Money and Prices in Estonia

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Abstract

This paper examines the relationship between money and prices in Estonia in the period 1997Q1-2003Q3. The concept of a price (or real money) gap suggested by the P-star theory is applied to investigate whether information about the current money stock can be used to explain and/or predict GDP deflator inflation over the sample period. The results show that the money gap measure dominates the output gap as an explanatory variable for inflation in the short run. However, the money gap does not seem to be a proper indicator for predicting inflation over longer horizons, say, 12 months ahead. There are some signs that the output gap is becoming a better indicator of future inflation over time, but more data are needed to confirm this hypothesis.

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Contents

1. Introduction

Since its establishment in 1992, the currency board arrangement has performed well in terms of providing a stable monetary environment for the Estonian economy. However, the Maastricht inflation criterion, which must be satisfied on the way to the EMU, sets an upper limit on the acceptable rate of inflation in the near future. In combination with the absence of monetary policy, this normative quantitative criterion may create a subtle policy problem if the actual rate of inflation turns out to be insufficiently low. In light of this, explaining and predicting inflation appear high on both policy and research agendas. This paper addresses the issue by investigating the usefulness of broad money (M2) as an indicator of Estonian inflation in the short to medium run.

In particular, the paper explores whether the price gap or the money gap concept (Svensson, 1999), suggested by the P-star theory, can be helpful in explaining Estonian GDP deflator inflation in the period 1997-2003. The theory defines the money gap as the deviation of actual real money stock from its long-run equilibrium level and postulates that the occurrence of such a gap must result in corrective changes in the inflation rate that are necessary to bring real money balances back to their long-run level (Hallman *et al*, 1991). One of the main reasons for applying the P-star approach in the present paper is the apparent empirical success of the theory as reported by Hallman *et al* (1991), Gerlach and Svensson (2003) and Reimers (2003), to mention just a few.

The P-star theory defines the long-run equilibrium stock of real money as the level of real balances that would prevail under the given nominal quantity of money if the price level, output, and the velocity of money were at their respective long-run equilibrium values. Hence, the empirical implementation of the money gap concept requires knowledge of both the money demand function and the long-run equilibrium levels of its determinants. The macroeconomic disturbance caused by the 1998 Russian crisis and the significant financial deepening that took place in the Estonian economy over the sample period complicate both tasks. For this reason, several money demand specifications and money gap measures are considered in the paper. The bounds testing approach to the analysis of level relationships (Pesaran *et al*, 2001) is applied to narrow the scope of possible money demand specifications, which are then estimated using the ARDL modelling framework and/or the Engle-Granger methodology.

The results show that the money gap outperforms the output gap as an inflation indicator in the short run. In particular, if both gap measures are included in a regression reminiscent of the Phillips curve for quarterly inflation, the presence of the money gap makes the output gap statistically insignificant. On the other hand, the money gap appears to have no predictive power for longer horizons, for example, one year.[1] In this case, only the output gap shows some potential, although more data are needed to confirm that this variable can be exploited in inflation forecasting.

The paper is structured as follows. Section 2 introduces the P-star (P*) theory of inflation. It provides the theoretical basis for the empirical analysis of the paper. Section 3 discusses the estimation of the long-run demand for broad money (M2). The details for calculating the money gap and the reasons for creating several such variables are explained in Section 4. Section 5 addresses the main research question of the paper. It contrasts the money and output gaps in terms of their ability to explain contemporaneous inflation and then investigates their usefulness for predicting inflation one year ahead. Section 6 concludes.

2. Methodology

This section introduces the basics of the P-star theory, discusses the construction of the money gap variable and describes the way it is used to model GDP deflator inflation in Estonia in the period 1997-2003. Since the empirical implementation of the P-star framework requires estimating the (long-run) demand for money function, this section also outlines the methods used and assumptions made on the way to obtaining the final specification(s) of the long-run money demand.

The P-star theory consists of two hypotheses.[2] Firstly, it assumes that there is a long-run relationship between some monetary aggregates (typically, broad money like M2 or M3) and price levels. Secondly, it postulates that the rate at which prices adjust to their long-run equilibrium level (i.e. inflation rate) depends on the gap between the current price level and the long-run equilibrium level (LRE) of prices. Based on the first hypothesis, the LRE price level is defined as the price level that would prevail with the current (nominal) money stock if the income velocity of money and output were at their long-run equilibrium levels. Letting small letters denote natural logarithms of various variables, the LRE price level p is defined as:

$$p_t^* \equiv m_t + v_t^* - y_t^*, \tag{1}$$

[1]These results hold for all the money gaps considered in the paper.

[2]The P-star theory was publicized by Hallman *et al* (1991), who developed the theory and applied it to US data. See also Tatom (1990a), Tatom (1990b), Tatom (1992), and a more recent application of the P-star theory by Orphanides and Porter (1998), Reimers (2003) and Gerlach and Svensson (2003).

where m_t is the (log of) nominal money stock, v_t^* is the LRE level of velocity $v_t \equiv p_t + y_t - m_t$ (defined later), and y_t^* is the LRE level of real output. The second proposition of the P-star theory can in turn be summarized by the following equation for inflation

$$\pi_{t+1} = \pi_{t+1,t}^e - \alpha_p(p_t - p_t^*) + \alpha_z z_{t+1} + \varepsilon_{t+1}, \tag{2}$$

where $\pi_{t+1} = p_{t+1} - p_t$ is the rate of inflation in period $t+1$, $\pi_{t+1,t}^e$ is the expectation of this inflation as of period t, and $p_t - p_t^*$ is the price gap corresponding to the long-run equilibrium (LRE) price level p_t^* at time t. Finally, z_{t+1} is meant to contain other exogenous variables affecting inflation at $t+1$.[3]

Svensson (1999) shows that the price gap in equation (2) can alternatively be interpreted as a gap in terms of real money balances. If, following Gerlach and Svensson (2003), real money balances are denoted by $\tilde{m}_t \equiv m_t - p_t$, and the LRE stock of real money is defined as

$$\tilde{m}_t^* \equiv m_t - p_t^* \equiv y_t^* - v_t^*, \tag{3}$$

the price gap can be expressed as the negative of the real money gap:

$$\tilde{m}_t - \tilde{m}_t^* = (m_t - p_t) - (m_t - p_t^*) = -(p_t - p_t^*). \tag{4}$$

As a result, the P-star model of inflation summarized by equation (2) can be re-stated as:

$$\pi_{t+1} = \pi_{t+1,t}^e + \alpha_m(\tilde{m}_t - \tilde{m}_t^*) + \alpha_z z_{t+1} + \varepsilon_{t+1}, \tag{5}$$

where $\alpha_m \equiv \alpha_p > 0$.

On the other hand, the P-star theory-based equation for inflation (4) can be contrasted with the (expectations) augmented Phillips curve

$$\pi_{t+1} = \pi_{t+1,t}^e + \alpha_y(y_t - y_t^*) + \alpha_z z_{t+1} + \varepsilon_{t+1}, \tag{6}$$

where $y_t - y_t^*$ is the real output gap in period t. It follows that encompassing can be used to investigate the relative performance of equations (6) and (5) as well as to judge the comparative ability of money to explain and predict inflation.

Although money demand equations differ somewhat across different papers, it is common to assume that the demand for real money can be represented by an error-correction mechanism

$$\Delta\tilde{m}_{t+1} = \kappa_0 - \kappa_m[\tilde{m}_t - \kappa_t t - \kappa_y y_t + \kappa_{oc} oc_t] + \kappa_1 \Delta\hat{m}_t + \kappa_x x_{t+1} + \varepsilon_{t+1}, \tag{7}$$

[3] E.g. energy prices in Gerlach and Svensson (2003).

where oc_t stands for the opportunity cost of holding money, and x_{t+1} denotes a vector consisting of the remaining dynamic terms and possibly other variables that are considered to be important for the short-run dynamics of real money balances.[4]

The next step is to consider the analytical expression for the money gap derived from this money demand function. Before doing so, however, it is worth highlighting two elements of equation (7) that will require a great deal of attention in the empirical section of this paper. First, nothing specific has been said about the opportunity cost term. Recent research on the relationship between money and prices tends to focus on broad monetary aggregates–M2 or M3. Consequently, the opportunity cost of money is often measured by the difference between the long-run bond interest rate and the interest rate paid on the corresponding aggregate (the self interest rate).[5] In contrast, the same principle cannot be applied in the current work because neither M3 nor government bonds are available in Estonia.[6] For this reason, several alternative proxies for the opportunity cost will be tried in the estimation, and these details will be covered in the next section.

The second remark concerns the linear time trend in the long-run part of equation (7). In applied work, one might want to include the trend simply to have a more general model to begin with. In general, however, the problem of whether and what deterministic terms should be included in the model is far from simple, especially in practical applications.[7] In the present work, the issue is likely to be of even greater importance due to the structural changes that took place in the economy. As discussed in greater length in the next section, the inclusion of the deterministic trend will seem necessary in order to try to account for a significant amount of financial deepening that is clearly

[4] The literature on money demand is vast, and no attempt will be made to survey it here. Nevertheless, it is worth noting that the majority of empirical research in this area uses some version of equation (7). Of course, the set of determinants can differ as, for example, in Doornik *et al* (1998) who include inflation in the long-run part of the model, Bahmani-Oskooee and Chi Wing Ng (2002) who consider a number of other variables relevant for the small open economy case, or Gerlach and Svensson (2003) who make the short-run adjustment of real money demand more flexible by including deviations of the actual inflation rate from the 'implicit objective' followed by monetary authorities. Such variations notwithstanding, equation (7) is sufficiently general for the current discussion. The issue of deterministic components in the long-run term is addressed in the next section.

[5] See Gerlach and Svensson (2003), and Brand and Cassola (2000), Coenen and Vega (1999), Golinelli and Pastorello (2000).

[6] Basically the entire range of money market instruments is covered by M2, while the absence of government bonds is the result of the balanced budget policy.

[7] The problem of deterministic terms is well recognized in the cointegration literature. For practical applications, a small sample of non-technical discussions on the issue would include Doornik *et al* (1998), Hassler (2000), Franses (2001) and Ahking (2002).

noticeable in the data.

Finally, it remains to describe the LRE level of real money balances implied by the money demand function (7). Since the long-run money demand that follows from this error-correction specification is given by

$$\tilde{m}_t = \kappa_y y_t + \kappa_t t - \kappa_{oc} oc_t, \tag{8}$$

the LRE level of real money balances corresponding to the LRE level of output and the LRE opportunity cost of money is

$$\tilde{m}_t^* = \kappa_y y_t^* + \kappa_t t - \kappa_{oc} oc_t^*. \tag{9}$$

Similarly, the LRE income velocity of money can be written as

$$v_t^* \equiv y_t^* - \tilde{m}_t^* = (1 - \kappa_y) y_t^* - \kappa_t t + \kappa_{oc} oc_t^*. \tag{10}$$

According to equation (9), the empirical implementation of the P-star theory requires determination of the LRE level of oc. In the case of developed economies, oc^* may be relatively easy to come up with, especially if this variable is measured using a spread between long and short interest rates. More pronounced shifts and trends in individual interest rates notwithstanding, the spread tends to be stationary and relatively stable.[8]

In contrast, section 4 of this paper will show that evaluating the *long-run equilibrium* cost of holding money over the period 1997-2003 in Estonia is quite complicated. Firstly, long and short interest rates declined over the period due to disinflation and a lowering of the risk premium.[9] At the same time, the interest rate spread shrank, perhaps as a result of improvements in the efficiency of the banking sector. These downward trends complicate the construction of the LRE interest rate series. Finally, additional problems arise due to the effect that the 1998 Russian crisis had on domestic interest rates. This shock distorted the otherwise steady decline in interest rates, making the assessment of the LRE level of interest rates (or their spread) even more difficult.[10] Crucially for the current exercise, equation (9) implies that any misjudgement concerning the LRE interest rates will distort the calculation of the LRE real money balances directly.

[8] Notably, the term structure of interest rates implies that short and long interest rates must constitute a cointegrating vector such that the spread between the two rates is stationary. See the references in footnote 5.

[9] The two bottom panels of Figure 1 show the evolution of Estonian interest rates on time deposits and long-term loans.

[10] When no structural model is employed to determine the LRE interest rates, it is not quite clear what the LRE level of interest rates is. A possible alternative is to use some time-series technique to obtain the 'long-term' component of the interest rate series. However, when time series are as short as in this analysis, the presence of significant disturbances will reduce the reliability of these methods. Unavoidably then, such a situation introduces considerable subjectivity into modeling LRE.

Therefore, purely for practical considerations, it might seem preferable to avoid using equation (9) and instead estimate the LRE money balances by directly evaluating the LRE level of velocity. Following this alternative, the LRE stock of real money can be obtained as $\tilde{m}_t^* = y_t^* - v_t^*$. Of course, the LRE velocity *is* a function of (LRE) interest rates (see equation 10), and so this alternative differs from the previous one only computationally. However, the effect of the Russian crisis on the velocity of money was not as pronounced as on domestic interest rates (Figure 1). Everything else being equal, this aspect of the data should make constructing the LRE path of velocity somewhat easier. In fact, the relatively smooth downward trend of velocity in Figure 1 suggests that it might be acceptable to model its long-run level as a function of time only. In such a case, the LRE path of real money balances could be calculated from only two variables: the time-dependent long-run velocity and potential output. This approach will be used as a robustness check for the results based on calculating $\tilde{m}_t^*$ using equation (9) in section 4.

3. Estimating the Demand for Money

This section describes the estimation of the long-run money demand function(s) later used for constructing money gap series. Depending on the particular specification of the money demand, several versions of the money gap will be computed. Their success in explaining and predicting GDP deflator inflation will be assessed in the next section.

The family of money demand functions considered here is represented by equation (7). Quarterly data are used for estimation, and although the sample size varies across regressions slightly, it is 1997Q1-2003Q3 in most of the cases. The real money balances are calculated from nominal M2 and the GDP deflator, both seasonally adjusted. Seasonally adjusted GDP deflator, real GDP and the estimate of potential GDP based on the production function approach are taken from the data set of Eesti Pank's macro model.[11] Finally, three different interest rates are used to proxy the opportunity cost of holding broad money: the weighted average interest rate paid on time deposits (domestic and foreign currency), the weighted average interest rate on ten-year and longer maturity loans (denominated in domestic and foreign currency) and finally, the interest rate on long-term government bonds in the Euro area. The source for the first two rates is Eesti Pank, while the last series is taken from International Financial Statistics (IMF).

Before discussing the details of estimating the money demand, two characteristics of the Estonian monetary sector and the financial system in general

[11] The series for M2 is also obtained from Eesti Pank.

are worth mentioning. First, due to the lack of financial instruments that typically differentiate M3 from M2, the latter is the broadest officially reported monetary aggregate available. Hence, in contrast to a number of recent contributions to the related literature, the present analysis is based on M2 rather than M3.[12] The second feature of the financial market that is particularly relevant in the current context is the absence of domestic government bonds.[13] Given that government bonds are unavailable, it is natural to ask what asset serves the role of a close substitute for quasi money in Estonia. Naturally, the answer to this question has direct implications for choosing the appropriate measure for the opportunity cost of M2.

The first option considered in this paper is that, given the high degree of openness in the domestic financial sector, foreign bonds constitute a readily available substitute for national bonds. If this were actually the case, the long-term bond interest rate in the Euro area or the difference between this rate and the rate paid on domestic time deposits would be a natural proxy for the opportunity cost in the money demand equation (7).[14]

An alternative proxy for the opportunity cost of M2 considered in the paper is the interest rate on long-term loans provided by commercial banks. It is basically the only domestic long-term interest rate that is available for a long enough period of time and that does not constitute remuneration for deposits. As such, it can be expected to reflect the dynamics of returns on the alternative use of resources held in the form of M2. The use of this interest rate as a proxy for the opportunity cost of money is not without complications, however. In the situation where government bonds are absent and the set of money market instruments available for keeping wealth is limited to M2, it is very likely that the relationship between the long-term lending rate and money has been affected by various structural changes that took place in the financial sector. For example, consider the problem of wealth allocation that includes residential investment. The expansion of the supply of long-term loans and the decline of interest rates on such loans must have had a positive influence on the level of resources channelled to the real estate market. Given that M2 is the broadest monetary aggregate available, it is difficult to exclude the possibility that the process of diverting wealth to property exerted a negative influence on M2.[15] In other words, the third factor problem may be a potential obstacle to establishing a robust statistical relationship between the interest rate on long-term

[12] See, e.g., Coenen and Vega (1999), Brand and Cassola (2000), Golinelli and Pastorello (2000).

[13] There is virtually no domestic public debt in Estonia.

[14] The yield of long-term German government bonds might seem to be a preferable variable here than the average interest rate of long-term bonds in the EMU. These rates are very highly correlated, however, so the choice between the two is not very relevant.

[15] Most likely through a negative influence on its quasi money component.

Table 1: The ADF tests for unit roots

Series	*Level*			*First difference*		
	Period	*Specif.*	*ADF*	*Period*	*Specif.*	*ADF*
M2	97Q1-03Q4	ct, 3	-4.09**	96Q3-03Q4	c, 0	-3.48**
GDP	97Q2-03Q4	ct, 4	-2.97	96Q3-03Q4	c, 0	-7.62***
IR time deposits	96Q3-04Q3	ct, 6	-4.49**	95Q3-04Q3	-, 1	-7.21***
IR long term loans	97Q2-04Q3	ct, 1	-2.36	98Q4-04Q3	c, 6	-3.19**
IR gov. bonds, EMU	95Q2-04Q2	c, 1	-3.14**	95Q3-04Q2	-, 0	-8.24***
M1	96Q3-03Q4	ct, 1	-2.83	96Q3-03Q4	c, 0	-3.37**
QM	96Q2-03Q4	c, 0	-4.52***	96Q3-03Q4	c, 0	-3.57**

Notes: In columns *Specif.*, ct means that the ADF equation included constant and trend, c – only constant, while the numbers refer to the number of lags included in the ADF equation. *** and ** denote significance at 1% and 5%, respectively.

loans and money in this exercise.

As discussed in section 2, knowledge of the long-run money demand function is necessary to compute the money gap. The choice of econometric methods that can be used to estimate level relationships such as money demand depends on the time series properties of the variables in question. To help assess the dynamic characteristics of the variables relevant for this work, Figure 1 shows real M2, real GDP, the average yield of long-term government bonds in the EU, and the domestic interest rates on term deposits and long-term loans. More formally, Table 1 presents the results of ADF tests for these and two additional variables: M1 and quasi money (QM). Of course, given the shortness of the series, these test results cannot be regarded as definite guidelines for modelling the money demand and should be viewed as only suggestive. Yet problems with the power of the test to discriminate between trend and difference stationarity notwithstanding, Table 1 is a good example of pre-testing that leads to a problematic outcome: real GDP and real M2 are found to be of different orders of integration. If taken very seriously, this result would imply that equation (8) is inappropriate, undermining the implementation of the money gap concept from section 2.[16] Instead, the analysis will proceed along an alternative route, which involves testing for the presence of level relationships like (8) directly, avoiding the uncertainty associated with pre-testing for unit roots.

Pesaran *et al* (2001) propose to test for the presence of level relationships

[16]The variables must be either stationary and linked according to (8) in the long run or nonstationary but cointegrated. A subset of cointegrated variables can also form a long-run level relationship with stationary variables. However, the finding that real M2 is trend stationary while real GDP is difference stationary cannot be squared with the notion of long-run money demand given by (8).

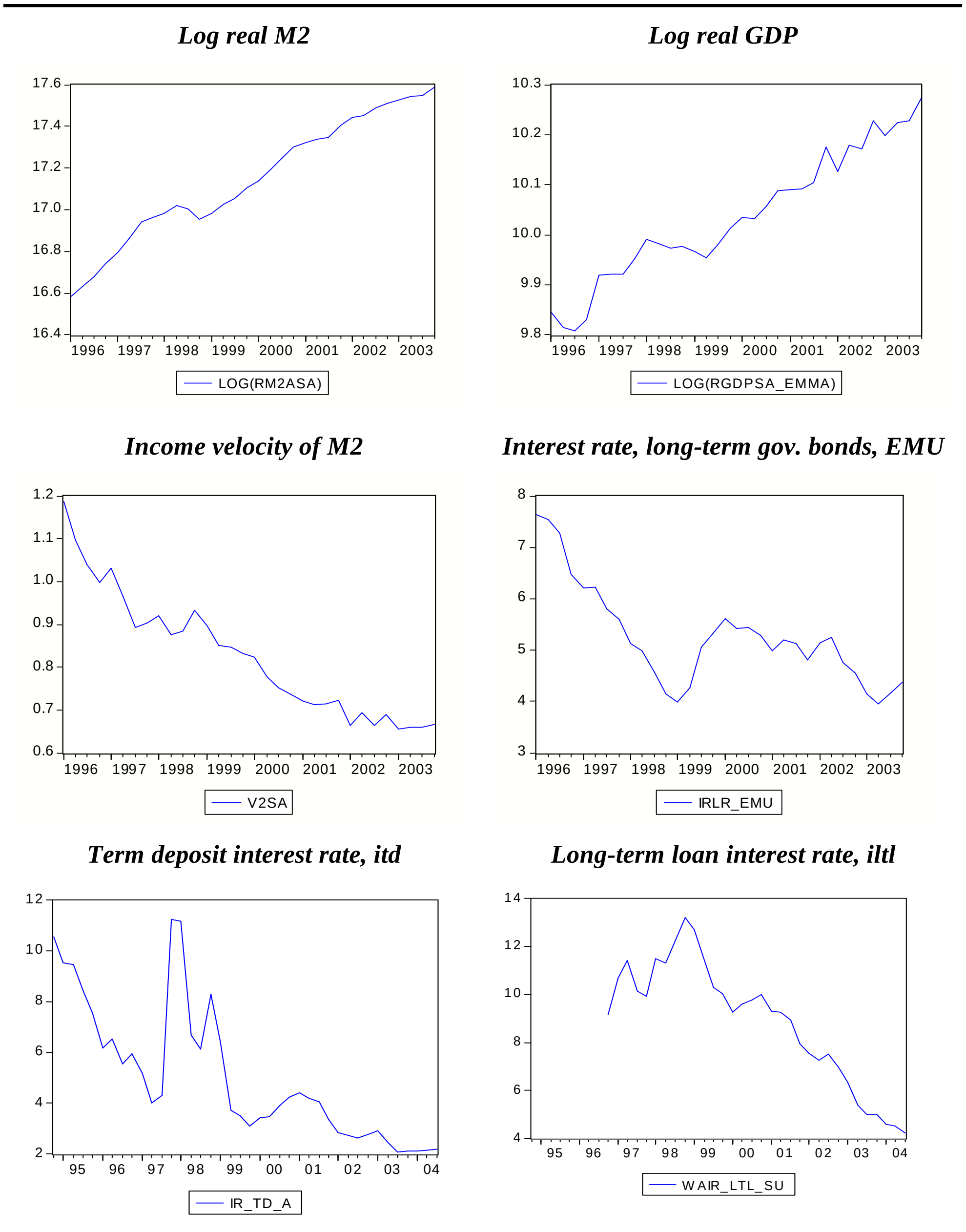


Figure 1: Real M2, real GDP, M2 velocity, the average yield of long-term government bonds (EMU), the average interest rate on time deposits and long-term loans.

using the bounds testing approach, which is meant to circumvent the problems of pre-testing. The method is developed in the context of a single ARDL equation, and it is applicable irrespective of the time-series properties of regressors. In particular, Pesaran *et al* (2001) show that the asymptotic critical values of the relevant F-test corresponding to the two assumptions of only I(0) or only I(1) regressors provide a range covering the critical values of the test for all other possible combinations of the regressors, be they I(0), I(1) or mutually cointegrated.

To implement the test in the context of money demand (7), the equation needs to be reparameterized as

$$\begin{aligned}
\Delta\tilde{m}_{t+1} &= \kappa_0 - \kappa_m[\tilde{m}_t - \kappa_t t - \kappa_y y_t + \kappa_{oc} oc_t] \\
&\quad + \kappa_1 \Delta\hat{m}_t + \kappa_2 \Delta x_{t+1} + \varepsilon_{t+1} \\
&= \kappa_0 - \theta_m \tilde{m}_t + \theta_t t + \theta_y y_t - \theta_{oc} oc_t \\
&\quad + \kappa_1 \Delta\hat{m}_t + \kappa_2 \Delta x_{t+1} + \varepsilon_{t+1},
\end{aligned} \tag{11}$$

where $\theta_m = \kappa_m$, $\theta_t = \kappa_m\kappa_t$, $\theta_y = \kappa_m\kappa_y$, $\theta_{oc} = \kappa_m\kappa_{oc}$. The proposed critical bounds test for the null hypothesis of no level relationship among the variables is then a joint F-test that $\theta_m = \theta_t = \theta_y = \theta_{oc} = 0$. The simulated lower and upper critical bounds of the test, which correspond to purely I(0) and purely I(1) regressors, respectively, are provided in Pesaran *et al* (2001). Importantly, these critical values depend on the particular specification of the deterministic part of the model, that is, if the relationship includes a constant and a linear time trend or not.

In the light of the methodological issues discussed above and the results presented in Table 1, the following modelling strategy will be adopted below. First, the critical bounds test by Pesaran *et al* (2001) will be applied to pin down the level relationship(s) that can be interpreted as the long-run demand for M2. In addition to establishing the level relationship(s) statistically, this part of the analysis will shed some light on two other important issues: whether the linear time trend should be included in the long-run money demand and which of the selected interest rate variables or a combination of them should be used to proxy the opportunity cost of M2 in equation (7).

In the next step, an autoregressive distributed lag (ARDL) model and its re-parameterizations will be used to estimate and analyze the selected level relationships. As discussed in Pesaran and Shin (1999), the ARDL modelling approach to estimating long-run relationships is applicable in the case of both non-stationary but cointegrated variables as well as stationary variables that have some long-run relationship in levels. In this respect, the ARDL approach is more general than some other methods designed for dealing exceptionally with I(1) variables and cointegration–for example, the Engle-Granger method. On the other hand, the ARDL modelling approach is usually general-to-specific, requiring long enough time series to estimate the initial (most likely overparameterized) model. In the present analysis, the series are short, and thus the ARDL-based estimation of long-run relationships may lack precision.

For this reason, the Engle-Granger two-step estimation procedure will also be applied. When doing so, the nonstationarity of variables will be *assumed* and equation (8) will be regarded as a potential cointegrating relationship. In terms of the underlying assumptions, this method is more restrictive, but the direct estimation of cointegrating relationships by static OLS regressions makes it particularly appealing when the time series at hand are short. On the other hand, Banerjee *et al* (1986) raised caution against the Engle-Granger method since it may lead to biased estimates of long-run parameters in finite samples, and on that basis, Banerjee *et al* (1998) suggested using a dynamic error-correction specification instead. All in all, the estimation strategy adopted in the current paper attempts to follow the 'general-to-specific' principle: the Pesaran *et al* (2001) critical bounds test is employed to establish the presence of level relationships statistically, the ARDL modelling approach is used to estimate the relationships as part of a flexible dynamic specification, and, finally, the Engle-Granger methodology is applied to obtain the (same) long-run relationships directly, possibly at a higher risk of a finite sample bias.

To implement the Pesaran *et al* (2001) critical bounds test on the basis of equation (11), it is necessary to determine the lag length of this ARDL regression. Table 2 reports the main criteria that were used to select the optimal lag structure for various specifications of equation (11): the Schwartz and Akaike information criteria (absolute values) and the LM statistics for serial correlation of order 1 and 1-4. Different columns of the table correspond to different specifications of the underlying regression. Real GDP (not reported) was included in all specifications, but the interest rates taken as proxies for the opportunity cost of money varied. In Table 2, the column headings specify which interest rates were used and whether a linear time trend was included in the estimation. Finally, the last row of the table summarizes the information by reporting the preferred lag lengths for each specification of the regression. These were selected on the basis of the information criteria, given that the LM test does not reject the null of no serial correlation at the 5 percent significance level.

On the basis of Table 2, several observations can be made. As expected, the Akaike information criterion tends to pick longer lags than the Schwartz criterion. When a deterministic time trend is included, there is a tendency for the information criteria to suggest adding an extra lag compared to the specifications without the trend. However, on the basis of the criteria alone, it

Table 2: Lag selection for the critical bounds test, 1997Q1-2003Q3

Order of ARDL in levels	IR time deposits and IR gov. bonds, EMU		IR time deposits and IR long term loans		IR time deposits		IR long term loans	
	With trend	*No trend*	*With trend*	*No trend*	*With trend*	*No trend*	*With trend*	*No trend*
	1(a)	*1(b)*	*2(a)*	*2(b)*	*3(a)*	*3(b)*	*4(a)*	*4(b)*
	Schwarz information criterion							
1	4.35	4.34	3.88	4.01	4.12	4.22	3.98	4.05
2	4.12	4.19	4.18	4.29	4.38	4.50	4.14	4.04
3	4.09	4.14	4.41	4.41	4.44	4.46	4.11	3.81
4	3.95	3.96	4.41	4.22	4.34	4.38	3.72	3.64
	Akaike information criterion							
1	4.78	4.73	4.32	4.41	4.46	4.51	4.32	4.35
2	4.75	4.77	4.82	4.88	4.86	4.93	4.63	4.48
3	4.90	4.93	5.25	5.20	5.07	5.04	4.74	4.40
4	4.96	4.92	5.45	5.20	5.11	5.11	4.50	4.38
	LM statistics for no autocorrelation (order 1)							
1	0.58	0.94	3.14*	2.31	5.27**	4.82**	3.35*	1.91
2	0.44	0.75	1.34	1.21	0.72	0.61	1.01	0.00
3	1.94	1.53	0.02	0.10	1.07	1.16	0.03	0.58
4	10.19**	9.69**	0.15	1.88	4.53*	2.65	4.36*	0.55
	LM statistics for no autocorrelation (order 4)							
1	4.72**	3.43**	1.28	0.53	1.27	1.56	1.63	0.59
2	3.42*	4.97**	3.68*	3.25*	3.47**	2.74*	3.13*	0.23
3	2.42	2.03	5.88*	1.73	1.23	1.22	3.06*	1.30
4	3.05	1.51	-	-	2.11	2.48	2.56	3.65*
Preferred lag length	3	3	3, 4	3, 4	3, 4	2, 3, 4	2, 3	1, 2

Notes: Estimations are based on equation (11). Real GDP was included in all ARDL specifications. The column headings indicate which interest rates were taken as proxies for the opportunity cost of and whether a linear time trend was also included. Absolute values of the Schwarz and Akaike information criteria are reported (a bigger number suggests preferable specification). ***, **, * denote significance at 1%, 5% and 10% level, respectively. LM (order 4) statistics could not be computed due to the lack of degrees of freedom. The preferred lag length is chosen on the basis of the information criteria and test results in the upper four panels of the table.

is hardly possible to decide if the time trend should be included or not. Finally, taking the results of the LM tests for no serial correlation into account, Table 2 appears to suggest that in the majority of cases, the ARDL model of order 3 or 4 should be used for carrying out the Pesaran *et al* (2001) critical bounds test (see the last row of the table).

Table 3 presents the results of the critical bounds test for level relationships among the variables included in the ARDL models of Table 2. The top panel of the table shows the test statistics, while the bottom one lists the critical bounds for the appropriate F-test as provided by Pesaran *et al* (2001). It appears that in only two cases does the test reject the null of no level relationship decisively. Regardless of whether a time trend is included or not, the test rejects the null hypothesis for the ARDL(1) specification that includes the interest rates on domestic time deposits and long-term EU government bonds, and for the ARDL(3) model with the time deposit interest rate, again, irrespective of whether the deterministic trend is present or not. Note, however, that the former model was shown to be plagued by serial correlation (see Table 2), which undermines the validity of the F-test. Hence, strictly speaking, the critical bounds test can be used to confirm the presence of a level relationship (at 5 percent significance) only in the case of specifications 3(a) and 3(b), that is, when the opportunity cost of money is proxied by the term deposit interest rate alone. Importantly, neither the information criteria nor the results of the F-test help choose between the model with the deterministic trend and the model without it.[17]

Finally, it remains to note that at least in one case, the critical bounds test turns out to be inconclusive. When the test is applied to the ARDL(3) model that includes the interest rates on domestic time deposits and long-term EU government bonds but no time trend (column 1(b) of Table 3), the F-statistic exceeds the lower critical bound at the 5 percent significance level but falls below the corresponding upper bound.[18,19] In such a situation, additional testing may be desirable in order to determine the time series properties of the regressors as well as possible mutual cointegration among them. Although

[17] At first glance, the test results reported in Table 3 may seem to be too sensitive to the lag length of the estimated ARDL regressions. Taking columns 3(a) and 3(b) as an example, the null hypothesis is rejected conclusively but only in the case of ARDL(3). Note however, that according to the LM tests for serial correlation, both ARDL(1) and ARDL(2) regressions are clearly misspecified, while the estimation of the ARDL(4) model is probably quite imprecise given the small number of observations.

[18] Hence, the level relationship would be established if all regressors were I(0) but it would be rejected if they were I(1).

[19] Similarly, the test also seems to signal the possibility of a level relationship in the case of ARDL(3) in column 2(b) of Table 3. However, the test falls into the inconclusive region formed by only the 90 percent confidence level, so this result is even less clear-cut than the one mentioned in the text and thus it is not discussed in greater detail.

Table 3: Critical bounds tests of level relationships

	IR time deposits and IR bonds, EMU		IR time deposits and IR long term loans		IR time deposits		IR long term loans	
Order of ARDL	*With trend*	*No trend*	*With trend*	*No trend*	*With trend*	*No trend*	*With trend*	*No trend*
	1(a)	*1(b)*	*2(a)*	*2(b)*	*3(a)*	*3(b)*	*4(a)*	*4(b)*
1	5.13**	5.41**	0.73	0.96	2.65	3.42	0.55	0.42
2	2.08	2.46	1.18	1.50	3.04	4.23	1.20	0.33
3	2.76	3.47**[(i)]	2.74	3.18*[(i)]	5.09**	6.06**	2.26	0.74
4	1.60	1.91	0.49	1.06	2.76	3.44	0.86	0.48
F***	4.30; 5.23	4.29; 5.61	4.30; 5.23	4.29; 5.61	4.99; 5.85	5.15; 6.36	4.99; 5.85	5.15; 6.36
F**	3.38; 4.23	3.23; 4.35	3.38; 4.23	3.23; 4.35	3.88; 4.61	3.79; 4.85	3.88; 4.61	3.79; 4.85
F*	2.97; 3.74	2.72; 3.77	2.97; 3.74	2.72; 3.77	3.38; 4.02	3.17; 4.14	3.38; 4.02	3.17; 4.14

Notes: Regression specifications are the same as in Table 2. The column headings indicate which interest rates were used and whether a linear time trend was included among the regressors. ***, **, * denote significance at 1%, 5% and 10% significance level, respectively. F***, F**, F* show the relevant critical value bounds for the F-statistic for testing the existence of a long-run money demand equation at 1%, 5% and 10% significance level, respectively. [(i)] indicates that the F-test is inconclusive. The critical values are taken from Pesaran et al. (2001).

some information on this has already been presented in Table 1, pre-testing is clearly problematic when the time series at hand are short. Therefore, it still seems worthwhile trying several combinations of regressors in order to determine the best specification(s) for the money demand. Hence, although the main focus will be on the case where the critical bounds test is decisive (ARDL(3) specifications 3(a) and 3(b) in Table 3), some alternative combinations of regressors will also be tried in what follows.

Table 4 describes several attempts to estimate the long-run demand for M2 using the autoregressive distributed lag (ARDL) modelling approach.[20] As alluded to above, an important virtue of the ARDL modelling is that it is applicable for estimating long-run level relationships both when the underlying time series are stationary (so that cointegration does not apply) and when they are non-stationary but cointegrated (Pesaran and Shin, 1999). Thus, in line with the motivation for using the Pesaran *et al* (2001) critical bounds test, this

[20]These estimations are based on a convenient re-parameterization of the ARDL model which allows to infer the long-run parameters more directly. See equation (11) and its coefficients θ, for example.

methodology makes the inference less sensitive to pre-testing.

Table 4: ARDL-based long-run demand for M2, 1997Q1-2003Q3

	1.	*2.*	*3.*	*4.*
IR time deposits	-0.049*** (0.016)	-0.056*** (0.017)	-0.039*** (0.010)	-0.243 (0.534)
IR gov. bonds, EMU	0.072 (0.065)			
IR long term loans		0.020 (0.014)		
RGDP	1.708*** (0.023)	1.722*** (0.006)	1.734*** (0.006)	1.969*** (0.612)
Trend				-0.050 (0.129)
Error-correction coefficient	-0.165 (0.071)	-0.307 (0.100)	-0.207 (0.068)	-0.049 (0.105)

Notes: reported are coefficient estimates, standard errors in parentheses.***/**/* show significance at the 1%, 5% and 10% level, respectively. Critical values for the error-correction term are taken from Banerjee et al. (1998) and Hassler (2000).

To save space, only the estimates of long-run elasticities and error-correction coefficients are reported in Table 4. The latter are instructive as they show whether equilibrium-correction does take place, implying that an estimated vector represents a long-run or even cointegrating relationship among the variables. If used as a test for cointegration, however, the t-test associated with the adjustment coefficients is non-standard and also depends on a particular specification of the deterministic part of the model. For this reason, appropriate simulated critical values were taken from Banerjee *et al* (1998).[21]

Four different versions of money demand (and thus the underlying ARDL equation) are considered in Table 4. Columns (3) and (4) report the estimation results for the two specifications that were chosen on the basis of the critical bounds test. In both cases, the demand for real balances is modelled as a function of the time-deposit interest rate and real GDP, but a linear time trend is added in the level relationship of column (4). For completeness, columns (1)-(2) show two alternative specifications of money demand, in which either the interest rate on long-term EU government bonds or the interest rate on domestic long-term loans is also included. None of these long-run rates appears to be statistically significant, however. In contrast, the semi-elasticity with respect to the time-deposit interest rate is highly significant, and its point estimate varies from about 4 to 5.5 percent. The semi-elasticity is negative rather than positive, implying that this rate does not fulfil the role of the own interest rate,

[21]The rule proposed by Hassler (2000) was followed in order to come up with the critical values when a deterministic time trend is present in the long-run term of the model.

as one could have expected *a priori*. Finally, the long-run income elasticity of the demand for M2 is estimated to be about 1.7, clearly above unity given the precision of the estimate.

In summary, Table 4 seems to support the previous conjecture that it is the time-deposit interest rate that tends to be associated with M2 in the long run. According to the results presented in columns (3) and (4), it also appears that the deterministic time trend should not be included in the level relationship for money. However, in light of the observed decline of M2 velocity (see Figure 1), this implication is somewhat surprising and perhaps should not be taken for granted in further analysis.

It is also worth mentioning that the error correction coefficients, although estimated with the correct sign and relatively high t-ratios, are in fact insignificant if the underlying t-ratios are regarded as the tests for cointegration. Given the sample size of around 28 quarterly observations effectively used in the estimations, the t-ratios are below the critical values provided in Banerjee *et al* (1998), implying that the vectors contained in Table 4 do not constitute cointegrating relationships. Note, however, that the time series at hand are very short indeed, and thus this result may very well be due to the low precision of the ARDL-based estimation. For this reason, it seems natural to try the Engle-Granger (E–G) methodology and estimate the level relationships directly. Under the *assumption* that the regressors are difference-stationary, the superconsistency property of the OLS estimator makes it possible to estimate the underlying cointegrating vector using static OLS regressions. In large samples, the ARDL and E–G approaches should lead to the same cointegrating vectors, but the results are likely to differ in the case of the small sample used here. Hence, it seems useful to compare the outcomes from the two approaches.

Table 5 shows the results corresponding to the first step of the E–G estimation procedure. The first three columns of the table refer to the same specifications of money demand as those considered in columns (1)-(3) of Table 4, so the estimates can be compared directly. As it turns out, the two long-term interest rates are again insignificant, while the semi-elasticity with respect to the time-deposit interest rate is marginally significant and negative as before. Note, however, that the point estimates of this elasticity are considerably lower (in absolute terms) and have standard errors twice as small compared to the ones obtained by the ARDL approach. In contrast, the estimated income elasticity of money demand is now 2.1, quite a bit higher than the previous 1.7, while the corresponding standard errors are considerably (as much as ten times) larger than before. Finally, the ADF statistics reported at the bottom of Table 5 suggest that the deviations from the estimated level relationships are stationary, supporting the idea that the estimated equations can in fact be considered as cointegrating relationships.

Table 5: Cointegration equations for M2, Engle-Granger, 1997Q1-2003Q3

	1.	***2.***	***3.***	***4.***	***5.***
Constant	-4.148***	-3.996*	-4.143***	7.635**	6.714**
	(1.327)	(2.063)	(1.088)	(3.403)	(2.970)
IR time deposits	-0.009*	-0.009*	-0.009*	0.002	
	(0.005)	(0.005)	(0.005)	(0.004)	
IR gov. bonds, EMU	0.0001				
	(0.017)				
IR long term loans		-0.001		-0.020**	-0.018**
		(0.010)		(0.009)	(0.008)
RGDP	2.127***	2.112***	2.126***	0.923**	1.017***
	(0.126)	(0.1977)	(0.107)	(0.344)	(0.300)
Trend				0.030***	0.029***
				(0.006)	(0.006)
Trend^2				-0.0004**	-0.0004**
				(0.0002)	(0.0002)
Adjusted R-squared	0.960	0.960	0.962	0.982	0.982
S.E. of regression	0.047	0.047	0.046	0.032	0.032
Schwarz criterion	-2.94	-2.94	-3.06	-3.56	-3.67
Durbin-Watson stat.	1.64	1.62	1.64	1.44	1.41
ADF	-5.28***	-5.24***	-5.27***	-4.01***	-4.01***

Notes: Standard errors in parentheses. ***,**,* denote significance at 1%, 5% and 10%, respectively. The ADF test is for the stationarity of residuals; critical values taken from Phillips and Ouliaris (1990).

At this moment, it is worth summarizing some tentative results concerning the long-run demand for M2. To begin, there are no qualitative differences between the Engle-Granger and ARDL estimations. Firstly, the two sets of estimates agree that it is the term-deposit interest rate that seems to matter for the long-run money demand, although in contrast to the initial expectations, the corresponding elasticity is estimated to be negative rather than positive. Also, the tendency for the long interest rates to be positively associated with the stock of real balances is somewhat unexpected, but these point estimates are not statistically significant. Secondly, both methodologies suggest that the income elasticity of demand exceeds unity, perhaps due to the fact that the specification of the money demand does not consider wealth effects explicitly. Hence, the differences between the estimations are largely related to the magnitude of the elasticities – the ARDL approach suggesting lower income elasticity and higher interest rate elasticity than the Engle-Granger method. Since small sample problems reduce the reliability of both estimators, it is hardly possible to choose one of them as preferable. What is perhaps more important for the current application is whether these differences in elasticity estimates are going to lead to qualitatively different money gap measures.

On the other hand, it is possible that the 'unexpected' aspects of the estimation results are more problematic than the quantitative differences between the two estimators. For example, the finding that the long-run demand for M2 does not depend on long interest rates, but depends negatively on the term-deposit interest rate is somewhat counter-intuitive. One possible reason for such results, the relatively low precision of estimation, which inevitably influenced the choice of final model specifications, has already been discussed. Yet another source of the problem may be associated with the largely neglected fact that considerable monetary deepening took place during the sample period. If the in-sample decline of interest rates is not fully responsible for the rise in monetization, the estimated elasticities may be misleading because of misspecification.

Expanding the set of regressors using deterministic time trends may help account for such structural changes and shed some light on the robustness of previous results. For the same reasons, a linear time trend was included in one of the ARDL equations (column 4 of Table 4), but its t-ratio was so low that the trend did not seem to be relevant statistically. Since introducing a linear trend in the E–G estimation did not seem to work either (not shown here), a quadratic trend was added on the grounds that the decline in M2 velocity decelerated over time (see Figure 1).[22] These results are reported in the last two columns of Table 5, and they show that the inclusion of both trends has more important consequences for the model. First, the t-ratios of trend coefficients are rather high, indicating that the quadratic specification of the deterministic term does pick out some nonlinear changes in velocity that are not explained by the behaviour of the interest rate. On the other hand, the estimated magnitudes of trend coefficients suggest that the nonlinear effects are not very big.[23] Second, the time-deposit interest rate becomes statistically insignificant. This

[22]The ADF tests reported in columns (1)-(3) are based on Phillips and Ouliaris (1990). However, I am not aware of any theoretical paper that would consider a quadratic time trend in the E–G setup. Hence, the regressions in columns (4) and (5) are purely heuristic, and the sole reason for estimating and discussing them here is to see what happens to the point estimates of other elasticities if the quadratic term is included in the level relationship for real balances. The critical values used for the ADF tests in columns (4)-(5) correspond to the specification when only a linear trend is present and thus are not correct.

[23]The point estimates imply that the velocity of money is declining by $400(0.029 - 0.0004t)$ percent per year and that this rate is itself diminishing by about 0.16 percentage points every year. Hence, it would take the quadratic term $0.029/0.0004 = 72.5$ quarters or 18 years to balance the linear trend. By then, this autonomous financial deepening would lower M2 velocity $e^{\frac{0.029*72.5}{2}} = 2.8$ times or to about 0.43, given that velocity was about 1.2 at the beginning of 1996 (see Figure 1).

time the interest rate on long-term loans appears to be a better proxy for the opportunity cost of M2.[24] Finally, adding the two trends significantly alters the estimate of the income elasticity of money. As can be seen from Table 5, it declines from 2.1 to about unity, although the associated standard errors increase substantially as well. One possible explanation for this effect could be that the time trends capture not only increasing financial deepening but also growing wealth in the economy and thus reduce the role of real GDP in these estimations. Overall, none of the changes caused by adding linear and quadratic trends seems to be unacceptable on economic grounds, and so in spite of the statistical concerns surrounding this specification, it could be used as one of the (competing) specifications of the long-run money demand in further analysis.

It is therefore time to decide which of the estimated long-run money demand functions will be used for calculating the money gap defined in section 2. The first alternative seems to follow from the specification arguably favoured by both estimation methods and the Pesaran *et al* (2001) test. According to this, real M2 is a function of only the time-deposit interest rate and real GDP (the third columns of tables 4 and 5). As there is no way to know whether the E–G or ARDL estimation is better, both will be considered. This gives two level relationships for M2. The third version of the money demand that will be used to calculate the money gap includes the interest rate on long-term loans, real GDP and linear as well as quadratic time trends (column (5) of Table 5). As a result, three different versions of the long-run demand for broad money will be employed in what follows. However, in order to use these functions to construct the money gap, it is necessary to obtain the series for long-run equilibrium values of the explanatory variables first. The next section undertakes this and then proceeds with estimating the money gap and evaluating its usefulness for explaining and predicting GDP deflator inflation.

4. Calculating the Money Gap

Corresponding to the selected specifications of the money demand, three alternative paths of the LRE real balances $\tilde{m}_t^*$ can be computed for every set of LRE series of right-hand-side variables. According to the first specification of equation (9), the LRE opportunity cost of money is accounted for by the LRE time deposit interest rate, itd_t^*:

$$\tilde{m}_t^* = \kappa_y y_t^* - \kappa_i itd_t^*. \tag{12}$$

[24] Qualitatively similar results were obtained when a quadratic trend was included in the ARDL model. The estimated semi-elasticity with respect to the interest rate on long-term loans was -0.07, different from -0.02 implied by the E–G estimation.

As discussed above, κ_y and κ_i are estimated using the E–G and ARDL approaches, which, in turn, will lead to two alternative series of $\tilde{m}_t^*$. The third version of $\tilde{m}_t^*$ follows from the E–G estimation of equation (9) with linear and quadratic time trends and the interest rate on long-term domestic loans, $iltl_t^*$, as the measure of the opportunity cost of money:

$$\tilde{m}_t^* = \kappa_y y_t^* - \kappa_i iltl_t^* + \kappa_{\tau 1} trend - \kappa_{\tau 2} trend^2. \tag{13}$$

The empirical counterpart of LRE real GDP, y_t^*, is going to be the production-function-based measure of potential output used in Eesti Pank's macro model. Hence, the only terms that are still needed before equations (12) and (13) can be used to construct the $\tilde{m}_t^*$ sequences are the LRE series for the corresponding interest rates.

To shed some light on what those LRE levels of itd_t and $iltl_t$ could possibly be, the top panel of Figure 2 shows the actual series for these interest rates over the sample period. The plots immediately point to at least two complications that have to be resolved on the way to obtaining the LRE interest rate paths: both series show clear downward trends and both are strongly affected by the 1998 Russian crisis. The first of these observations implies that it is not going to be appropriate to assume that itd_t^* and $iltl_t^*$ are constants. Although the end-of-sample levels of itd_t and $iltl_t$ suggest that interest rate convergence is basically over, and hence from now on the properties of the interest rates may be such that modelling their LRE levels as constant will be a good first approximation, the same does not apply for the in-sample itd_t^* and $iltl_t^*$. Under the assumption of constant LRE interest rates, the within sample deviations of the actual rates from their LRE would be very persistent, leading to equally persistent estimates of the money gap, which would hardly have any explanatory power with respect to inflation. Thus, to get more meaningful results, the LRE interest rate series must reflect the fact that these rates have undergone significant convergence. Finally, a very similar problem arises when considering the impact of the South-East Asian and Russian crises on the long-run equilibrium level of Estonian interest rates: to what degree do the spikes in domestic interest rates represent temporary deviations of the rates from their LRE levels and to what extent do they show shifts in the LRE levels of the interest rates themselves?

Clearly, it is difficult to define, let alone determine, what the long-run equilibrium interest rates are when they are not modelled endogenously. In such a case, it must be made clear that any technique that is going to be used to obtain the LRE interest rates is necessarily arbitrary and will have a considerable degree of subjectivity. Importantly, only univariate methods will be considered in this exercise.

In particular, the LRE series of the time-deposit and long-term loan interest rates will be obtained on the basis of two polar *assumptions* about how much the South-East Asian and the Russian financial crises influenced the LRE paths of these rates. The first conjecture is that the crises had a significant impact on itd_t^* and $iltl_t^*$. Hence, the fitted curves that are meant to proxy the LRE rates are allowed to have a break in the quarter the crisis episode started. This alternative is illustrated in the middle panel of Figure 2. The left figure in the middle panel shows that the LRE path for the time deposit interest rate is modelled by fitting two exponential functions: one before 1997Q4 and one after.[25] The right figure in the middle panel does the same for the interest rate on long-term loans. However, since this interest rate declined more or less linearly over time, its LRE path is modelled by simply fitting two trend lines.[26]

On the basis of these itd_t^* and $iltl_t^*$ series, three different money gap measures can be constructed: two corresponding to the ARDL and E–G estimates of equation (12) and one resulting from the E–G estimate of money demand (13). In what follows, itd_t^*, $iltl_t^*$, $\tilde{m}_t^*$ and the related money gap series will be referred to as a 'with crisis' scenario (WC), to emphasize the underlying assumption that the LRE interest rates were strongly affected by the crises.

According to the alternative assumption, which is a polar opposite to the first and thus will be referred to as a 'no crisis' scenario (NC), the 1997-98 episode has had no influence on the long-run equilibrium level of the time-deposit and long-term loan interest rates. To obtain itd_t^* under this conjecture, a set of quarterly dummies is used to 'exclude' the 1997Q4-1998Q2 period when fitting an exponential function to the data. The resulting curve is shown in the bottom-left graph of Figure 2. As can be seen, the spike in the original series now represents only a temporary deviation of itd_t from its LRE path. Similarly, the bottom-right graph of Figure 2 shows the alternative LRE series for the interest rate on long-term loans, $iltl_t^*$, which is obtained using the HP filter. The decision to apply the HP filter was determined by the need to not only smooth the original series considerably but also to allow for some concavity in the dynamics of $iltl_t$ noticeable in the data.

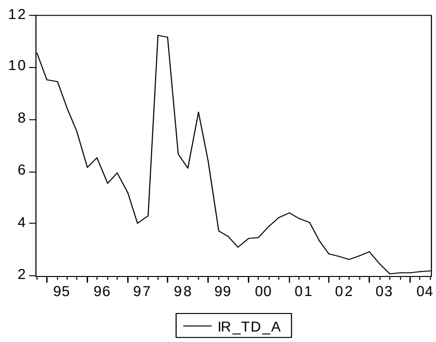
Given the long-run money demand functions and the LRE paths of their determinants, it remains to construct the respective money gap series. Before discussing them, some bookkeeping might be useful, however. To start with, three different versions of the long-run demand for M2 have been selected:

[25] In particular, the following equation was fitted by nonlinear least squares: $c_1 + (c_2 + c_3 \cdot d97q4on)c_4^{trend}$, where c_1, c_2, c_3, c_4 are estimated parameters and $d97q4on$ is a step dummy variable equal to 1 when $t \geq$1997Q4 and 0 otherwise.

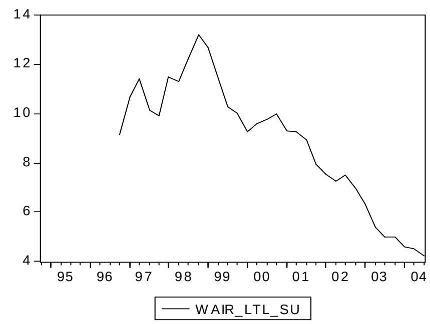
[26] Equation $c_1 + c_2 \cdot d97q4on + c_3 trend$ was estimated by OLS. Note that although the upward shift in $iltl_t$ came somewhat later than that in itd_t, the timing of the break was deliberately chosen to be the same for both series. Given that the shock was due to a well defined external event, it seemed appropriate to impose such a restriction.

Term deposit interest rate, itd	***Long-term loan interest rate, iltl***

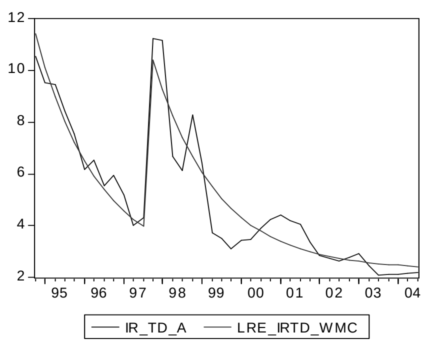
Historical series



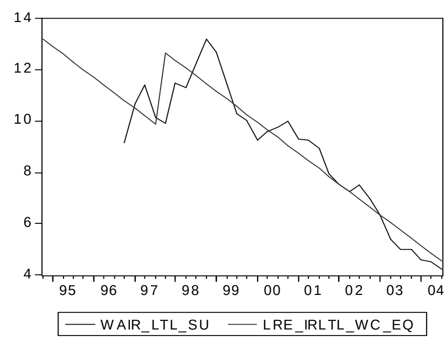
Historical series



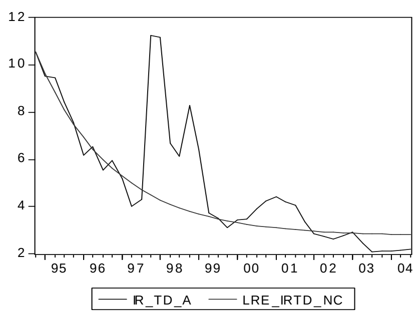
Fitting two exponential trends (up to 1997Q4 and after)



Fitting two linear trends (up to 1997Q4 and after)



Fitting one exponential trend (the crisis period ignored)



Applying the HP filter

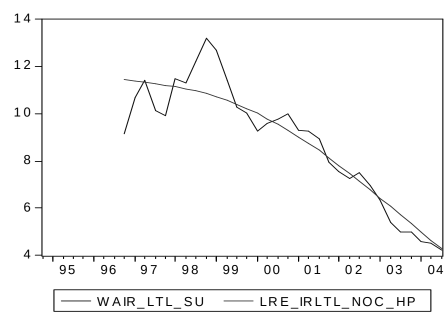


Figure 2: Actual and assumed LRE interest rates

two given by equation (12) (column (3) in Table 4 and specification (3) in Table 5), and one corresponding to equation (13) (specification (5) in Table 5). Since the two formulations of the money demand involve different interest rates, the time-deposit rate and the long-term loan interest rate, respectively, and given that two alternative LRE paths have been constructed for each of the interest rate series – 'with crisis' (WC) and 'no crisis' (NC) – as many as six versions of the money gap will be calculated.

The LRE real balances and money gap series corresponding to the ARDL-based estimation of equation (12) are shown in Figure 3. The left graph shows the actual real M2 and its long-run equilibrium paths ($\tilde{m}_t^*$) calculated for the two alternative assumptions about the LRE sequences of the time-deposit interest rate (WC and NC). The graph on the right plots the respective money gap series as well as the output gap, to which the former can be compared directly. On the basis of Figure 3, it immediately follows, that the money gaps calculated using the money demand estimated by the ARDL procedure have a problem. Regardless of whether the LRE interest rate is allowed to have a break in the crisis period (WC) or not (NC), the calculated LRE series for real M2 tend to be persistently above the actual real balances. As a result, the difference between $\tilde{m}$ and $\tilde{m}^*$ is continuously negative, and that fact cannot be reconciled with the theoretical notion of the 'money gap' that it is meant to measure. More importantly, however, this shows that the ARDL estimation procedure has failed to deliver an empirically meaningful estimate of the long-run demand for M2. Since the general-to-specific ARDL modelling approach is rather 'expensive' in terms of the number of estimated parameters, the insufficient length of the time series at hand is probably the most likely culprit for the misleading long-run estimates obtained here.

Clearly, the money gap series calculated on the basis of the static estimation of the long-run (under the E–G methodology) will be centred on zero and thus avoid similar problems by construction. As discussed above, four alternative money gaps can be obtained using the two money demand functions estimated in such a way (specifications (3) and (5) in Table 5). Figure 4 presents these results. The actual stock of real money ($\tilde{m}$) and its LRE series ($\tilde{m}^*$) calculated using specification (3) (Table 5) are shown in the top-left panel of Figure 4, while the respective money gaps as well as the output gap are presented in the bottom-left graph. As before, two LRE paths of itd (WC and NC) are considered. Finally, analogous constructs for the money demand specification (5) (Table 5) are shown in the top-right and bottom-right panels of Figure 4.

A striking feature of Figure 4 is that all the money gap series appear to be quite similar, be they compared according to the specification of the money demand or the different assumptions about the degree of influence that the 1997-98 crisis episode had on the LRE paths of the interest rates. As can

ARDL based money demand, no time trend

M2-star with crisis, no crisis, and actual real M2 | *M2-star gaps (with crisis, no crisis) and GDP gap*

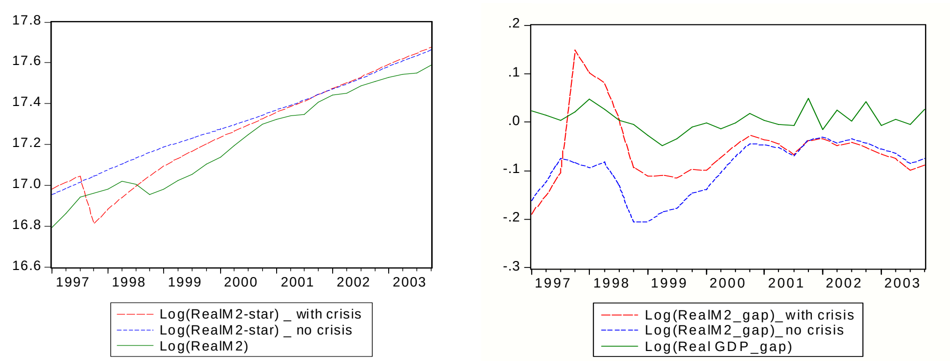


Figure 3: LRE real M2 based on ARDL

be seen from the graphs in the top panel of Figure 4, the LRE real money balances ($\tilde{m}^*$) corresponding to assumptions 'with crisis' (WC) and 'no crisis' (NC) differ only around the crisis period itself but otherwise are almost indistinguishable. Of course, a very similar pattern can be observed when comparing the respective money gaps in the bottom panel of the figure. In fact, if looked from this perspective, the differences between the money gaps corresponding to assumptions WC and NC are not only momentary but also relatively small in magnitude. The same seems to be true for the money gap series *across* the graphs at the bottom of Figure 4, suggesting that the presence of the time trends in the money demand function does not have significant implications for the money gap either. Finally, over the whole sample period, the money gap series seem to follow the output gap rather closely. That is not the case, however, if the dynamics of these variables are considered over shorter periods of time.

To get a more precise evaluation of the degree of similarity across the four money gap measures as well as between the money gaps and the output gap, a matrix of respective paired correlations is presented in Table 6. Above the diagonal, correlation coefficients between the gaps in levels are reported. Below it, correlations based on quarterly growth rates in these variables are shown. As it turns out, the cross-correlations between the money gaps are high (exceeding 80 percent) both in levels and percentage changes. Correlation between the output gap and money gap measures in levels varies from 49 to 65 percent and is therefore neither particularly strong nor very weak. Interestingly, this correlation seems to be lower when the money demand does not

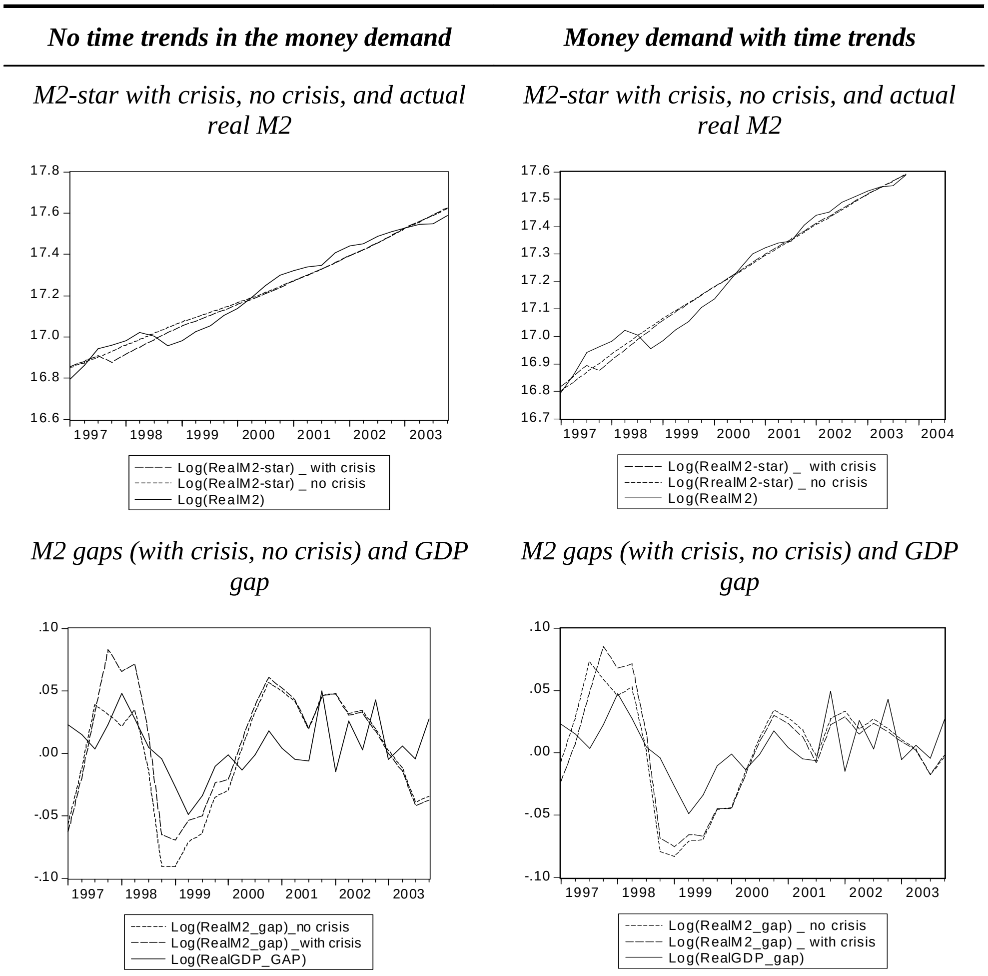


Figure 4: Real M2-star and money gaps based on Engle-Granger estimations

include deterministic time trends. In the case of quarterly growth rates for the output and money gaps, however, the coefficient of correlation declines to only 17-21 percent, most likely because of movements in the interest rates. Overall, the correlation matrix presented in Table 6 supports the idea that the four money gap measures are quite similar among themselves, but that they are rather different from the output gap measure.

To close this section, its main findings can be summarized by the following two conclusions. First, the money gap measures constructed on the basis of the long-run money demand estimated by the ARDL methodology are not centred around zero and thus do not seem to be suitable for further analysis.[27] This

[27]On the other hand, these money gap measures are strongly correlated with those corresponding to the E–G estimation. This seems to support the conclusion that the main problem

Table 6: Correlations between various money gap measures and the GDP gap

	M2 gap (no crisis, with trend)	M2 gap (with crisis, with trend)	M2 gap (no crisis, no trend)	M2 gap (with crisis, no trend)	GDP gap
M2 gap (no crisis, with trend)	1	0.96	0.88	0.85	0.65
M2 gap (with crisis, with trend)	0.93	1	0.84	0.89	0.67
M2 gap (no crisis, no trend)	0.98	0.91	1	0.94	0.49
M2 gap (with crisis, no trend)	0.89	0.98	0.92	1	0.50
GDP gap	0.17	0.21	0.17	0.21	1

Notes: Common sample (28 obs.). Correlations between levels are reported above the diagonal; below the diagonal, correlations between changes in gaps are shown.

narrows the set of alternative money gaps to those based on the static estimation of the long-run money demand. The remaining four variants result from two different specifications of the money demand (with time trends and without) and two assumptions about the LRE paths of the interest rates (strongly influenced by the 1997-98 crisis, WC, and not, NC).

The second important observation, supported by the evidence reported in Figure 4 and Table 6, is that the four money gap measures appear to be quite similar, although their contemporaneous correlation with the output gap differs somewhat depending on whether the underlying money demand includes time trends or not. All in all, it remains to be seen which of the four money gaps, if any, is more useful in modelling inflation. This issue is addressed in the next section.

5. Modelling GDP deflator inflation: Money gap versus output gap

This final section investigates the relative performance of the money and output gaps in terms of their ability to explain GDP deflator inflation. The exercise is carried out by merging the two alternative explanations for inflation

here is indeed the mean of the former. However, if the dynamic properties of alternative gap measures are very similar, there is no gain in carrying on with all of them. Hence, focusing on a subset of money gaps seems to be justified.

that were discussed in section 1 – the P-star theory based equation (5) and the expectations-augmented Phillips curve (6). As opposed to Gerlach and Svensson (2003), no attempt will be made to model forward-looking inflation expectations explicitly. Instead, the $\pi^e_{t+1,t}$ term will be replaced by lagged inflation rates in both equations. This can be interpreted as trying to account for backward looking adjustments in inflation expectations.

The vector of control variables z_{t+1} in equations (5) and (6) will include two exogenous influences: log changes in the price of oil (in US dollars) and log changes in the US dollar exchange rate. Since the latter is expressed as the amount of domestic currency per US dollar, it is expected that both control variables will be positively correlated with Estonian inflation.

Before presenting the estimation results, it is worth noting that the intention of contrasting the performance of the money gap measures with that of the output gap in explaining inflation is not meant to imply that the latter is known to be very relevant for Estonian inflation individually. As a matter of fact, previous research has not yet established the output gap as a robust and important determinant of domestic inflation. Instead, this variable is usually found to be only marginally statistically significant, and the decision to keep it as one of the explanatory variables in some equations for inflation has been based on theoretical rather than statistical considerations (Dabusinskas *et al*, 2005).

The estimation results when both the money and output gap variables are included in the Phillips-curve-type of equation for inflation are presented in Table 7. The column headings at the very top of the table indicate that the table consists of three sections. The two sections under column headings 'Money demand specification' (3) and then (5), present regressions that include both gap variables. Figures (3) and (5) in combination with the sub-headings 'With crisis' and 'No crisis' indicate which of the two money demand specifications and which of the two assumptions about the LRE paths of interest rates the respective money gap is based on. Finally, the third section of the table, its last column, shows the estimation that includes only one gap measure, the output gap, and thus corresponds to the Phillips curve equation 6 in section 1.

The first thing to notice about the relative explanatory power of the two gap measures is that the money gap always dominates the output gap in Table 7. All the equations reported in the table are the result of general-to-specific modelling, when up to four lags of quarterly inflation, M2 gap and GDP gap were initially included. In none of the eight sets of estimations has the GDP gap appeared to be statistically significant, while the (one quarter lagged) impact elasticity with respect to the money gap is always significantly different from zero and equal to 17-18 percent (point estimate). Interestingly, the co-

Table 7: Money gap versus output gap in inflation equations

	Money demand specification (3)				Money demand specification (5)				Phillips curve
	With crisis		No crisis		With crisis		No crisis		
Constant	.029***	.029***	.032***	.032***	.027***	.027***	0.026***	.026***	
	(.002)	(.002)	(.003)	(.003)	(.002)	(.002)	(0.002)	(.002)	
Time trend	-.0007***	-.0007***	-.0008***	-.0008***	-.0006***	-.0006***	-0.0006***	-.0006***	
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(0.0001)	(.0001)	
Dlog(GDP def(-1))									.401***
									(.123)
Dlog(GDP def(-2)									.528***
									(.124)
M2 gap(-1)	.182***	.171***	.165***	.166***	.171***	.167***	0.148***	.121***	
	(.024)	(.023)	(.029)	(.028)	(.025)	(.023)	(0.026)	(.016)	
M2 gap(-2)	-.146***	-.145***	-.096**	-.095***	-.077***	-.080***	-0.026		
	(.024)	(.024)	(.034)	(.033)	(.026)	(.025)	(0.029)		
GDP gap(-1)	-.047		.006		-.016		-0.031		
	(.038)		(.033)		(.033)		(0.035)		
GDP gap(-2)									.077**
									(.035)
Dlog(Poil)	.012**	.012**	.010*	.010*	.013**	.013**	0.015***	.018***	.021***
	(.005)	(.005)	(.005)	(.005)	(.005)	(.005)	(0.005)	(.004)	(.006)
Dlog(Poil(-1))	-.014**	-.010**							
	(.006)	(.004)							
Dlog(USD ER)			.037*	.037*	.056***	.056***	0.070***	.072***	.072***
			(.019)	(.018)	(.018)	(.017)	(0.017)	(.015)	(.020)
Dlog(USD ER (-1))	-.041**	-.041**	-.041*	-.041*			0.019	.030**	
	(.017)	(.017)	(.020)	(.020)			(0.017)	(.013)	
D98Q3	-.017***	-.018***	-.019***	-.019***	-.018***	-.018***	-0.018***	-.018***	-.018***
	(.003)	(.003)	(.004)	(.003)	(.003)	(.003)	(0.003)	(.003)	(.005)
OBS	28	28	28	28	28	28	27	28	28
Ad. R-sq.	.91	.86	.84	.85	.86	.87	0.88	.89	.73
S.E.E.	.003	.003	.003	.003	.003	.003	0.003	.003	.004
Schwarz criterion	-8.13	-8.17	-7.96	-8.07	-8.17	-8.28	-8.23	-8.43	-7.66
DW stat.	1.83	1.79	1.68	1.67	1.67	1.67	2.04	1.98	1.92
Normality, p-val.	.49	.34	.92	.93	.76	.68	0.35	.59	.20
LM AR(4), p-val.	.17	.39	.38	.36	.03	.06	0.26	.17	.25
White, p-val.	.36	.91	.54	.53	.49	.36	0.45	.79	.87

Note: standard errors in parantheses.
*/**/*** denotes significance at the 10% / 5% / 1% level.

efficient of the second lag is always negative, usually statistically significant, and in the case of the first two regressions, almost equal to the impact elasticity in absolute terms. This suggests the possibility that it is the change in the money gap rather than its level that should enter these regressions. However, there are at least two reasons why this proposition is not very appealing, and thus will not be pursued in what follows. First, the original P-star theory is about the relationship between the rate of inflation and the *level* of the money gap, not its growth rate. Hence, if the empirically observed relationship between prices and the money gap were of a different nature indeed, the P-star theory introduced in section 1 would be simply incorrect. Second, the coefficient associated with the second lag of the money gap tends to be as large as the impact elasticity in only one out of four sets of regressions. In fact, there is even a case, namely, the NC scenario for $iltl_t^*$ and the money gap based on specification (5) in Table 5, when the lagged coefficient is *not* significant. In summary, Table 7 appears to provide sufficient evidence that the money gap dominates the output gap as a determinant of inflation in this Phillips-curve-cum-money-gap framework. It also seems to confirm that inflation responds to the money gap itself and not only to the rate at which it changes, which is in line with the P-star theory.

On the other hand, no single equation in Table 7 stands out as clearly preferable. One problem with the first two regressions is their counter-intuitive pass-through effects, suggesting that an appreciation of the US dollar would have a negative effect on domestic inflation. However, the most likely reason for this discrepancy is the fact that the contemporaneous changes in the exchange rate have been dropped as statistically insignificant. Therefore, the origin of this problem seems to be related to low estimation efficiency. If anything, the regression reported in the penultimate column may seem to be somewhat superior relative to the rest as it has the lowest Schwarz inflation criterion, one of the highest adjusted R-squared and passes all the specification tests reported at the bottom of the table. Note that in this regression, only the first lag of the money gap is statistically significant, which makes the estimated quantitative effect of the money gap on inflation the strongest across all specifications.

The above conclusion, that the money gap outperforms the output gap as an explanatory variable for inflation, is drawn from the analysis of inflation in the very short run. A different but not less important question is how the two variables fare in terms of predicting inflation for longer horizons – say 4 quarters ahead. Before addressing this issue directly it may be instructive to look at the pattern of correlations between the constructed gap measures and inflation at various lags and leads. The top panel of Figure 5 plots such correlations for all gap measures (money and output) and quarterly inflation when the mismatch in timing between the two changes from eight quarters back to eight quarters forward: $corr\,(\tilde{m}_t - \tilde{m}_t^*, \pi_{t+i})$, $i = -8, -7, .., 7, 8$, where $\pi_t = p_t - p_{t-1}$ is quarterly inflation. It turns out that for all 4 money gap measures as well as the output gap the time pattern of such correlations is very similar. Contemporaneous correlations are positive (indicated by '0' on the horizontal axis), some as high as 40 percent, but they decline very quickly as the timing of inflation is pushed forward. In fact, all the money gaps are negatively correlated with quarterly inflation two or more quarters ahead. This contrasts sharply with positive correlations reported by Gerlach and Svensson (2003) for the EMU.

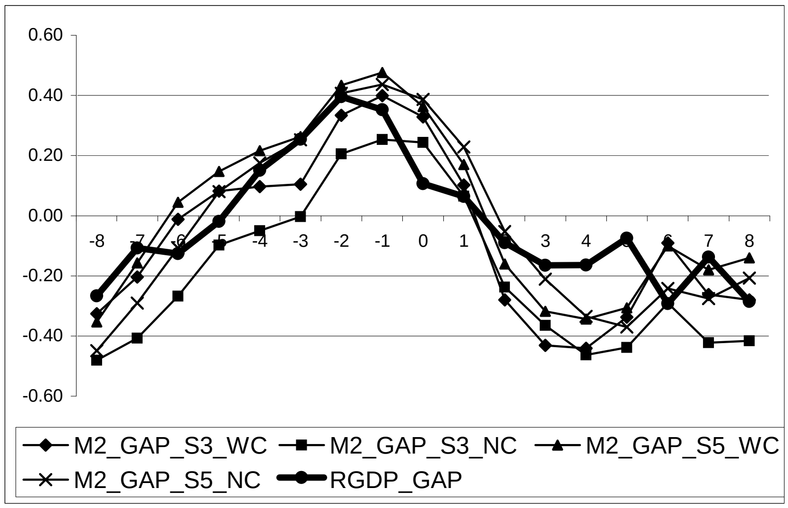
On the other hand, the same top panel of Figure 5 shows that the money gap measures have considerably longer 'inflation memory,' that is, they are positively correlated with past inflation, and in some cases, these correlations remain positive for up to 6 quarters into the past. Although not necessarily correct, the overall impression provided by the top panel of Figure 5 is that these money gaps can serve as indicators of future inflation for only a very short time horizon, perhaps for only one quarter into the future, as is the case in the inflation regressions of Table 7. Of course, the gaps can correlate negatively with future inflation, and that, in principle, could be used in forecasting inflation, but the nature of the relationship would be at odds with the P-star theory.

Finally, it is worth noting that although the output gap is similar to the money gaps in how quickly it becomes negatively correlated with future inflation, for the output gap this negative relationship is weaker. That is particularly true for the 3-5 quarter leads of inflation, when the correlation coefficient is less than 20 percent for the output gap (see the bold line in the top panel of Figure 5) and about 40 percent for some money gaps. This suggests that if dynamic estimation is to be used for predicting inflation 2 or more quarters ahead, the 'wrong sign' problem is more likely to arise in the case of the money gaps than the output gap.

A slightly different perspective on the correlation between money and output gaps and inflation over time is undertaken in the bottom panel of Figure 5. Here, quarterly inflation rates are replaced by future annual inflation: $corr\,(\tilde{m}_t - \tilde{m}_t^*, \pi_{t+5+i})$, $i = -8, -7, .., 7, 8$, where $\pi_{t+5} = p_{t+5} - p_{t+1} = \Delta_4 p_{t+5}$ is annual inflation in $t+5$. Hence, the case when $i = 0$ ('0' on the horizontal axis in the bottom panel of Figure 5) shows correlations between some gap measure in period t and annual inflation from $t+1$ to $t+5$.[28] As can be seen, even the contemporaneous (defined here as $i = 0$) correlations between various gap measures and annual inflation are negative, and they remain so for as many as 4 quarters into the future ($i = 4$), that is, for any reasonable

[28]Note that $\Delta_4 p_{t+5}$ can be written as $(\log p_{t+5} - \log p_{t+4}) + \cdots + (\log p_{t+2} - \log p_{t+1}) = \Delta p_{t+5} + \cdots + \Delta p_{t+2}$, which indicates a clear link between the top and bottom panels of Figure 5.

Correlation of money and output gaps with quarterly inflation at various lags and leads



Correlation of money and output gaps with annual inflation at various lags and leads

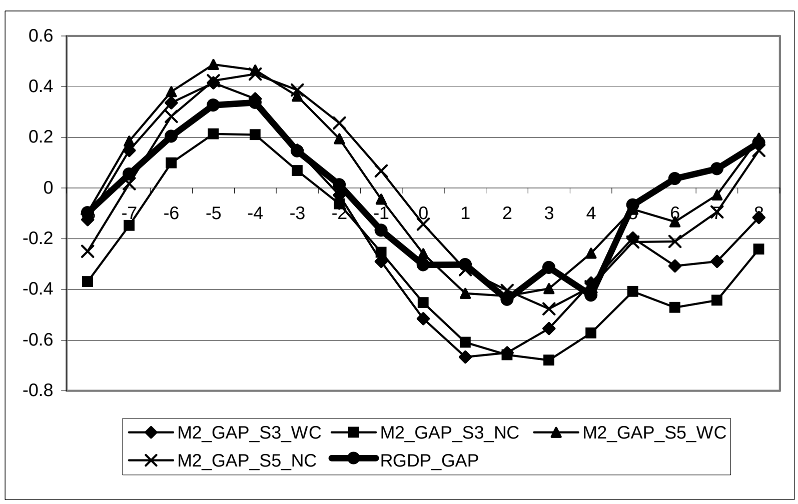


Figure 5: Correlations between money and output gaps and inflation rates

forecasting horizon in the current exercise. In summary, these results seem to confirm the previous conjecture that the P-star theory is a more appropriate description of the relationship between the money gap and future inflation in the short run. In the medium run, empirical correlation between the two variables is negative, and thus the story of the P-star does not seem to be applicable.

Finally, the performance of the money and output gap measures as indicators of future inflation can be further investigated by applying regression analysis similar to that presented in Table 7. Since the focus is on prediction, it seems preferable to perform dynamic estimation, that is, to regress the variable to be forecast π_{t+h}, where h is the forecasting horizon, *directly* on the explanatory variables dated t and earlier. In the current application, quarterly variables dated t and earlier will be used to predict annual inflation from $t+1$ to $t+5$, that is $\Delta_4 p_{t+5}$.

Unfortunately, these regressions turned out to be considerably unstable, especially with regard to the parameters of interest – the coefficients associated with the money and output gaps. Whatever the reason for this lack of stability – the small sample size, which is further reduced when calculating the annual inflation rate, multi-collinearity between the money and output gaps or something else – the exercise shows that the money gaps considered here are not helpful for predicting inflation in the longer run.

To be more specific about the outcome of this regression analysis nevertheless, some estimation results are presented in Table 8. Instead of considering all the four money gap variables again, the table focuses on only two of them, those computed on the basis of money demand specification (5) in Table 5 and scenarios WC and NC for $iltl^*$. Importantly, the specifications reported in Table 8 *do not* represent the 'best' models selected for forecasting $\Delta_4 p_{t+5}$, given the information set considered here. Instead, the aim is to contrast the performance of the money and output gaps in the role as inflation indicators. For that reason, some statistically insignificant lags (and even redundant variables) are kept. Finally, the table shows estimations for two sample periods, 1997Q4-2002Q4 and 1998Q4-2002Q4. Although reducing the already very small sample may seem absolutely unreasonable, it is done for the sole reason of showing that in this particular case, the results are basically unchanged and that the output gap seems to become slightly more relevant for predicting inflation in the smaller sample. At this moment, the latter observation is no more than just a hypothesis for future research, of course.

Overall, Table 8 offers several implications. The most conclusive result is that the money gap variables do not play any economically sensible role in these regressions. According to the P-star theory, the money gap and inflation should be correlated positively. The statistically significant negative coeffi-

Table 8: Predicting annual inflation

	Money demand specification (5)			
	With crisis		No crisis	
Constant	.072***	.089***	.068***	.085***
	(.004)	(.009)	(.006)	(.011)
Time trend	-.001***	-.002***	-.001***	-.002***
	(.0002)	(.0004)	(.0002)	(.0004)
M2 gap(-1)	-.276***	-.180**	-.204***	-.165*
	(.052)	(.078)	(.067)	(.082)
M2 gap(-2)	.029	.002	.005	.001
	(.054)	(.055)	(.069)	(.059)
GDP gap(-1)	.202**	.232**	.126	.220**
	(.083)	(.079)	(.096)	(.084)
GDP gap(-2)	.078	.081	.027	.061
	(.086)	(.089)	(.100)	(.092)
Dlog(Poil(-4))	.043***	.035***	.046	.036***
	(.008)	(.008)	(.011)	(.009)
Dlog(USD ER (-2))	.107**	.113**	.085	.112**
	(.036)	(.036)	(.046)	(.038)
Sample	1997Q4	1998Q4	1997Q4	1998Q4
	2002Q4	2002Q4	2002Q4	2002Q4
OBS	21	17	21	17
Ad. R-sq.	.87	.91	.78	.94
S.E.E.	.005	.004	.006	.005
Schwarz criterion	-7.11	-7.31	-6.59	-7.19
DW stat.	1.67	2.16	1.73	2.12

Note: standard errors in parantheses.
*/**/*** denotes significance at the 10% / 5% / 1% level.

cient next to the first lag of the money gap is therefore a nuisance. Although the output gap does not get much support from these regressions either, its coefficients have the correct sign and tend to be marginally significant. There is some indication that the statistical relevance of the output gap tends to increase when the regressions are estimated for the more recent part of the sample. However, more data are needed to see if the output gap is indeed becoming a better indicator of future inflation.

6. Conclusions

In this paper, I investigated whether information contained in M2 could improve our ability to explain and predict inflation in Estonia. Specifically, I applied the price (or real money) gap concept suggested by the P-star theory to model GDP deflator inflation over 1997Q1-2003Q3. The performance of the money gap was examined mainly by contrasting this variable with the output gap, the more "traditional" gap measure used in the Phillips-curve-type equations for inflation.

As constructing the money gap involved estimating the long-run demand for money and evaluating the long-run equilibrium levels of its determinants, a number of complications had to be resolved. For example, both the influence of the Russian crisis and the fact that significant financial deepening took place over the sample period had to be taken into account when assessing the long-run equilibrium paths of the relevant interest rates. Since no single modelling strategy was clearly dominant, several money demand specifications and more than one money gap variable were considered in the analysis.

In terms of the main research question of the paper, the results show that the money gap dominates the output gap as an explanatory variable for inflation in the short run. In particular, if both gap measures are included in a regression reminiscent of the Phillips curve for quarterly inflation, the presence of the money gap makes the output gap statistically insignificant.

However, when the money gap is used for predicting inflation over longer forecasting horizons, for example, one year, the relationship between the two variables becomes rather unstable and, in fact, turns negative, compromising the initial conjecture that, in accordance with the P-star theory, the money gap would have significant predictive power for inflation in the longer run as well. In the latter case, only the output gap shows some potential, although more data are needed to confirm that this variable can be exploited in inflation forecasting.

These findings are quite different from Gerlach and Svensson (2003), who report that the money gap complements, in a significant way, the predictive power of the output gap for forecasting long-run inflation in the EMU. Although clarifying the reasons for the differences in the results has not been an objective of the current paper, several explanations can be suggested. One obvious difference between this paper and (some of) the related empirical literature is a different monetary aggregate used in the analysis. Using M2 (here) instead of M3 can be important in that M2 may lead to a less stable relationship between the stock of money and prices and thus contain less "forward-looking" information about the price level in the future. In addition, the absence of Estonian government bonds and the fact that M2 is the broadest monetary aggregate available make the empirical assessment of the opportunity cost of money more difficult. Although the main results were not sensitive to the choice of particular interest rates or their LRE paths, the question of what would be the best way to account for the opportunity cost of M2 in Estonia remains open.

Another important point is that the P-star theory should be more applicable in the case of a closed (or large) economy rather than a small and open one. In principle, a high degree of openness should make domestic inflation relatively more dependent on external forces and make it less sensitive to domestic factors, including the money gap measure. For this reason, the paper has focused on GDP deflator rather than consumer price inflation, but the argument is still valid and may be one of the reasons why the money gap is not been found to be a good indicator of future inflation in the current exercise.

Finally, the presence of a currency board in Estonia implies that adjustments can take place through changes in the money stock, not prices, possibly further weakening the case for the P-star theory in this application, at least for predicting long-run inflation.

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