

Historical Analysis of Monetary Policy Reaction Functions: Do Real-Time Data Matter?*

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Abstract

This paper investigates the differences between parameter estimates of monetary policy reaction functions using real-time data and those using revised data. The model is a New Keynesian DSGE model of the Czech, Hungarian and Polish small open economies in interaction with the euro area. Unlike the related literature, this paper uses separate vintages of real-time data for all successive estimations. The paper reports several statistically significant differences between parameter estimates of monetary policy reaction functions based on real-time data and those based on revised data. The parameter whose estimate is the most affected by the usage of real-time data is preference for output growth. This result is common across the countries in the study. The results suggest that real-time data matter when conducting a historical analysis of monetary policy preferences.

1. Introduction

The unreliability of real-time macroeconomic data is a well-known issue and many studies have investigated the properties of data revisions. Orphanides and van Norden (2002) report that revision of U.S. published data is not the main issue; it is the unreliability of end-of-sample trend estimates. These results are confirmed by Marcelino and Musso (2011) on euro area data, and by Ince and Papell (2013) on data for nine OECD countries. On the other hand, Cusinato *et al.* (2013) find that data revision and the end-of-sample problem contribute to uncertainty about the Brazilian output gap, but do not find any evidence that the former is less important than the latter. Investigating the empirical properties of U.S. macroeconomic data, Aruoba (2008) finds that the revisions are biased and predictable. Rusnák (2013) reports that revisions of Czech GDP and its components are rather large. He also studies whether the revisions are “news” or “noise”, i.e. whether the revisions are predictable or unpredictable, and ascertains in-sample predictability and out-of-sample unpredictability for most variables of interest.

Clearly, there are many possible problems with data revisions, and they are quantitatively of variable importance in different countries. However, the fact that the data revisions are large does not necessarily mean that they must create problems for economic agents. A researcher who wants to find out how significant the revisions are for decision-making in different situations must incorporate real-time data

* I am grateful to two anonymous referees and Roman Horváth for their helpful comments and suggestions. Computational resources were provided by the MetaCentrum under the program LM2010005 and the CERIT-SC under the program Centre CERIT Scientific Cloud, part of the Operational Program Research and Development for Innovations, Reg. no. CZ.1.05/3.2.00/08.0144.

A companion paper investigates the differences between the remaining parameter estimates (not pertaining to monetary policy) using real-time data, and those using revised data, on a bigger set of countries. See Čapek (2015).

or data revisions into the decision-making process and observe if there are noteworthy differences in the results. A great deal of research effort has focused on the analytic consequences of bad real-time data quality for monetary policy. The literature goes back to Maravall and Pierce (1986), who investigate the conduction of monetary policy in real-time and ask whether policy would have been different if final data had been available. The authors conclude that the answer to that question is no. A similar research question is also investigated by a stream of literature that focuses on monetary rule under real-time conditions: Orphanides (2001) uses a Taylor-type rule to look at the effect of different policy recommendations using real-time data compared to final data and argues that monetary policy reaction functions estimated on final data provide a misleading description of historical policy. Similar results, i.e. that real-time data play a (significant) role, were also reached by Aurelio (2005), Gerdesmeier and Roffia (2005), Gerberding *et al.* (2005), Horváth (2009), and Belke and Klose (2011). More recent literature also uses DSGE models with monetary rules as a tool for monetary policy investigation. Vázquez *et al.* (2010) and Casares and Vázquez (2012) find that monetary policy parameters are robust to real-time specification. On the other hand, Neri and Ropele (2012) show that there is indeed a statistically significant difference in policy parameters when real-time data are considered (rather than final data). Interested readers are referred to Croushore (2011) for an extensive survey of the real-time data literature.

This paper follows the aforementioned literature in exploring the analytic consequences of using real-time versus revised data for monetary policy decision-making. Prior to the main analysis, it may be interesting to look briefly at the statistical properties of data revision that may play a role in the main analysis. Section 3 of the paper investigates the statistical properties of data revisions for Czech, Hungarian and Polish GDP growth and inflation. The data revision analysis is followed (in Section 4) by the main part of the paper, which is an investigation of the influence of using real-time data for a historical analysis of Czech, Hungarian and Polish monetary policies. Theoretically speaking, using the most recent revised data for ex-post analyses on a historical time-sample may be misleading because revised data were not available at that time. This study uses a small-scale monetary macroeconomic DSGE model to analyze the importance of real-time data, focusing on the differences in implied decision-making by the monetary authority. In the model, the monetary authority's decision-making is approximated by a Taylor-type monetary rule, whose parameters can be interpreted as the monetary authority's preferences. Therefore, the operational goal of the paper is to investigate the differences between parameter estimates of monetary policy reaction functions using real-time data and using revised data.

The analysis proceeds from a Bayesian estimation of model parameters and its results are also presented in terms of the statistical significance of the differences in parameter estimates. Note that, unlike all cited literature, this paper uses separate vintages of data for the estimation, not just a single series of real-time data. Such an approach should better mimic the time series that are actually available to the decision-maker.

2. Methodology and Preliminaries

2.1 Model

This paper uses a New Keynesian (NK) Dynamic Stochastic General Equilibrium (DSGE) model. The model is derived from microeconomic behavior of particular economic agents. These include domestic and foreign households, domestic and foreign producers, domestic importers and domestic and foreign monetary authorities. Most of the model assumptions are adopted from Lubik and Schorfheide (2006).¹

In baseline setting, domestic and foreign monetary authorities follow Taylor-type rules (the variant where central monetary authorities care about year-on-year rather than quarter-on-quarter changes is also investigated):

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) [\psi_1 \pi_t + \psi_2 (\Delta y_t + z_t) + \psi_3 \Delta e_t] + \varepsilon_{r,t}$$
$$r_t^* = \rho_r^* r_{t-1}^* + (1 - \rho_r^*) [\psi_1^* \pi_t^* + \psi_2^* (\Delta y_t^* + z_t^*)] + \varepsilon_{r,t}^*$$

where r_t is the nominal interest rate at time t , ρ_r is a backward-looking parameter, π_t is inflation, Δy_t is the growth rate of real output, z_t is the growth rate of a worldwide technology shock, Δe_t is the depreciation of the domestic currency, ψ s are the preference parameters and $\varepsilon_{r,t}$ is a monetary policy shock.² Variables and parameters with a star superscript refer to a foreign economy.

The model is in a small open economy (SOE) setting, so it presumes two countries—a small open economy influenced by a big closed economy. Also, the model incorporates an exchange rate channel, and the two countries in the model should therefore have different currencies. Finally, the formulation of the interest rate rule corresponds best with the inflation targeting regime.

Given the typical scope of the journal, this study concentrates on the countries of the Visegrád Four, of which three countries meet the restrictions given by the model formulation.³ The small open economy is therefore the Czech, Hungarian or Polish economy. In all three cases, the euro area with 12 countries is the large economy.

2.2 Data

The observed variables were chosen in accordance with Lubik and Schorfheide (2006), where the authors use quarterly data for seven observable variables—output growth, CPI inflation and the three-month nominal interest rate, all for domestic and foreign economies, and the growth rate of bilateral nominal exchange rate

The data were acquired from OECD databases. GDP and the Consumer Price Index were acquired from a real-time database,⁴ while the interest rates and the exchange rates were acquired from Key Economic Indicators.⁵

¹ See the *Appendix* for an extensive model description and log-linearized model form.

² See *Table 4* for a list of estimated parameters.

³ Slovakia does not have independent monetary policy.

⁴ <http://stats.oecd.org/mei/default.asp?rev=1>

⁵ <http://stats.oecd.org/Index.aspx?DataSetCode=KEI>. Note that the Hungarian interest rate has several missing observations in the OECD database. The series was substituted from the Eurostat database (the data are virtually the same) where there is only one missing observation in 2004q3 which was linearly interpolated.

Real-time data is usually structured in vintages. A “vintage” is the quarter when the data become available or the time of publishing. For example, if the Czech Statistical Office releases an estimate of GDP growth for the last quarter of 2012 sometime in April of 2013, it is said that the data for the fourth quarter of 2012 are of the April 2013 vintage.

The term “real-time data” pertains to data that become available right after collection. Real-time macroeconomic data are usually available 3–4 months after the end of a quarter, typically being the first estimates published for that quarter. As time passes, new vintages become available and revised data become more accurate estimates of real values. The most recent vintage is referred to as the “final” value. The difference between the final and real-time data is a “total revision”.

The original OECD real-time dataset for CPI has 180 *monthly* vintages (February 1999–January 2014) that cover 36 (January 1996–December 1998) to 215 *monthly* observations (January 1996–November 2013). The original real-time dataset for GDP also has 180 *monthly* vintages that cover 11 (1996Q1–1998Q3) to 71 *quarterly* observations (1996Q1–2013Q3).⁶

GDP in constant prices that was *not* seasonally adjusted in the dataset has been seasonally adjusted in Demetra⁷ program using the Tramo & Seats method. Computed growth rates are quarter-on-quarter log-differences, the monthly Consumer Price Index was also seasonally adjusted. The third month in each quarter was used to compute quarter-on-quarter inflation (as log-differences). Both datasets were truncated so that there are at least 30 quarterly observations for the estimation.

Finally, there is the issue of which *monthly* vintages to select for estimation in each *quarter*. Since the model is quarterly, there are three choices available: to use January/April/July/October vintages, February/May/August/November vintages or March/June/September/December vintages. There are many difficulties with this choice and arguably none of the options is ideal. The approach used in this article is to use the vintage set that ensures the highest number of *balanced* real-time data subsets. A balanced real-time data subset in this context means that it includes the same number of quarterly observations for both GDP growth and inflation. This approach is convenient in that we do not need to discard any existing quarterly observations, nor do we need to estimate (nowcast) any non-existent observations. However, there are also drawbacks to this approach. First, since we focus only on quarterly observations, we disregard any monthly observations of inflation that may be available. Second, this approach does not discriminate between flash estimates (of GDP) and “regular” releases of national accounts data.^{8,9} Third, the unbalanced real-time data subsets are not addressed—the affected vintages are simply not used for the estimation and no results are reported for that vintage. For the Czech and Polish economies, the January/April/July/October selection ensures the highest number

⁶ Missing observations occur in some vintages for some countries. Such vintages are not used for the estimation.

⁷ <http://circa.europa.eu/irc/dsis/eurosam/info/data/demetra.htm>

⁸ I've conducted a sensitivity analysis (on Czech data and baseline setting) and used all three possible choices of sets of monthly vintages (in this case, ragged ends were cut) and the similarity of the results do not suggest there is a problem of vintage choice.

⁹ I would like to thank an anonymous referee for pointing out these possible problems.

Table 1 Data, Trend, and Total Revision

Variable	Data revision	Trend	Total revision
domestic GDP growth	yes	constant	= data revision
domestic inflation	yes	constant	= data revision
domestic interest rate	no	HP filter	= trend revision
foreign GDP growth	yes	constant	= data revision
foreign inflation	yes	constant	= data revision
foreign interest rate	no	linear	= trend revision
nom. exchange rate growth	no	constant	= none

Notes: Domestic economies are Czech, Hungarian, and Polish. Foreign economy is euro area.

of balanced real-time data subsets (36 for CZ and 37 for PL).¹⁰ The Hungarian data were probably published with different timing and ensure only one balanced real-time subset for the January/April/July/October vintages. On the other hand, the March/June/September/December vintages offer 21 balanced subsets and this setup is therefore used for the estimation on Hungarian data.

There are no real-time datasets for the remaining observable variables and truncated time series are therefore used for the estimation. The interest rates are three-month interbank rates without any transformation.¹¹ Quarterly nominal exchange rates were collected as “USD monthly averages” and transformed into domestic currency vs. euro in direct quotation, which means that the rise of its value reflects the depreciation of the domestic currency.¹² The growth rate of the nominal exchange rate was calculated as log-differences.

If the originally published data need to be detrended prior to use, then the issue of trend recomputation comes into play. When new data become available, their influence can be seen in two directions. First, the new vintage delivers more accurate data for historical periods—this influence is often referred to as “data revision”. Secondly, the new data point for the new period enables a more accurate estimation of the trend for historical periods—this influence is “trend revision”. The sum of data and trend revisions yields total revision.

Table 1 summarizes which macroeconomic variables are subject to data revision and which are subject to trend revision. Domestic and foreign GDP growth and inflation are part of the real-time database and are therefore subject to data revision. However, these variables are stationary and detrending them only requires deducting the means. Trend revision is negligible for constant trend, which is

¹⁰ The following table shows the number of (un)balanced data subsets for Czech data and baseline model setting.

Vintage set	Balanced	Unbalanced	Total
January/April/July/October	36	5	41
February/May/August/November	1	39	40
March/June/September/December	19	21	40

¹¹ Note that several missing values were filled in with Eurostat data, which are consistent with OECD data.

¹² This selection and computation was used because the OECD dataset does not contain currencies quoted in EUR. The calculations were cross-checked against Eurostat datasets and the series are virtually the same.

the reason why it is omitted in this study. Interest rates are not subject to data revision, but are not stationary. The interest rates in the euro area are detrended by a (linear) time trend. Domestic interest rates are even less regular and are detrended by a Hodrick-Prescott filter. Nominal exchange rate growth is not subject to data revision and the series is stationary, which means that this series is not subject to any revision. Due to the availability of variables in the real-time database and the choice of detrending methods, no variable is subject to both types of revision.

In order to conveniently distinguish between data and trend revisions, the concept of so-called “quasi real-time data” is usually introduced.¹³ Quasi real-time data are constructed with knowledge of the latest vintage but not of future values. The researcher therefore knows what data revision for today’s value will occur tomorrow but she does not know any values for tomorrow’s time period. Therefore, quasi real-time data isolates trend revision. Quasi real-time data minus real-time data is data revision and final data minus quasi real-time data is trend revision.

All observable variables enter the model as quarter-on-quarter growth rates (interest rates are quarterly) and *per quartal*.¹⁴

2.3 Recursive Estimates and Statistical Significance

This study undertakes a recursive analysis in order to analyze the influence of the use of real-time data on the differences in monetary authorities’ preference parameter estimates in the course of time. The recursive analysis is conducted in such a way that the first observation is always the same and the last observation shifts by a quarter each time a new estimation is carried out. A logical implication is that the time frame of the estimate grows. The series of such estimates may be intuitively perceived as the exploration of the information in the newly added data. Although this intuition is not entirely correct, this paper concentrates on the influence of real-time data rather than on weaknesses of recursive estimation.

The log-linearized DSGE model is estimated using Bayesian methods. A numerical-optimization procedure is used to maximize the posterior. At least 1,000,000 draws from posterior density are generated with a random-walk Metropolis-Hastings algorithm, after which the convergence is checked according to Brooks and Gelman (1998) convergence diagnostics. If the chain does not converge, 1,000,000 more samples are added and the convergence is rechecked until convergence is reached.¹⁵ Then 90% of the original sample is discarded and the rest is used for posterior analysis. The estimation is carried out in the Dynare software.¹⁶ A Monte Carlo-based optimization routine is used for computing the mode so that different estimates all reach suitable acceptance rate. Parameters’ prior densities are the same for all estimates.

Note that, unlike the cited literature, data enter the estimation in respective vintages for each estimation. A typical approach in the existing literature is to form one time series of real-time data and repeatedly truncate it to obtain recursive esti-

¹³ See, for example, Orphanides and van Norden (2002) and Ince and Papell (2013).

¹⁴ See part 2.4 for two exceptions with selective year-on-year transformation.

¹⁵ When the chain does not converge, results are not reported.

¹⁶ See <http://www.dynare.org/>; version 4.4.1 was used.

mates. The approach of this article is different: it uses the whole vintage of data for each successive recursive estimation. The data source for one “real-time” macroeconomic variable is therefore not one time series, but a matrix of data with separate vintages. Although computationally more demanding, this approach mimics more closely the data actually available to economic agents at any point in time.

For real-time estimates, the trend estimates are based only on the data that were actually available. For quasi real-time estimates, all data are fully revised but values for future periods are not known. For final estimates, all data are fully revised and future values are available for computation of the trend. In order to capture the evolution of the estimates, final data series are truncated to match the period of estimation.

In order to be able to conclude whether potential differences between real-time, quasi real-time and final estimates are statistically significant, Section 3 reports the lowest significance level at which the (major) mode is out of the Highest Posterior Density bands for the two most different estimates.

2.4 Estimated Variants

The study offers several different model specifications, data treatments and estimation procedures to show the robustness of the results. The setting introduced in previous sections of part 2 is called *baseline*.

CPI not s.a. stands for the model variant with the Consumer Price Index not seasonally adjusted; *GDP HP* denotes a variant with the growth rate of Gross Domestic Product detrended by a Hodrick-Prescott filter; *rolling* uses estimation (of the baseline model) in a moving window of fixed length 30; *YOY* stands for a variant with monetary authorities that care about year-on-year (rather than quarter-on-quarter) changes and *YOY+GDP HP* denotes a variant with monetary authorities that care about year-on-year changes and GDP is detrended by HP filter.

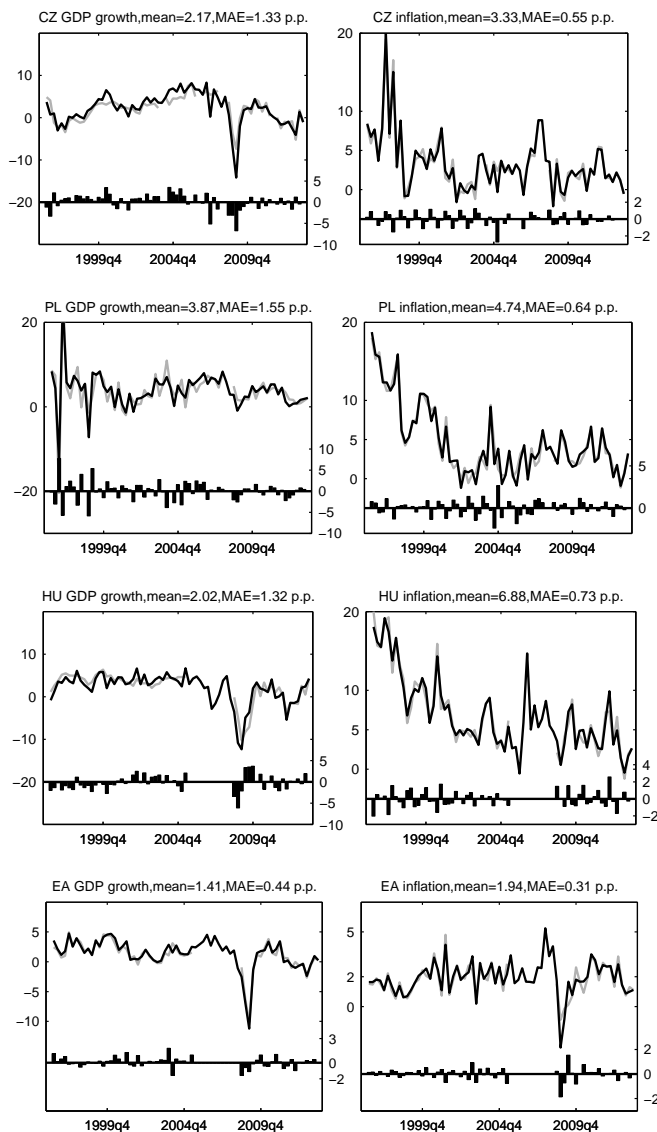
3. Recursive Analysis of Real-Time Data

Figure 1 displays real-time and final data for the Czech, Polish, Hungarian and euro area economies. Note that in order to see the magnitude and regularity of data revisions, the data are not detrended here. Also, in order to form one “real-time” time series for each macroeconomic variable, only the most recent data point per vintage is considered. This treatment corresponds to the use of “real-time” data in the literature and is therefore directly comparable. However, note that these depicted series do not enter the estimation; separate vintages do.

In all of the countries in the study GDP growth suffers from revision much more than inflation. Also, the depicted data for the euro area are markedly less subject to data revision than data of the remaining countries.

Close inspection of the GDP graphs reveals some similarities and some specific aspects among countries. In all of the countries, the severity of the economic crisis of 2009 was underestimated, i.e. it was milder according to real-time data than it actually was after revisions. The economic crisis was also the period with the largest revisions on the sample for the Czech and Hungarian economies. Polish revisions of GDP growth were biggest prior to 1999 and there are no apparent differences in revisions in the euro area.

Figure 1 Real-Time and Final Data



Note: The *black* line denotes final data (left axis), the *gray* line denotes real-time data (left axis), *errorbar* depicts data revision (right axis), *mean* denotes the average of final data over the sample, and *MAE* denotes the mean absolute error in data revision.

As for the inflation graphs depicted in the right-hand panels of *Figure 1*, revisions for all of the countries except for the euro area are autocorrelated in lags 2 and 4. This autocorrelation seems to be an artifact of seasonal adjustment of the underlying CPI series. However, since the series of revisions do not enter the estimation (separate data vintages do), this problem remains only with the statistics in *Table 2*.

Table 2 Summary Statistics of Data Revisions

	<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>St. Dev.</i>	<i>RMSE</i>	<i>N/S</i>	<i>Corr</i>	<i>p-val</i>	<i>AR(1)</i>	<i>Rev+</i>
Output growth										
Czech Rep.	0.13	-6.77	3.46	1.80	1.80	0.49	0.88	0.68	0.32	0.58
Poland	0.04	-5.86	7.72	2.17	2.18	0.52	0.91	0.83	-0.40	0.57
Hungary	-0.19	-6.14	3.63	1.73	1.74	0.49	0.88	0.49	0.36	0.40
EA12	0.14	-1.59	2.26	0.71	0.73	0.29	0.96	0.15	0.07	0.63
Inflation										
Czech Rep.	-0.02	-2.71	1.20	0.73	0.73	0.20	0.98	0.73	0.00	0.54
Poland	0.03	-2.36	2.66	0.83	0.83	0.19	0.98	0.60	-0.16	0.54
Hungary	0.01	-2.02	2.56	0.93	0.93	0.20	0.98	0.94	-0.31	0.45
EA12	0.04	-1.86	1.54	0.44	0.45	0.40	0.91	0.29	-0.14	0.59

Notes: *N/S* denotes the noise-to-signal ratio defined as the standard deviation of the revisions divided by the standard deviation of the final value of the variable; *Corr* is the correlation of final and real-time data; *p-val* is a *p*-value for a test that the mean revision is zero using autocorrelation and heteroscedasticity-consistent standard errors. *AR(1)* denotes an autocorrelation coefficient of the first order (missing data are estimated in an iterative fashion using default order state-space models); *Rev+* denotes the frequency at which final data is greater than real-time data, i.e. final revision is positive.

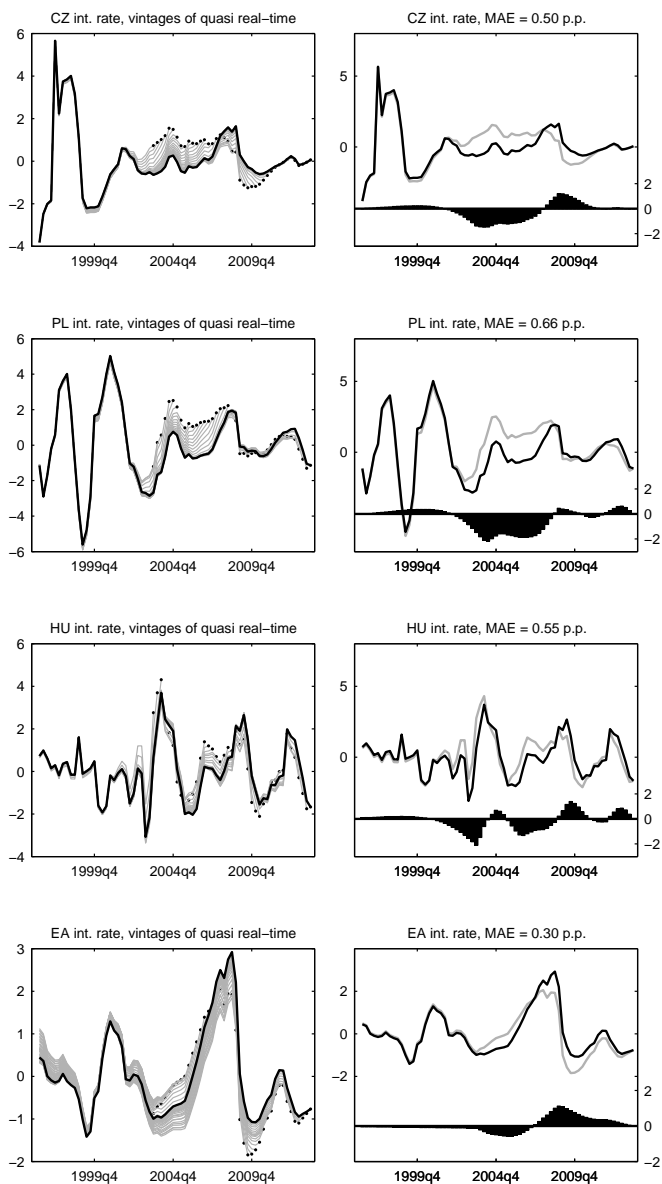
Apart from the autocorrelation, there does not seem to be any other regularity in inflation revisions.

Table 2 summarizes the statistics of data revision. The revisions are unbiased for all of the countries and both variables since the lowest *p*-value (0.15) is greater than conventional levels. All correlations are high, which means that the final and real-time data have very similar dynamics. Revisions show a very low autocorrelation coefficient (of order 1), which indicates that period-to-period revisions are not systematic. Euro area GDP growth suffers from modest underestimation of growth, as the real-time estimate is lower than the final data 63% of the time. The noise-to-signal ratio for GDP growth confirms that the relative magnitude of revisions is lowest for the euro area, and the remaining countries exhibit an approximately 70% higher value of this indicator. The noise-to-signal ratios for inflation are rather unexpected, with the value of the ratio being twice that of the remaining central European countries. Note that this result also probably stems from the seasonal adjustment of the CPI series.¹⁷

Figure 2 presents a graphical illustration of trend revisions for the Czech, Polish, Hungarian and euro area interest rates. The left-hand panels illustrate the evolution of vintages of quasi real-time data. Each thin gray line displays the evolution of quasi real-time data in a particular vintage. Considering only the *last* values (denoted as black dots) of each quasi real-time vintage yields the curve of quasi real-time data depicted in the right-hand panels (in gray). The difference between final and quasi real-time data is trend revision. Since the trend estimation changes gradually, trend revision is highly autocorrelated. Note that the interest rates depicted in first three rows of the panels (Czech, Polish and Hungarian interest rates) are detrended by a Hodrick-Prescott filter, whereas the euro area interest rate is detrended by a linear time trend.

¹⁷ Summary statistics of data revisions for the Czech economy are largely in line with Rusnák (2013), with the exception of *p*-values, where the author in Table 1 (p. 250) reports *p*-values even greater than one.

Figure 2 Final and Quasi Real-Time Data



Notes: The left-hand panels display final detrended data (black) and all vintages of quasi real-time data (gray). The right-hand panels display final detrended data (black) and quasi real-time data (gray), while both use the left axis. The difference between final detrended data and quasi real-time data is trend revision depicted with the errorbar that uses the right axis. *MAE* denotes the mean absolute error in trend revision.

Table 3 offers summary statistics for trend revisions. As has already been mentioned, all trend revisions are highly (first-order) autocorrelated. Over/under-

Table 3 Summary Statistics of Trend Revisions (final–quasi real-time data)

	<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>St. Dev.</i>	<i>RMSE</i>	<i>N/S</i>	<i>Corr</i>	<i>p-val</i>	<i>AR(1)</i>	<i>Rev+</i>
Interest rate										
Czech Rep. (HP)	-0.15	-1.49	1.21	0.68	0.70	0.44	0.91	0.39	0.98	0.57
Poland (HP)	-0.39	-2.16	0.63	0.86	0.95	0.43	0.91	0.08	0.98	0.50
Hungary (HP)	-0.14	-2.11	1.39	0.72	0.74	0.55	0.85	0.42	0.93	0.51
EA12 (linear)	0.06	-0.58	1.12	0.41	0.41	0.40	0.92	0.56	0.98	0.36

Notes: *Corr* is the correlation of final and quasi real-time data, *Rev+* denotes the frequency at which final data is greater than quasi real-time data. *HP* denotes the Hodrick-Prescott filter as a detrending method; *linear* denotes the linear time trend as a detrending method. For other notes, see *Table 2*.

Table 4 Summary of Model Parameters Relating to Domestic and Foreign Monetary Policy

<i>Par.</i>	<i>Description</i>
ψ_1	weight on inflation in domestic monetary rule
ψ_2	weight on output growth in domestic monetary rule
ψ_3	weight on nominal depreciation in domestic monetary rule
ψ_1^*	weight on inflation in foreign monetary rule
ψ_2^*	weight on output growth in foreign monetary rule
ρ_r	AR1 persistence in domestic monetary rule
ρ_r^*	AR1 persistence in foreign monetary rule

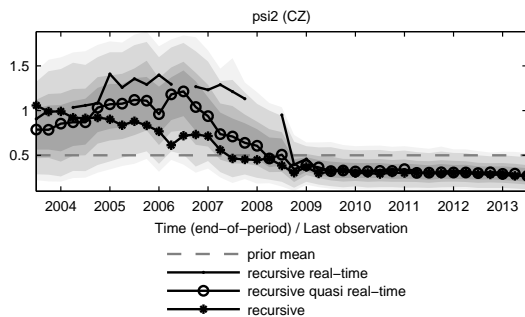
estimation of the final trend is roughly balanced for all economies except for the euro area, where quasi real-time data underestimate the final trend in 64% of periods. *p-val* for Poland is another result that stands out in *Table 3*. It is 0.08, which makes it the only biased revision in the whole study, i.e. the mean of the revision -0.39 is statistically different from zero at the 0.1 significance level.

4. Recursive Estimates of the Preferences of Monetary Authorities

4.1 Czech Republic

Figure 3 displays the evolution of recursive, recursive real-time and recursive quasi real-time estimates for the weight on output growth ψ_2 in the Czech Taylor rule. Probability bands are drawn around quasi real-time estimates and this depiction is therefore convenient for identification of deviations from quasi real-time estimates. The evolution of the estimates in time is different. Recursive estimates (on final data) gradually decrease, while recursive real-time estimates remain at parameter values over 1 and the estimate falls below 0.5 in 2008q3. Quasi real-time estimates are between the other two, which suggests that data revision and trend revision shift the estimate in the same direction. The fact that only real-time estimates do not gradually decrease indicates that the information of the change was not in the data

Figure 3 Recursive Estimates of the Weight on Output Growth ψ_2 in Domestic Taylor Rule, Czech Economy



Note: The depicted estimates are posterior modes with 95%, 90%, 68% and 50% Highest Posterior Density Intervals (HPDI) for recursive quasi real-time estimates.

earlier than 2008q3. The other two estimates contain the information due to subsequent revisions. The period 2008q3 matches the onset of the current economic crisis, which is—considering real-time conditions—unpredicted. Following the results for real-time data, the central bank did not change its reaction to output growth until 2008q3, when a drastic change occurred. On the other hand, following the results for quasi real-time and final data, the central bank gradually lowered its preference parameter towards output growth. This result suggests that conducting ex-post analysis of monetary policy on revised data indeed generates misleading results.

Table 5 presents significance values for various model alternatives in order to determine whether the difference between recursive real-time estimates and the remaining estimates is statistically significant.

Following the discussion related to parameter ψ_2 , we can see that the real-time vs. quasi real-time significance value is 0.06, thus being significant at the 10% level. Since the difference between real-time and quasi real-time estimates is only caused by data revision, the interpretation is that the nature of real-time data causes significantly different estimates of the preferences of the Czech central bank to output growth. However, the robustness of this result is limited. While it is robust to seasonal adjustment of CPI, the year-on-year specification in Taylor rules and the moving-window estimation, it is clearly not robust to the detrending method of GDP growth.

There are two more selectively significant results in Table 5. The weight on output growth ψ_2^* in the foreign Taylor rule is significantly different in *Trend revision*, which indicates that detrending is the reason. Moreover, the result is valid only for model variants where the central bank uses the year-on-year specification. A rather different story is behind the significant result for the smoothing term in the domestic Taylor rule ρ_r . The difference is only significant for the moving-window estimation, but since the results are under *Data revision*, the reason is the nature of real-time data itself, not the detrending issue. This significance occurs due to a lag in shifting between two regimes in the parameter ρ_r .

Table 5 Significance Values for Estimates on the Czech and Euro Area Economies

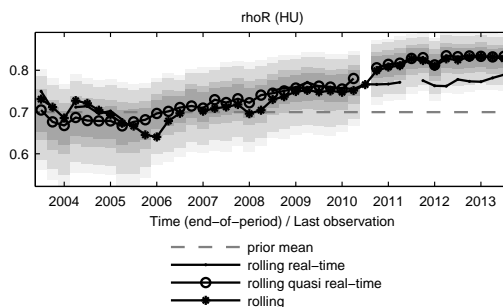
	Baseline	CPI not s.a.	GDP HP	Rolling	YOY	YOY+GDP HP
ψ_1 weight on inflation in domestic monetary rule						
Trend revision	0.86	0.89	0.77	0.23	0.82	0.84
Total revision	0.61	0.62	0.54	0.16	0.79	0.84
Data revision	0.56	0.62	0.55	0.36	0.77	0.84
ψ_2 weight on output growth in domestic monetary rule						
Trend revision	0.05**	0.32	0.73	0.06*	0.22	0.59
Total revision	0.01***	0.02**	0.73	0.01***	0.01***	0.38
Data revision	0.06*	0.06*	0.73	0.10*	0.02**	0.44
ψ_3 weight on nominal depreciation in domestic monetary rule						
Trend revision	0.75	0.79	0.81	0.71	0.80	0.89
Total revision	0.44	0.68	0.63	0.45	0.65	0.83
Data revision	0.58	0.70	0.63	0.42	0.70	0.85
ψ_1^* weight on inflation in foreign monetary rule						
Trend revision	0.61	0.68	0.70	0.55	0.33	0.26
Total revision	0.48	0.64	0.53	0.56	0.27	0.06*
Data revision	0.59	0.77	0.63	0.50	0.49	0.25
ψ_2^* weight on output growth in foreign monetary rule						
Trend revision	0.31	0.45	0.46	0.28	0.01***	0.03**
Total revision	0.47	0.42	0.23	0.35	0.04**	0.01***
Data revision	0.45	0.54	0.35	0.42	0.53	0.08*
ρ_r AR1 persistence in domestic monetary rule						
Trend revision	0.49	0.61	0.68	0.59	0.63	0.76
Total revision	0.29	0.46	0.54	0.01***	0.57	0.67
Data revision	0.60	0.61	0.71	0.01***	0.42	0.59
ρ_r^* AR1 persistence in foreign monetary rule						
Trend revision	0.58	0.62	0.53	0.51	0.15	0.34
Total revision	0.27	0.61	0.32	0.31	0.07*	0.30
Data revision	0.41	0.77	0.51	0.36	0.57	0.31

Notes: The numbers in the table are the lowest levels of significance at which the posterior mode is out of the Highest Posterior Density interval bands for the most different estimates. *Trend revision* relates to computation of significance values on recursive versus quasi real-time results; *Total revision* relates to recursive versus real-time results' and *Data revision* relates to quasi real-time versus real-time results. Values lower than or equal to 0.1 are denoted with a star, those lower than or equal to 0.05 with two stars, and those lower than or equal to 0.01 with three stars (due to the computational procedure, values in the table are rounded up).

4.2 Hungary

This subsection investigates the case of the small open economy of Hungary in interaction with the euro area. *Figure 4* depicts the evolution of the persistence in the domestic monetary rule ρ_r . *Figure 4* demonstrates a different course of rolling

Figure 4 Recursive Estimates of the AR1 Persistence in the Domestic Monetary Rule ρ_r , Hungarian Economy



Note: The depicted estimates are posterior modes with 95%, 90%, 68% and 50% Highest Posterior Density Intervals (HPDI) for recursive quasi real-time estimates.

the real-time estimate and two remaining rolling estimates. This observation suggests that real-time data do not favor the rise in the smoothing parameter as the revised data do. The central bank does not have sufficient grounds in real time to change its policy, but according to the revised data, it should have changed the policy.¹⁸

Table 6 indicates statistically significant results for parameter ψ_2 in a variety of estimated models and for parameters ψ_2^* , ρ_r and ρ_r^* only in the rolling estimation. Observing the results more closely, the significance values in the case of parameter ψ_2 seems to stem from the uninformativeness and bimodality of respective distributions, which indicates either a switch between parameter regimes or an artifact of poor data quality. As for the remaining three parameters with statistically significant results only for rolling estimates, the explanation for domestic and foreign smoothing parameters is the same and it is a preference of lower interest rate smoothing when real-time data are considered. Note that the distributions are rather informative and unimodal in these two cases; the results are therefore convincing. On the other hand, the results for parameter ψ_2^* stem from the bimodality of respective distributions. The different modes are major at different times and switching between the two creates significant results.

4.3 Poland

This section presents the results for a model with the domestic economy of Poland. Figure 5 displays the course of estimates of parameter ψ_2 . There is an apparent switch in the weight on output from the values close to prior distribution to the values three times larger. However, this regime switch occurs in different periods, which generates statistically significant results across all estimated model variants.

Similarly to the previous countries, Table 7 presents significance values of various estimates. The case of ψ_2 has already been discussed and there is no other economically interesting statistically significant result for the Polish economy.¹⁹

¹⁸ Note that the discussed result is significant only for the moving-window estimation, since in the recursive estimates the newly added information in the data is not strong enough to dilute the predominant information from the beginning of the sample.

¹⁹ The results for ψ_2^* are consequences of the bimodality of distributions.

Table 6 Significance Values for Estimates on the Hungarian and Euro Area Economies

	Baseline	CPI not s.a.	GDP HP	Rolling	YOY	YOY+ +GDP HP
ψ_1 weight on inflation in domestic monetary rule						
Trend revision	0.85	0.56	0.78	0.13	0.64	0.60
Total revision	0.42	0.68	0.49	0.37	0.79	0.47
Data revision	0.50	0.54	0.55	0.33	0.65	0.19
ψ_2 weight on output growth in domestic monetary rule						
Trend revision	0.01***	0.31	0.13	0.01***	0.01***	0.01***
Total revision	0.70	0.78	0.51	0.30	0.37	0.01***
Data revision	0.03**	0.40	0.67	0.04**	0.01***	0.01***
ψ_3 weight on nominal depreciation in domestic monetary rule						
Trend revision	0.67	0.71	0.72	0.67	0.79	0.85
Total revision	0.55	0.77	0.58	0.47	0.80	0.81
Data revision	0.61	0.79	0.61	0.54	0.80	0.82
ψ_1^* weight on inflation in foreign monetary rule						
Trend revision	0.66	0.62	0.65	0.65	0.25	0.44
Total revision	0.48	0.49	0.59	0.37	0.19	0.35
Data revision	0.62	0.71	0.64	0.25	0.63	0.76
ψ_2^* weight on output growth in foreign monetary rule						
Trend revision	0.19	0.20	0.35	0.02**	0.08*	0.03**
Total revision	0.16	0.19	0.11	0.01***	0.17	0.02**
Data revision	0.49	0.35	0.12	0.02**	0.48	0.07*
ρ_r AR1 persistence in domestic monetary rule						
Trend revision	0.44	0.58	0.50	0.32	0.47	0.20
Total revision	0.63	0.68	0.58	0.07*	0.62	0.29
Data revision	0.35	0.76	0.50	0.04**	0.49	0.09*
ρ_r^* AR1 persistence in foreign monetary rule						
Trend revision	0.42	0.67	0.41	0.34	0.15	0.32
Total revision	0.51	0.54	0.22	0.03**	0.21	0.29
Data revision	0.56	0.68	0.46	0.04**	0.72	0.22

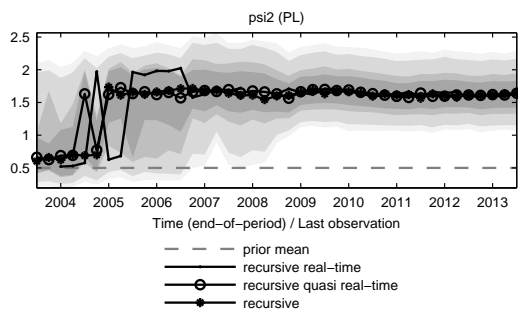
Note: See Table 5 below.

Table 7 Significance Values for Estimates on the Polish and Euro Area Economies

	Baseline	CPI not s.a.	GDP HP	Rolling	YOY	YOY+ +GDP HP
ψ_1 weight on inflation in domestic monetary rule						
Trend revision	0.52	0.41	0.59	0.62	0.72	0.71
Total revision	0.37	0.31	0.36	0.18	0.76	0.73
Data revision	0.43	0.32	0.15	0.20	0.72	0.73
ψ_2 weight on output growth in domestic monetary rule						
Trend revision	0.74	0.68	0.72	0.20	0.11	0.18
Total revision	0.01***	0.03**	0.01***	0.04**	0.09*	0.02**
Data revision	0.01***	0.05**	0.01***	0.03**	0.09*	0.02**
ψ_3 weight on nominal depreciation in domestic monetary rule						
Trend revision	0.70	0.66	0.70	0.65	0.75	0.87
Total revision	0.68	0.57	0.60	0.44	0.53	0.77
Data revision	0.68	0.58	0.65	0.51	0.54	0.83
ψ_1^* weight on inflation in foreign monetary rule						
Trend revision	0.73	0.67	0.48	0.70	0.17	0.42
Total revision	0.65	0.69	0.46	0.53	0.32	0.43
Data revision	0.79	0.70	0.62	0.49	0.50	0.79
ψ_2^* weight on output growth in foreign monetary rule						
Trend revision	0.37	0.30	0.51	0.47	0.03**	0.27
Total revision	0.39	0.24	0.40	0.45	0.02**	0.24
Data revision	0.40	0.27	0.69	0.44	0.01***	0.58
ρ_r AR1 persistence in domestic monetary rule						
Trend revision	0.69	0.75	0.60	0.61	0.44	0.63
Total revision	0.62	0.64	0.49	0.23	0.35	0.30
Data revision	0.61	0.71	0.53	0.16	0.50	0.28
ρ_r^* AR1 persistence in foreign monetary rule						
Trend revision	0.60	0.64	0.45	0.52	0.22	0.21
Total revision	0.33	0.35	0.22	0.33	0.21	0.07*
Data revision	0.51	0.44	0.56	0.50	0.77	0.09*

Note: See Table 5 below.

Figure 5 Recursive Estimates of the Weight on Output Growth ψ_2 in Domestic Taylor Rule, Polish Economy



Notes: The depicted estimates are posterior modes with 95%, 90%, 68% and 50% Highest Posterior Density Intervals (HPDI) for recursive quasi real-time estimates.

5. Conclusion

The goal of this paper is to investigate the differences between parameter estimates of monetary policy reaction functions using real-time data and those using revised data. Because such analysis uses real-time datasets, this paper also offers an analysis of real-time macroeconomic data, data revision and trend revision in the Czech Republic, Poland, Hungary and the euro area.

Data revisions of GDP growth and inflation are unbiased and not auto-correlated in all countries. Inflation is usually measured accurately in real time. Its noise-to-signal ratio ranges from 0.19 in Poland to a surprising 0.40 in the euro area. GDP growth is generally subject to greater data revision, with a noise-to-signal ratio ranging from 0.29 in the euro area to 0.52 in Poland.

Trend revisions are calculated with a linear time trend in the euro area and using the Hodrick-Prescott filter in the remaining countries. As was expected, trend revisions are highly autocorrelated and unbiased; the only exception to this is in Poland, where trend revision is biased. The noise-to-signal ratios are similar in value and range from 0.40 in the euro area to 0.55 in Hungary.

In its main analysis, this paper has revealed many statistically significant differences between parameter estimates of monetary policy reaction functions calculated using real-time data and those calculated using revised data. However, only a few of these results are robust enough to conclude that monetary authorities' preferences are different when considering real-time data as opposed to final data. The difference between estimates for the preference for output growth is the most common statistically significant result across countries. In other words, the monetary policy reaction to changes in output growth is statistically significantly different in strength when based only on the data available at the time of the monetary policy decision rather than on revised data. This result is in line with expectations, since the statistics for output growth data revision indicate that it is much more pronounced than inflation revision. Although several more differences were ascertained, only a few of them are adequately robust to different model specifications.

The results achieved raise several questions. Since the statistical offices in the Visegrád Four countries are rather young, would the results of such an analysis

for developed countries in Western Europe be different? Also, if there are differences in policy parameters, are there also differences in other model parameters (possibly even deep parameters)? These questions could be a possible focus of further research.

REFERENCES

- Aruoba SB (2008): Data Revisions Are Not Well Behaved. *Journal of Money, Credit and Banking*, 40:319–340.
- Aurelio MM (2005): Do we really know how inflation targeters set interest rates? *FRB Kansas City Working Papers*, no. 05-02.
- Belke A, Klose J (2011): Does the ECB Rely on a Taylor Rule During the Financial Crisis? Comparing Ex-post and Real Time Data with Real Time Forecasts. *Economic Analysis & Policy*, 41:147–172.
- Brooks SP, Gelman A (1998): General Methods for Monitoring Convergence of Iterative Simulations. (American Statistical Association, Institute of Mathematical Statistics, and Interface Foundation of America) *Journal of Computational and Graphical Statistics*, 7:434–455.
- Čapek, J (2015): Estimating DSGE model parameters in a small open economy: Do real-time data matter? *Národohospodářský obzor-Review of Economic Perspectives*, forthcoming. (DOI: 10.1515/revecp-2015-0001)
- Casares M, Vázquez J (2012): Data Revisions in the Estimation of DSGE models. *University of the Basque Country, Dpt. of Foundations of Economic Analysis II (DFAEII)*, Series/Report no. 2012.06 (<http://hdl.handle.net/10810/8759>).
- Cogley T, Sbordone AM (2005): A search for a structural Phillips curve. FRB of New York, Research Paper Staff Report, no. 203.
- Croushore D (2011): Frontiers of Real-Time Data Analysis. *Journal of Economic Literature*, 49:72–100.
- Cusinato R, Minella A, Silva Pôrto (Jr.) S da (2013): Output gap in Brazil: A real-time data analysis. *Empirical Economics*, 44:1113–1127.
- Gerberding C, Seitz F, Worms A (2005): How the Bundesbank really conducted monetary policy. *North American Journal of Economics and Finance*, 16:277–292.
- Gerdesmeier D, Roffia B (2005): The relevance of real-time data in estimating reaction functions for the euro area. *North American Journal of Economics and Finance*. 16(3):293–307.
- Horváth R (2009): The time-varying policy neutral rate in real-time: A predictor for future inflation? *Economic Modelling*, 26:71–81.
- Ince O, Papell D (2013): The (un)reliability of real-time output gap estimates with revised data. *Economic Modelling*, 33:713–721.
- Lubik T, Schorfheide F (2006): A Bayesian Look at the New Open Economy Macroeconomics. *NBER Macroeconomics Annual 2005* (vol. 20):313–382.
- Maravall A, Pierce D (1986): The transmission of data noise into policy noise in US monetary control. *Econometrica*, 54:961–979.
- Marcellino M, Musso A (2011): The reliability of real-time estimates of the euro area output gap. *Economic Modelling*, 28:1842–1856.
- Neri S, Ropele T (2012): Imperfect Information, Real-Time Data and Monetary Policy in the Euro Area. *The Economic Journal*, 122(561):651–674.
- Orphanides A (2001): Monetary Policy Rules Based on Real-Time Data. *American Economic Review*, 91:964–985.
- Orphanides A, Norden S van (2002): The Unreliability of Output-Gap Estimates in Real Time. *Review of Economics and Statistics*, 84:569–583.

Pivetta F, Reis R (2007): The persistence of inflation in the United States. *Journal of Economic Dynamics and Control*, 31:1326–1358.

Rusnák M (2013): Revisions to the Czech National Accounts: Properties and Predictability. *Finance a úvěr-Czech Journal of Economics and Finance*, 63:244–261.

Schorfheide F (2008): Comment on "How Structural Are Structural Parameters?" *NBER Macroeconomics Annual 2007* (vol. 22):149–163.

Vázquez J, María-Dolores R, Londoño J (2010): *Data Revisions and the Monetary Policy Rule: An analysis based on an extension of the basic New Keynesian model*. The University of the Basque Country. Mimeo, available at:

http://www.ehu.es/jesusvazquez/note_v12.pdf or http://www.ehu.es/jesusvazquez/VML_OBES.pdf.