of M3 into the model. The non-monetary variables are also tested within the *P**-model of inflation.

On the third step of analysis the main working hypotheses are as follows:

- H_{31}: Inflation is a stationary variable, perhaps, in the presence of multiple mean shifts;
- H_{32}: Monetary variables can be considered as the leading indicators of inflation in Belarus, i.e. both the real money gap, obtained on the basis of real money demand function, and growth rate of nominal M3 are statistically significant and have an expected signs in appropriate *P**-model of inflation along with additional non-monetary variables;
- H_{33}: *P**-model of inflation is recursively stable over the examined period.

Finally, one important remark should be made. While applying a cointegrated VAR methodology, one can use seasonally adjusted or raw (seasonally unadjusted) data. In accordance with Ericsson, Hendry and Tran (1994), cointegrating vectors are invariant to a wide class of seasonal adjustment procedures. This means that a number of cointegrated vectors and the values of long-run parameters will be in fact similar regardless of whether seasonally adjusted or unadjusted data are used. However, seasonal adjustment may affect the exogeneity status of variables. Since exogeneity status of the variables is of particular interest in our research we decided to use seasonally unadjusted data.[2]

In our research the following econometric software is used: CATS 2 in RATS (Dennis, 2006) and Structural VAR, version 0.45 provided by Anders Warne[3] – for applying cointegrated VAR methodology; OxMetrics 7.1 (Doornik and Hendry, 2013) – for estimating and evaluating *P**-model of inflation.

4. Results of empirical analysis

4.1. Data used

We used the following raw data in the empirical analysis:

- monetary base (MB) in Belarusian rubles which includes cash in circulation, cash in banks' offices, required reserves, banks' deposits and deposits of other sectors of the economy (excluding general government);
- monetary aggregate M3 (broad money) in Belarusian rubles which includes cash in circulation, transferable deposits of natural persons and legal entities, other deposits of natural persons and legal entities, securities issued by banks (outside bank circulation) in national currency, deposits in foreign currency (transferable and other deposits of natural persons and legal entities), securities issued by banks (outside bank circulation) in foreign currency and deposits in precious metals;[4]
- nominal refinancing rate (NIRR);
- consumer price index (CPI);
- real gross domestic product (RGDP);

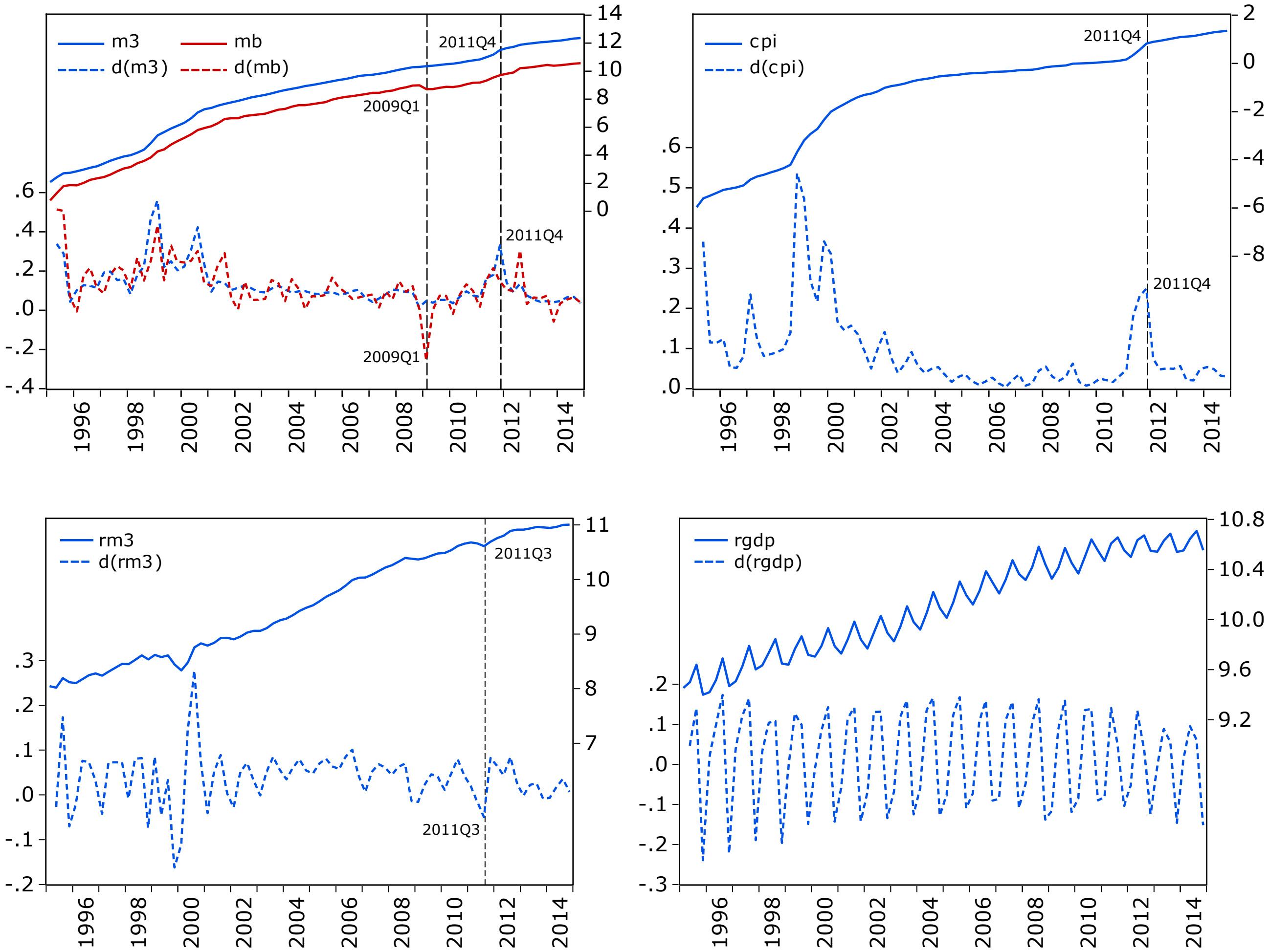
Quarterly seasonally unadjusted data for the period 1995q–2014q4 (20 years, 80 quarters) is used. The sample is sufficient for applying a cointegration analysis. We used quarterly data of real GDP in average 2009 prices. Since the official statistics does not represent the real GDP in average 2009 prices for the con-

[2] It should be noted that experiments with seasonally adjusted data demonstrate actually the same results as we have obtained using seasonally unadjusted data.
[3] http://texlips.hypermart.net/svar/index.html
[4] The definitions of the monetary base and broad money supply can be found at http://www.nbrb.by.

sidered period, the real GDP data for a number of years in 1995, 2000 and 2005 prices were converted into real GDP in 2009 prices by using available quarterly growth rates of real GDP. Quarterly CPI index, MB and M3 are obtained by averaging monthly data. Quarterly NIRR is also calculated by appropriate averaging available point data.

Such variables as a MB, M3, CPI and RGDP were transformed into natural logarithms: $mb_t = \ln \mathrm{MB}_t$, $m3_t = \ln \mathrm{M3}_t$, $cpi_t = \ln \mathrm{CPI}_t$, $rgdp_t = \ln \mathrm{RGDP}_t$. The first differences of the variables are used as approximations of the growth rates: $\Delta mb_t = mb_t - mb_{t-1}$, $\Delta m3_t = m3_t - m3_{t-1}$ $\Delta cpi_t = cpi_t - cpi_{t-1}$ $\Delta rgdp_t = rgdp_t - rgdp_{t-1}$. The log levels ant the first differences of these variables are depicted in Figure 4. These variables will be used further as endogenous in the cointegration analysis.

Figure 4. The main time series: endogenous variables



Note: all variables are in natural logarithms, seasonally unadjusted; d is the difference operator Δ.
Source: own estimations based on Belstat and the NBB data.

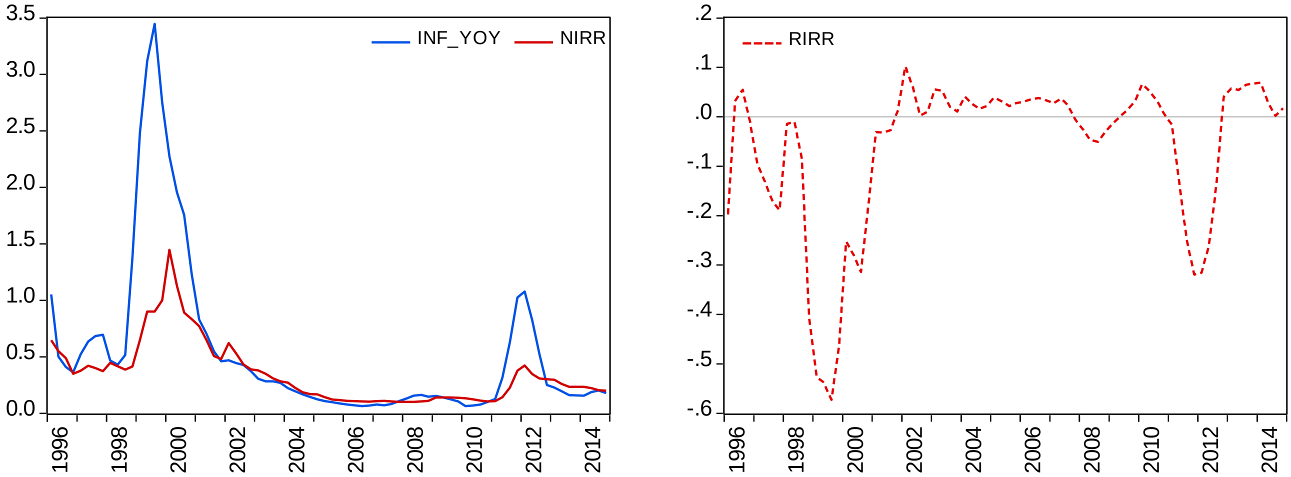
The graphical representation of the data shows that the monetary base and broad money are growing with approximately the same trend and potentially may be cointegrated. There are apparent level shifts in the dynamics of these variables in the last years: 2009q1 for the monetary base and 2011q4 for the monetary aggregate *m*3. All these structural breaks correspond to the financial crises in 2009 and 2011. Prices also demonstrate a level shift in 2011q4. Approximately at this time one can see a level shift (2011q3) in the dynamics of real *m*3. Thus, the main variables face practically similar structural breaks in the last years. Real GDP has a pronounced seasonal pattern. We also tested all other time series, presented in Figure 4, for the presence of identifiable seasonality using automatically TRAMO-SEATS procedure.[5] As a result, time series

[5] Software JDemetra+ 2.0 is used for testing seasonality.

appear to have seasonal patterns (in accordance with a combined test for presence of identifiable seasonality). So, these data characteristics have to be taken into account in econometric analysis through inclusion of seasonal dummies into the models and testing their statistical significance.

In Figure 5 we present three additional variables: the nominal refinancing rate (NIRR), the year-on-year inflation rate (INF_YOY) and the real refinancing rate (RIRR). In contrast to earlier considered time series, these variables are calculated as the growth rates of raw data and express as the coefficients. The real refinancing rate is obtained on the basis of the nominal refinancing rate and year-on-year inflation. It should be noted that for these variables we use a bit shorter sample 1996q1–2014q4 because of computational purposes. We tested these time series for the presence of seasonal pattern and existence of seasonality have been rejected. These variables (namely, RIRR and INF_YOY) will be used further as exogenous in cointegrated VAR models.

Figure 5. Auxiliary time series: exogenous variables



Note: all variables are the appropriate growth rates of raw data express as the coefficients.
Source: own estimations based on Belstat and the NBB data.

All log levels of the variables are evidently non-stationary, so we tested for a unit root only the first differences of the variables, presented in Figure 4 and the levels of variables depicted in Figure 5. A conventional augmented Dickey-Fuller unit root test was applied (ADF-test). For the variables with detected seasonal patterns this test includes seasonal dummies. All ADF-tests contain a constant as a deterministic variable. Lag length in ADF-tests for unit root is chosen to provide for the absence of residuals correlation. The results are presented in Table 3. Importantly, that H_0 of no residuals correlation in the appropriate regressions is not rejected for every tested variable. The null hypothesis of a unit root was rejected for Δcpi, $\Delta m3$, Δrm and RIRR at 1% significance level, for Δmb and $\Delta rgdp$ at 5% significance level. The unit root for INF_YOY is not rejected on a convenient 5% level. Thus, this variable with some reservations can be considered as non-stationary (year-on-year inflation looks quite smoothed and displays short-run trend of inflation dynamics).

Table 3. Unit root tests

Variable	Specification	Lag length	*t*-ADF	*p*-value	AR 1–5 (*p*-value)
Δcpi	C, S	0	−3.75	0.005	0.071
$\Delta m3$	C, S	0	−3.87	0.004	0.922
Δmb	C, S	2	−2.91	0.044	0.250
$\Delta rm3$	C, S	0	−7.22	0.000	0.223
$\Delta rgdp$	C, S	3	−3.28	0.016	0.543
INF_YOY	C	3	−2.77	0.062	0.180
RIRR	C	1	−5.31	0.000	0.290

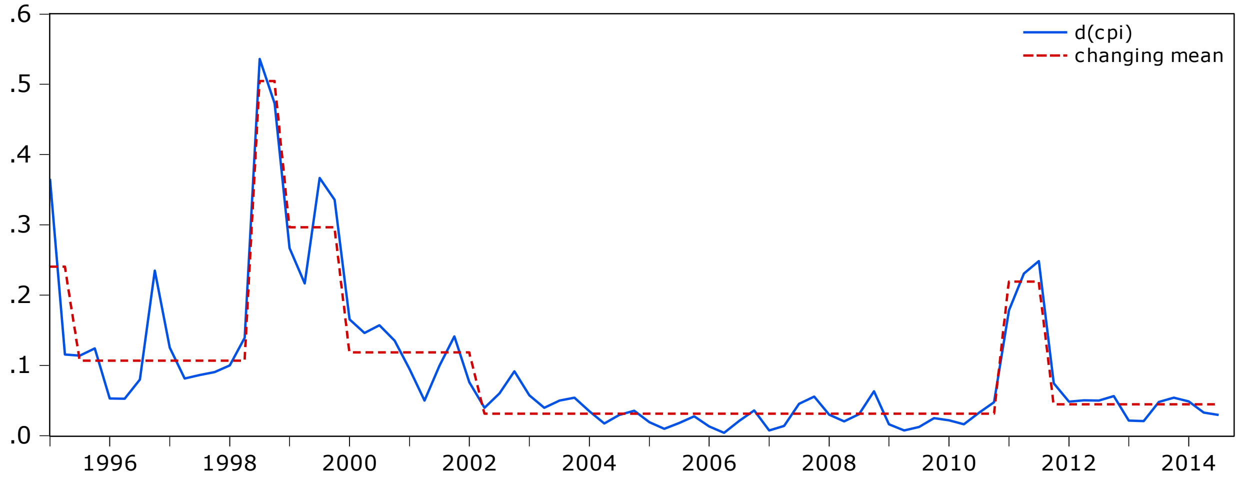
Note: C is constant, S are seasonal dummies. Lag length in ADF-tests for unit root is chosen so provide the absence of residuals correlation in the appropriate regressions. AR 1–5 is F-test for residuals correlation of 1–5 order; H_0 *denotes the absence of residuals correlation.*
Source: own estimations.

Stationarity of inflation (Δcpi) is extremely important for our further analysis. At first sight, inflation is a stationary variable in accordance with the conventional Dickey-Fuller unit root test. However, tests for serial correlation are only marginally insignificance at the 5% level. Moreover, the graph of inflation in Figure 4 demonstrates very complicated dynamics with possible multiple structural breaks. Therefore, we need a more in-depth analysis of this variable.

In Pelipas (2011, 2012) it is argued that an augmented Dickey-Fuller unit root test is intrinsically a univariate case of the vector autoregression model with an equilibrium correction mechanism. If a variable of interest is stationary, then it is cointegrated with itself. This means that any departure of a variable from its equilibrium level after a shock will be corrected. In fact, this is similar to the feedback coefficients in Johansen's multivariate cointegration model that characterize the speed of the equilibrium correction in the system.

In such a context, it is possible to reformulate the Dickey-Fuller unit root test, treating the multiple changes of the mean defined endogenously as in the vector autoregression model with equilibrium correction mechanism in the case when a constant is restricted in cointegration space. The appropriate coefficient in the model one can treat as an equilibrium correction mechanism and its significance can be tested using critical values from the cointegration test for conditional equilibrium correction model (Ericsson and MacKinnon, 2002). The step dummies in a model can be considered as the additional variables in cointegration vector and then one can use the critical values in accordance with the total number of such variables.

Figure 6. Inflation dynamics with changing mean



Note: step indicator saturation procedure with $\alpha = 0.001$ for Δcpi and fixed constant is applied.
Source: own estimations.

Using step indicator saturation procedure (Castle, Doornik, Hendry and Pretis, 2015) for the model containing Δcpi and fixed constant with a very small significance level $\alpha = 0.001$, we detected multiple mean shifts in inflation dynamics (see Figure 6). Then these shifts were used in Dickey-Fuller unit root test implemented in OxMetrics with two lags to avoid residuals correlation. The results clearly reject the null hypothesis of unit root for Δcpi (*t*-ADF is equal to −10.689, which exceeds the critical value at 1% significance level). Thereby, we confirmed the hypothesis H_{31} that inflation is a stationary variable in the presence of multiple mean shifts.

4.2. Money supply: Testing the relationship between operational and intermediate target

Testing the controllability of the intermediate target (*m*3) by means of the operational target (*mb*) we have to examine at least the following:[6]

- existence of cointegration between *m*3 and *mb*;
- weak exogeneity of *mb* with respect to *m*3;
- Granger causality from Δmb to Δm3, but not vice versa, i.e. strong exogeneity of *mb*;

[6] Controllability testing within the cointegrated VAR model is discussed, for instance, in Hendry, Mizon (1998) and Johansen, Juselius (2003).

– positive significant long-run impact of *mb* shock on *m3* from the long-run impact matrix C, but not vice versa.

At first, we experimented with pairwise cointegration between *m3* and *mb*, however, this does not lead to sensible results in terms of weak exogeneity and Granger causality. Then an additional variable – the real refinancing rate was included into the system. It is important to note that RIRR is a stationary variable in accordance with the results of Table 3 and this fact should be taken into account while applying the cointegrated VAR model. To handle a stationary variable in the cointegrated VAR model, we apply the approach proposed by Rahbek and Mosconi (1999) where stationary variables accumulated into the long-run part of the model and included in its initial form in the short-run part of the model with appropriate lags.

As a result, we use the system (*m*3, *mb*) with 2 lags, unrestricted constant, restricted into cointegration space trend and centered seasonal dummies. The step dummy for 2009q1 (St2009q1) is included in the cointegrating vector in accordance with the procedure proposed in Johansen Mosconi and Nielsen (2000) in order to make allowance of pronounced level shift in *mb* due to the financial crisis. The variable RIRR is included in the short-run part of the cointegrated VAR model with current lag only and in the cointegrating vector as an accumulated variable, cum (RIRR). The model also includes two impulse dummies for 2009q1 and 2009q2, reflecting the level shift effect in the short-run part of the model, and one differenced impulse dummy which is equal to 1 in 1999q1 and – 1 in 1999q2. This dummy corrects for large residuals and needs to improve model specification.

This specification is tested for residuals correlation; normality and heteroskedasticity (see Table A1 in the Annex). Multivariate tests of serially uncorrelated residuals indicate that the null of no residuals correlation cannot be rejected against the alternative hypothesis of first and fourth order correlation, respectively. Multivariate normality of the residuals is rejected but this rejection is due to residuals skewness but not due to excess kurtosis. However, simulation studies have demonstrates that statistical inference in cointegrated VAR is sensitive to residual correlation, residual skewness and parameters non-constancy, while excess kurtosis and heteroskedasticity are not so serious problem (Juselius, 2006). Taken this into account, one can conclude that our initial model is well specified and can be used for further analysis.

Table 5. Money supply: results of cointegration analysis

(1) Cointegration test

Null hypothesis, H_0	Eigenvalue	LR(trace)	*p*-value, asymptotic	*p*-value, bootstrap
$r = 0$	0.5436	74.4467	0.0000	0.0005
$r \leq 1$	0.1564	13.2691	0.2221	0.4037

(2) Standardized cointegrating vector, β' and α-coefficients

Variables	*m*3	*mb*	Cum(RIRR)	Sd2009q1	trend
Cointegrating vector, β'	1.0000	−1.0898	0.0227	−0.3198	0.0049
α-coefficients	−0.4620	0.1102			

(3) Tests for significance of a given variable in β' and weak exogeneity tests (*p*-value in the parentheses)

Variables	*m*3	*mb*	Cum(RIRR)	Sd2009q1	trend
Significance of a given variable in β', $\chi^2(1)$	47.5252 (0.0000)	45.6331 (0.0000)	0.8250 (0.2637)	22.7983 (0.0000)	0.9957 (0.3183)
Weak exogeneity, $\chi^2(1)$	42.3803 (0.0000)	1.2940 (0.2553)			

(4) Testing restrictions (*p*-value in the parentheses)

$\beta_{trend} = 0$	$\chi^2(1)$ = 0.9957 (0.3183)
$\alpha_{mb} = 0$	$\chi^2(1)$ = 0.8562 (0.3548)
$\beta_{trend} = 0 \cap \alpha_{mb} = 0$	$\chi^2(2)$ = 1.8519 (0.3962)

(5) Estimated cointegrating vector with restrictions

Variables	*m*3	*mb*	Cum(RIRR)	Sd2009q1	trend
Cointegrating vector, β'	1.0000	−1.0440	0.0434	−0.2692	–
Standard errors	–	0.0092	0.0125	0.0253	–
α-coefficients	−0.5176	–			
Standard errors	0.0546	–			

Note: All calculations were carried out with Structural VAR 0.45 software. Asymptotic p-values for cointegration test are obtained by CATS in RATS 2 using simulations.
Source: own estimations.

The results of cointegration test are presented in Table 5. Since our cointegrated VAR includes stationary exogenous variable and shift dummy in cointegrated space, the appropriate asymptotic critical values are simulated, using the number of replication equal to 10,000 with length of random walks equal to 500. Additionally, bootstrap critical values are also calculated.

The null hypothesis of no cointegration between *m*3 and *mb* is clearly rejected. Thus, there is a long-run relationship between operational and intermediate target. Additionally, *mb* is weakly exogenous variable in accordance with the appropriate test.

Since the trend is not significant in the cointegrating vector, it can be excluded from further analysis. After that, the variable cum(RIRR) becomes significant in the cointegrating vector with the theoretically expected negative sign.[7] The coefficient at *mb* is positive and highly significant. Its point estimates is equal to 1.044 with bootstrap 95% confidence intervals equal to [1.026 1.064], i.e. the main parameters of long-run relationship is estimated quite precisely.

In accordance with the cointegration analysis, the money supply function can be expressed as follows:

$$m3 = 1.044mb - 0.043Cum(RIRR) + 0.269St2009q1. \tag{2}$$

[7] It should be noted that in all tables with cointegration analysis results signs are reversed: minus means positive impact, plus means negative impact. It is a convenient representation henceforth for formulation of equilibrium correction terms.

Adjustment to disequilibria is quite fast here; it takes about two quarters to restore equilibrium after unexpected shocks (1/0.5176).

The constancy of the determined long-run relationship over the full sample is of great importance. Usually, recursive estimates over a limited time period and visual inspection of recursive Chow forecast, break-point, or predictive failure tests have been used to examine this problem. Such diagnostics are useful for preliminary analyses but any inferences drawn from them neglects a large fraction of the sample period and do not takes into account that such tests are formal tests only for a single point in time. Following Bruggeman, Donati and Warne (2003) we applied a set of stability tests to examine the constancy of (1) non-zero eigenvalues; (2) parameters of long-run relationship; (3) sort-run parameters. In the first case, Hansen-Johansen fluctuation test of the constancy of the non-zero eigenvalues is used (Hansen and Johansen, 1999); in the second case, Nyblom supremum and mean tests of the constancy of the long-run parameters is used (Nyblom, 1989); in the third case Ploberger-Kramer-Kontrus fluctuation test of the constancy of short-run parameters is used (Ploberger, Kramer and Kontrus, 1989). These tests do not require trimming of the sample as a base period, so the full sample can be used while analyzing constancy.

Table 6. Money supply: constancy analysis

Fluctuation test of the constancy of the non-zero eigenvalues	$\sup_{t\in T} \tau_{t\|T}(\lambda_1)$ = 0.4151 (0.8214)
Tests of the constancy of the long-run parameters:	
supremum	$\sup_{t\in T} Q_T^t$ = 0.4710 (0.9010)
mean	$\text{mean}_{t\in T} Q_T^t$ = 0.1400 (0.7659)
Fluctuation test of the constancy of short-run parameters	
*m*3	S(11) = 0.8022 (0.6648)
mb	S(11) = 0.8672 (0.5368)

Note: Short-run parameters are fixed at mean sample level while calculating fluctuation test of the constancy of the non-zero eigenvalues and tests of the constancy of the long-run parameters. The tests of the constancy of the long-run parameters are calculated for the restricted model; other tests are applied for unrestricted model. Bootstrap p-values are in parentheses.
Source: own estimations.

The results of constancy analysis are presented in Table 6. In accordance with obtained tests and appropriate bootstrap *p*-values, one can conclude that the money supply function do not show any non-constancy in non-zero eigenvalues, long-run and short-run parameters of the model. Thus, the results of the cointegration analysis are constant over the whole sample.

Next, we performed Granger causality tests on the basis of the obtained restricted cointegrated VAR. The results are shown in Table 7. As one can see, Granger non-causality for *mb* relative to *m*3 is strongly rejected. In its turn, *m3* does not Granger cause *mb* according to both asymptotic and bootstrap *p*-values. Thus, taken into account the results of weak exogeneity tests, we can conclude that the monetary base is a strongly exogenous variable relative to the monetary aggregate M3. These results are in striking contrast with those presented in Table 2 as simple preliminary causations.

Table 7. Granger causality between mb and m3

Granger test	Wald test (χ^2)	*p*-value, asymptotic	*p*-value, bootstrap
mb⇏*m*3	48.8059	0.0000	0.0000
*m*3⇏*mb*	3.3944	0.1357	0.1896

Note: x⇏y corresponds to null hypothesis (H_0) that a variable x dies not Granger cause a variable y. Cointegrated VAR model with restriction β_{trend} = 0 is used.
Source: own estimations.

The coefficients of the C-matrix, represented in Table 8, can be interpreting as a long-run effect on variables *m*3 and *mb* coming from shocks (innovations) ε_{m3} and ε_{mb}. In this case, the controllability of *m*3 by means of *mb* implies a positive significant long-run impact of *mb* shock on *m*3 but not vice versa. The results of Table 8 confirm this: monetary base shock has a permanents impact on the monetary aggregate M3. The opposite impact can be only transitory.

Table 8. The C-matrix: long-run cumulative impact of the shocks

Variable	Shocks	
	ε_{m3}	ε_{mb}
*m*3	0.2595 (0.2452)	1.2377 (0.2982)
mb	0.2486 (0.2348)	1.1856 (0.2856)

Note: standard errors are in parentheses. Cointegrated VAR model with restriction $\beta_{trend} = 0$ is used.
Source: own estimations.

We have actually confirmed all formulated hypotheses concerning money supply function (H_{11}–H_{16}). Summarizing the obtained results we can note the following:

- There is strong evidence for the existence of cointegration (long-run relationship) between operational target (*mb*) and intermediate (*m*3);
- Operational target (*mb*) is strongly exogenous with respect to intermediate target (*m*3), i.e. weak exogeneity of *mb* and Granger non-causality from $\Delta m3$ to Δmb are took place, when the real refinancing rate is included into the system of equations;
- There is a significant positive long-run impact of an operational target (*mb*) shock on intermediate target (*m*3), but not vice versa.

Thus, in accordance with Belarusian historical data, one can conclude that the intermediate target is controllable by the operational target.

4.3. Estimating M3 money demand

We start our analysis of money demand with the estimation of the nominal money demand function, mainly to test price homogeneity and interrelationship between money and prices. So, the nominal money demand function serves as an intermediate tool of analysis.

For analyzing the nominal money demand function we use the system (*m*3, *cpi*, *rgdp*) with 4 lags, unrestricted constant, restricted into cointegration space trend and centered seasonal dummies. A step dummy for 2011q4 (St2011q4) is included in the cointegrating vector in order to take into account the level shift in *m*3 due to the financial crisis. Again, this was done according to the procedure proposed in Johansen, Mosconi and Nielsen (2000). There are several impulse dummies in the short-run part of the model, namely D1997q1, D1998q4 and D2000q1. This dummy corrects for large residuals and is needed to improve the model specification. It should be noted, however, that the system for nominal money is poorly specified (see Table A2 in Annex). Nevertheless, we used it just to test some important hypotheses, and if they are not rejected moving on to real money demand analysis[8].

[8] Model specification can be improved treating *rgdp* as weakly exogenous variable and using partial system for cointegration analysis with more impulse dummies correcting for large residuals.

Table 9. Nominal money demand: results of cointegration analysis

(1) Cointegration test					
Null hypothesis, H_0		Eigenvalue	LR(trace)	*p*-value, asymptotic	*p*-value, bootstrap
$r = 0$		0.4048	66.2652	0.0005	0.0100
$r \leq 1$		0.2232	26.8337	0.1248	0.2171
$r \leq 2$		0.0956	7.6343	0.5156	0.1786
(2) Standardized cointegrating vector, β' and α-coefficients					
Variables	*m*3	*cpi*	*rgdp*	Sd2011q4	trend
Cointegrating vector, β'	1.0000	−0.9803	−2.5277	−0.1498	0.0012
α-coefficients	−0.3990	0.1392	−0.0344		
(3) Tests for significance of a given variable in β' and weak exogeneity tests (*p*-value in the parentheses)					
Variables	*m*3	*cpi*	*rgdp*	Sd2011q4	trend
Significance of a given variable in β', $\chi^2(1)$	17.2684 (0.0000)	17.6896 (0.0000)	17.3347 (0.0000)	6.0063 (0.0143)	0.0316 (0.8590)
Weak exogeneity, $\chi^2(1)$	30.5518 (0.0000)	4.1227 (0.0423)	0.3233 (0.5696)		
(4) Testing restrictions (*p*-value in the parentheses)					
$\beta_{trend} = 0$	$\chi^2(1)$ = 0.0316 (0.8590)				
$\beta_{cpi} = -1$	$\chi^2(1)$ = 1.0039 (0.3164)				
$\beta_{cpi} = -1 \cap \beta_{trend} = 0$	$\chi^2(2)$ = 4.0808 (0.1300)				
$\alpha_{rgdp} = 0$	$\chi^2(1)$ = 0.3402 (0.5597)				
$\alpha_{cpi} = 0$	$\chi^2(1)$ = 4.4652 (0.0346)				
$\beta_{cpi} = -1 \cap \beta_{trend} = 0 \cap \alpha_{rgdp} = 0$	$\chi^2(3)$ = 4.4210 (0.2194)				
(5) Estimated cointegrating vector with restrictions					
Variables	*m*3	*cpi*	*rgdp*	Sd2011q4	trend
Cointegrating vector, β'	1.0000	−1.0000	−2.3481	−0.1366	–
Standard errors	–	–	0.0377	0.0329	–
α-coefficients	−0.2932	0.1328	–		
Standard errors	0.0574	0.0569	–		

Note: All calculations were carried out with Structural VAR 0.45 software. Asymptotic p-values for cointegration test are obtained by CATS in RATS 2 using simulations.
Source: own estimations.

Several important results follow from Table 9. First, the null hypothesis of no cointegration between *m3* and *mb* is rejected in accordance with both asymptotic and bootstrap p-values[9]. The null of two cointegrating vectors is rejected. Thus, there is a long-run relationship between *m3, cpi* and *rgdp,* representing a nominal money demand function. Secondly, all variables, except the time trend, are significant in the cointegration vector. Thirdly, money and price are interrelated according to weak exogeneity tests (also for prices weak exogeneity is rejected only at the 5% significance level). On the contrary, *rgdp* is a weakly exogenous variable. Fourthly, the hypothesis about price homogeneity cannot be rejected (both for a model with a time trend or without it). The adjustment coefficients for money (−0.2932) and prices (0.1328) have the "right" signs: when the money market is in disequilibrium, nominal money balances decrease and prices increase.

These results have important implications for further modeling. As far as money and prices are interrelated, it is possible to analyze inflation in a money demand function context and correctly apply the P*-model of

[9] Since this cointegrated VAR includes shift dummy in cointegrated space, the appropriate asymptotic critical values are simulated, using the number of replication equal to 10,000 with length of random walks equal to 500.

inflation. Additionally, price homogeneity permits us to use real money balances in further analysis without the loss of information.

In accordance with the cointegration analysis, the nominal money demand function can be expressed as follows:

$$m3 = cpi + 2.348rgdp + 0.137St2011q4\,. \qquad (3)$$

Adjustment to disequilibria takes about 3.4 quarters for *m*3 and about 7.5 quarters for *cpi* to restore equilibrium after unexpected shocks. We think that relatively slow price adjustment can be explained by the practice of administrative price regulation in Belarus.

Table 10. Real money demand: results of cointegration analysis

(1) Cointegration test					
Null hypothesis, H_0	Eigenvalue	LR(trace)	*p*-value, asymptotic	*p*-value, bootstrap	
$r = 0$	0.6161	85.1805	0.0000	0.0005	
$r \leq 1$	0.1890	15.2971	0.1377	0.1791	
(2) Standardized cointegrating vector, β' and α-coefficients					
Variables	*rm*3	*rgdp*	INF_YOY	Sd2011q3	trend
Cointegrating vector, β'	1.0000	−2.4613	0.0884	−0.1458	0.0005
α-coefficients	−0.4752	0.0901			
(3) Tests for significance of a given variable in β' and weak exogeneity tests (*p*-value in the parentheses)					
Variables	*rm*3	*rgdp*	INF_YOY	Sd2011q3	trend
Significance of a given variable in β', $\chi^2(1)$	50.8643 (0.0000)	50.3172 (0.0000)	37.2171 (0.0000)	22.0099 (0.0000)	0.0327 (0.8566)
Weak exogeneity, $\chi^2(1)$	101.1923 (0.0000)	2.6831 (0.1014)			
(4) Testing restrictions (*p*-value in the parentheses)					
$\beta_{trend} = 0$	$\chi^2(1)$ = 0.0327 (0.8566)				
$\alpha_{rgdp} = 0$	$\chi^2(1)$ = 2.6610 (0.1028)				
$\beta_{trend} = 0 \cap \alpha_{rgdp} = 0$	$\chi^2(2)$ = 2.6937 (0.2601)				
(5) Estimated cointegrating vector with restrictions					
Variables	*rm*3	*rgdp*	INF_YOY	Sd2011q3	trend
Cointegrating vector, β'	1.0000	−2.4331	0.0874	−0.1422	–
Standard errors	–	0.0254	0.0101	0.0201	–
α-coefficients	−0.4952	–			
Standard errors	0.0463	–			

Note: All calculations were carried out with Structural VAR 0.45 software. Asymptotic p-values for cointegration test are obtained by CATS in RATS 2 using simulations.
Source: own estimations.

Table 10 contains the cointegration analysis results for real money demand function. We use the system (*rm*3, *rgdp*) with 3 lags, unrestricted constant, restricted into cointegration space time trend and centered seasonal dummies. A step dummy for 2011q3 (St2011q3) is included in the cointegrating vector in order to take into account the level shift in *rm*3 due to the financial crisis. Additionally, year-on-year inflation INF_YOY) is included as non-stationary *I*(1) exogenous variable with lag = 0 in order to take into account the opportunity costs of holding real money balances. Importantly, without an opportunity cost variable it is not possible to identify cointegration between *rm*3 and *rgdp*. The model also contains three impulse dummies in the short-run part of the model, namely D1997q1, D1998q4 and D2000q1. This model is well specified (see Table A3 in Annex). It passed practically all misspecification tests. The only problem is residual correlation at lag 4. We tested additionally for residuals correlation at lags 3 and 5 but found no problems. Probably, autocorrelation at lag 4 is related to the seasonal pattern of the data.

There is one clear-cut cointegrating vector, representing a long-run real money demand function. All the coefficients have the anticipated signs and reasonable values for the Belarusian economy. When the insignificant time trend was excluded from the cointegrated vector, the real money demand function can be expressed as follows:

$$rm3 = 2.433 rgdp - 0.087 \mathrm{INF\_YOY} + 0.142 St2011q3\,. \quad (4)$$

Point estimate of the coefficient at *rgdp* is equal to 2.433 with bootstrap 95% confidence intervals equal to [2.50 2.37], i.e. the main parameters of long-run relationship is estimated quite precisely. The same is true for INF_YOY: 95% confidence intervals equal to [−0.066 −0.110] that is not for from the point estimate equal −0.087. Adjustment to disequilibria for *rm*3 is rather quick and takes about 2 quarters.

Table 11. Real money demand: constancy analysis

Fluctuation test of the constancy of the non-zero eigenvalues	$\sup_{t\in T} \tau_{t\mid T}(\lambda_1)$ = 0.5464 (0.1171)
Tests of the constancy of the long-run parameters:	
supremum	$\sup_{t\in T} Q_T^t$ = 0.5780 (0.6683)
mean	$\mathrm{mean}_{t\in T} Q_T^t$ = 0.2033 (0.4297)
Fluctuation test of the constancy of short-run parameters	
*m*3	S(14) = 0.9286 (0.3552)
mb	S(14) = 1.3683 (0.0525)

Note: Short-run parameters are fixed at mean sample level while calculating fluctuation test of the constancy of the non-zero eigenvalues and tests of the constancy of the long-run parameters. The tests of the constancy of the long-run parameters are calculated for the restricted model; other tests are applied for unrestricted model. Bootstrap p-values are in parentheses.
Source: own estimations.

The results of the constancy analysis are presented in Table 11. In accordance with obtained tests and appropriate bootstrap p-values, we can conclude that the real money supply function does not show any non-constancy in non-zero eigenvalues, long-run and short-run parameters of the model. Thus, the results of the cointegration analysis for *rm*3 are constant over the whole sample.

We have actually confirmed all formulated hypotheses concerning nominal and real money demand function (H_{21}–H_{25}). Summarizing the obtained results we can note the following:

- There is quite a stable, well-specified money demand function for real M3 in Belarus with the expected signs of the long-run parameters and reasonable values of the estimated coefficients;
- The cointegrating vector representing real money demand function can be used for construction of real money gap;
- The real money gap is estimated on the basis of restricted cointegrating vector from Table 10, where *rgdp* is replaced by *rgdp** (potential or trend rgdp);
- Real money gap can be used as the variable characterizing disequilibrium on the money market within the P*-model of inflation.

4.4. Money as a leading indicator of inflation: testing the relationship between intermediate and final target

To evaluate leading indicator properties of money for inflation we apply the *P**-model of inflation with the real money gap as the main explanatory variable (see Gerlach and Svensson, 2003).The real money gap is calculated as follows:

$$rm3gap = rm3 - 2.433 rgdp^* + 0.087 \mathrm{INF\_YOY} - 0.142 St2011q3\,, \quad (5)$$

where *rgdp** is potential (or trend) real GDP. Potential real GDP is estimated using the unobserved component model. We used a so-called smooth trend model where the level (trend) is fixed and the slope (growth rate of the trend) is stochastic. Additionally, the model contains a seasonal component, a stochastic cycle of order one and an irregular component. The model is corrected for possible structural breaks using an automatic detection procedure implemented in STAMP 8.3 (OxMetrics 7.1). More details concerning potential output estimation is presented in Pelipas, Kirchner and Weber (2014).

Besides the real money gap, our *P**-model includes lagged inflation, the growth rate of nominal M3 and non-monetary variables such as the nominal exchange rate (BYR/USD) and the price index of primary commodities. Thus, *P**- can be expressed formally in the following manner:

$$\Delta cpi_t = \mathrm{E}(\Delta cpi_t \mid \Theta_{t-1}) + \alpha_p (rm3_{t-1} - rm3^*_{t-1}) + \beta_z z_t \,. \qquad (6)$$

Thus, inflation in this model is determined by inflation inertia (expectations, $\mathrm{E}(\Delta cpi_t \mid \Theta_{t-1})$; the real money gap with lag 1, $rm3gap_{t-1} = rm3_{t-1} - rm3^*_{t-1}$; and other monetary and non-monetary variables. Initially, we built a model with 2 lags of all short run variables, the real money gap with lag 1, constant and centered seasonal dummies. Then a general-to-specific reduction of the initial model with automatic model selection along with step and impulse indicator saturation at $\alpha = 0.001$ is implemented. The final model with specification tests is presented in table 12.

Table 12. *P-model of inflation (1996q1–2014q4)**

Variables	Coefficient	Standard error	*t*-statistics	*p*-value
Constant	0.5160	0.0317	16.30	0.0000
Δcpi_{t-1}	−0.1594	0.0313	−5.09	0.0000
Δcpi_{t-2}	1.7405	0.3966	4.39	0.0000
$\Delta m3_t$	0.3489	0.0334	10.40	0.0000
$\Delta m3_{t-2}$	0.1412	0.0279	5.07	0.0000
Δner_t	0.2334	0.0158	14.80	0.0000
$rm3gap_{t-1}$	0.1170	0.0265	4.42	0.0000
Seasonal(1)	−0.0239	0.0035	−6.90	0.0000
Seasonal(2)	−0.0163	0.0036	−4.46	0.0000

Specification tests

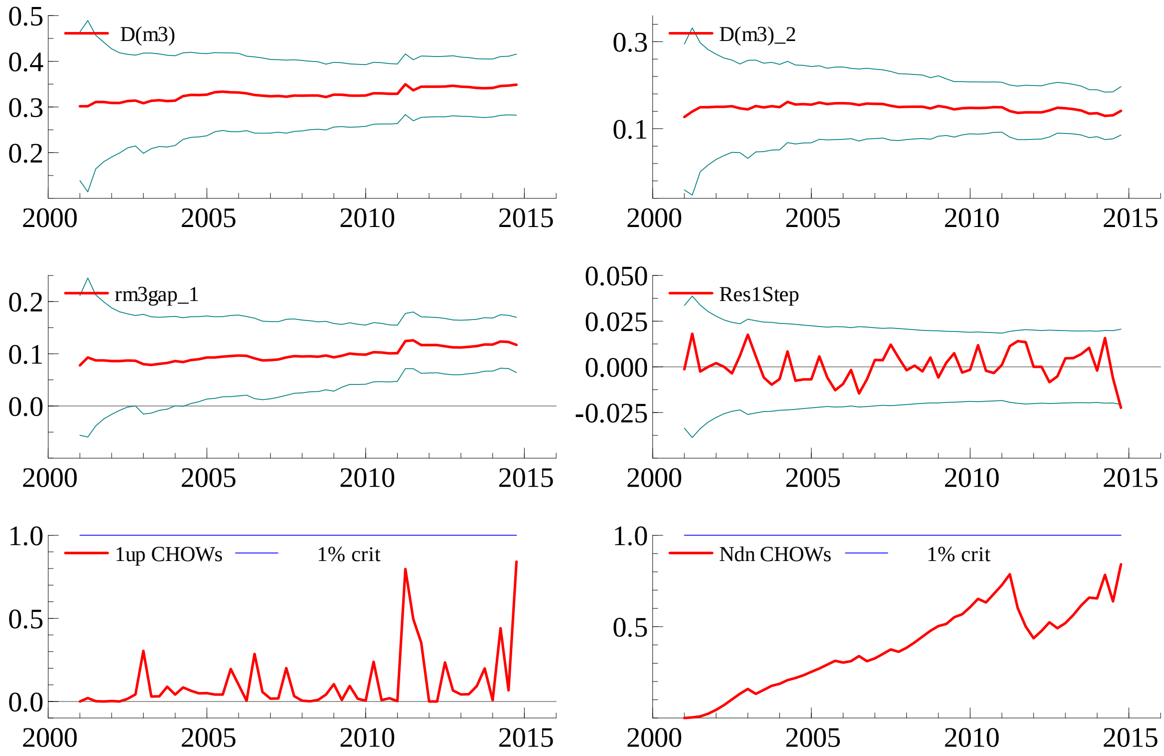
AR 1-5: F(5,52) = 1.1869 (0.3284)   ARCH 1-4: F(4,68) = 0.16694 (0.9545)

Normality: $\chi^2(2)$ = 6.0797 (0.0478) Hetero: F(18,51) = 1.0959 (0.3828)

RESET23: F(2,55) = 1.5251 (0.2266)

Note: the model also includes statistically significant impulse (I) and step (S) dummies I1997q1, I1998q3, I1998q4, I1999Q4 u S1999q4, S2000q1, S2001q1, S2002q2, S2011q4, S2012q1, respectively. AR is a test for residuals correlation of 1–5 orders, H_0: denotes the absence of residuals correlation; ARCH is a test for ARCH-effect, H_0: ARCH-effect is absent; Normality is a test for normality of the residuals, H_0: denotes that residuals are normally distributed; Hetero is a test for heteroskedasticity, H_0: heteroskedasticity is absent; Reset is the test for linearity, H_0: model has a linear specification; p-values are in parentheses
Source: own estimations.

Figure 7. Recursive stability of *P-model of inflation**



Note: Res1Step is one-step recursive residuals with confidence bands equal to 0±2σ; 1up CHOWs is one-step Chow test Ndn CHOWs is the break-point Chow test; 1% crit is a line, normalizing the Chow tests at 1% significance level. The values of the test that exceed the 1% blue line demonstrate model instability or the presence of outliers. o. D(m3), D(m3)_2 u rm3gap_1 are recursive estimates of appropriate regression coefficients with confidence bands equal to 0±2σ.
Source: own estimations.

As follows from Table 12, we have obtained a well specified model of inflation with significant monetary variables. The real money gap has a positive impact on inflation dynamics (as expected). The growth rate of nominal money is also positively related to inflation. It impacts with the current and the second lag. Additionally, the nominal exchange rate also leads to an increase of inflation in the current period. Inflation inertia according to this model is rather moderate. The model passed all misspecification tests (only null of normality is marginally rejected at the 5% level, but not at 1% level). It is important that the *P**-model of inflation is recursively stable as follows from Figure 7. This means that the influence of monetary variables is active over the whole sample. It should be noted, that index of the primary commodities does not enter the model significantly.

So we have actually confirmed our formulated hypotheses concerning the relationships between monetary variables and inflation (H_{31}–H_{33}). Summarizing the obtained results we can note the following:

- Money is a significant variable both in the long- and short-run in *P**-model of inflation;
- The real money gap and nominal money growth can be treated as leading indicators for inflation dynamics;
- Such relationships seem quite stable over the examined sample;
- Inflation persistence is not a very significant factor of inflation in Belarus;
- Inflation adjusts to disequilibrium on the money market rather slow, probably due active administrative price regulation in the country.

5. Conclusions and policy implications

In this paper, we provide econometric evidence that the operational target, intermediate target and final target are related in the right manner for monetary targeting in Belarus. Such relationships are confirmed for a rather long period: 1995Q–2014Q4**.**

The monetary base and M3 are cointegrated. The monetary base is strongly exogenous related to M3. The intermediate target is controllable by the operational target. Thus, **the first requirement for monetary targeting is fulfilled**.

Money and prices are homogeneous, so the usage of real money is an appropriate option. In a nominal system, money and prices are interrelated, which is a good prerequisite for monetary targeting and P*-modeling of inflation.

There is quite a stable money demand function for real M3. Thus, **the second requirement for monetary targeting is relatively fulfilled**. However, the absence of a relevant opportunity cost indicator (beside inflation) makes the real money demand function for M3 less informative concerning the behavior of economic agents.

The cointegrating vector from the real money demand function is used for construction of the real money gap, reflecting disequilibrium on the money market. The real money gap (with one lag) and changes of M3 are statistically significant in a P^*-model of inflation. Thus, **the third requirement for monetary targeting is fulfilled**.

To sum up, monetary targeting in Belarus can be justified from an econometric point of view using relatively long historical data. However, the obtained relationships are very sensitive to model specification. Moreover, the real money demand function for M3 is far from a traditional one with a set of opportunity cost measures. Taking into account these complexities, monetary targeting should be considered as a transitional regime of monetary policy in Belarus.

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Annexes

Table A1. Specification tests: money supply

Tests	Unrestricted model (r=2)	Restricted model (r=1)
Residuals correlation		
LM(1)	$\chi^2(4)$ = 2.1373 (0.7105)	$\chi^2(4)$ = 1.1774 (0.8818)
LM(4)	$\chi^2(4)$ = 2.2082 (0.6975)	$\chi^2(4)$ = 2.4861 (0.6471)
Normality	$\chi^2(4)$ = 38.7840 (0.0000)	$\chi^2(4)$ = 22.7971 (0.0001)
skewness	$\chi^2(2)$ = 1.5647 (0.4573)	$\chi^2(2)$ = 1.6642 (0.4351)
kurtosis	$\chi^2(2)$ = 37.2143 (0.0000)	$\chi^2(2)$ = 21.1329 (0.0000)
ARCH		
LM(1)	$\chi^2(9)$ = 24.1087 (0.0041)	$\chi^2(9)$ = 7.7559 (0.5589)
LM(4)	$\chi^2(36)$ = 102.5533 (0.0000)	$\chi^2(36)$ = 84.0163 (0.0000)

Table A2. Specification tests: nominal money demand

Tests	Unrestricted model (r=2)	Restricted model (r=1)
Residuals correlation		
LM(1)	$\chi^2(9)$ = 29.1213 (0.0006)	$\chi^2(4)$ = 27.8393 (0.0010)
LM(4)	$\chi^2(9)$ = 13.7865 (0.1301)	$\chi^2(4)$ = 15.8085 (0.0710)
Normality	$\chi^2(6)$ = 73.3172 (0.0000)	$\chi^2(6)$ = 150.8711 (0.0000)
skewness	$\chi^2(3)$ = 31.1897 (0.0000)	$\chi^2(3)$ = 50.7870 (0.0000)
kurtosis	$\chi^2(3)$ = 42.1276 (0.0000)	$\chi^2(3)$ = 100.0904 (0.0000)
ARCH		
LM(1)	$\chi^2(36)$ = 60.4899 (0.0065)	$\chi^2(4)$ = 67.0740 (0.0013)
LM(4)	$\chi^2(144)$ = 226.8560 (0.0000)	$\chi^2(4)$ = 227.4860 (0.0000)

Table A3. Specification tests: real money demand

Tests	Unrestricted model (r=2)	Restricted model (r=1)
Residuals correlation		
LM(1)	$\chi^2(4)$ = 3.2179 [0.5221]	$\chi^2(4)$ = 2.7329 [0.6035]
LM(4)	$\chi^2(4)$ = 19.3078 [0.0007]	$\chi^2(4)$ = 23.2693 [0.0001]
Normality	$\chi^2(4)$ = 2.2326 (0.6931)	$\chi^2(4)$ = 2.7414 (0.6020)
skewness	$\chi^2(2)$ = 0.8503 (0.6537)	$\chi^2(2)$ = 1.4577 (0.4825)
kurtosis	$\chi^2(2)$ = 1.3823 (0.5010)	$\chi^2(2)$ = 1.2837 (0.5263)
ARCH		
LM(1)	$\chi^2(9)$ = 12.2552 [0.1993]	$\chi^2(9)$ = 11.4403 [0.2467]
LM(4)	$\chi^2(36)$ = 45.4545 [0.1343]	$\chi^2(36)$ = 48.6908 [0.0770]

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