**Economics Doctoral School**

# COLLECTION OF THESES

**of**

## Péter Bauer

## Essays on Inflation

Ph.D. dissertation

**Supervisor:**

**János Vincze, Ph.D**
Associate Professor

Budapest, 2012

**Mathematical Economics and Economic Analysis Department**

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# Contents

# 1. Motivation and summary of the thesis

The thesis consists of four independent papers. Their topics are connected to the effect that each are associated to the understanding of inflation and the analysis of pricing behavior.

After the first, introductory chapter, the second chapter presents the study of micro-level pricing behavior. For this we use Hungarian data for shop-level, individual product prices. (This chapter is an edited version of Bauer [2008].). The analysis is basically of a descriptive nature, it tries to explore what regularities can be observed related to the changes of prices, and how frequently prices changes in Hungary at all.

Its importance is on the one hand that the effect of monetary policy and the modeling of this effect strongly depend on the behavior of price changes. On the other hand to understand inflation is also a reasonable goal for its own sake, and the analysis of micro level price developments can be helpful for it as consumer price index is an aggregation of these micro price data.

The main conclusion of the chapter is that Hungarian prices were significantly rigid in the sample period in a moderate inflation environment, and out of the well-known pricing models the features of menu-cost models fit best with our empirical results.

The third chapter is closely connected to the second one, as we write down a semi-structural pricing model and estimate it based on data that was also used in the second chapter. We try to estimate the menu-cost and based on the results we can revisit some conclusion from the previous chapter. These results that come from a formal model confirm the statements that were made in the second chapter.

After micro level analysis, in the fourth chapter we study inflation on a more aggregated level. We examine the persistency of services' (nontraded) and manufactured goods' (traded) inflation from different viewpoints. (This chapter is an edited version of Bauer-Gábriel [2009].). We look for answers to the question that which factors caused the stable and high level of Hungarian service inflation that could be observed from 2005 to the middle of 2008.

During the analysis we compare results for the nontraded to features of the traded inflation and evaluate our findings in international context. Based on our analysis, main features of price and wage setting in the two sectors turned out to be similar. The factors that had an impact on nontraded inflation would have make significant volatility into nontraded inflation individually, but these shocks appeared in such a way that their effect jointly resulted in stable inflation.

In the fifth chapter we try to construct an indicator that captures the underlying developments in inflation. In essence, we filter out the effect of temporary, extreme movements in inflation by systematic ways to get an indicator that reflects the trend in inflation.

We apply methods on Hungarian data that were approved in the international literature, and we analyze the effect of revision resulting from seasonal adjustment on our findings. A novelty of our work that we apply dynamic factor model on Hungarian data to construct an underlying inflation indicator, this method is relatively new in even the international literature.

# 2. Methods that were applied in the thesis

We review methods separately for chapters.

## 2. 1. Analysis of price rigidity based on micro data

In this chapter we show stylized facts characterizing the rigidity of prices and more generally the features of pricing in Hungary. We use mainly descriptive statistics for it.

To do this we use unpublished, monthly observed shop-level price data that are used for the calculation of the consumer price index by the Hungarian CSO. We use only a subset of the consumer basket, these are food items. Findings are compared to similar results of the international literature.

Since in the essay we make micro level studies so we work with the notion of price rigidity used usually in micro level analysis. Thus we define price rigidity as the phenomenon that a given shop does not change the price of a given product for some periods.

We examine the following:

- measures of price rigidity
- average size of a price change
- whether the probability of a price change constant or variable in time
- synchronization of price changes between and within shops
- relation between frequency and size of price changes
- the number of periods since the last price change and the probability of a price change

- the number of periods since the last price change and the size of a price change
- relative prices

## 2. 2. A semi-structural pricing model

In this chapter we estimate the parameters of a simple semi-structural econometric model based on the (S,s) pricing model. The goal of this analysis is to get an estimate for the menu-cost, or more precisely for the size of the S and s thresholds.

A modell megbecslése egy nemlineáris panel-modell becslését jelenti, amely maximum-likelihood módszerrel történik. A becslési eredményeket összehasonlítjuk Dhyne et al. [2006] eredményeivel.

Estimating the model means that we estimate a nonlinear panel model. This is done by the maximum-likelihood method. We compare the results with Dhyne et al [2006].

## 2. 3. Persistency of inflation in the traded and nontraded sector

The causes of the change of the price level can be more accurately understood if inflation processes are analyzed not only at an aggregated level but rather at sectoral level. In this chapter we overview the main features of the market services and manufacturing sectors from a point of view that is relevant for price developments. We also examine the possible differences between sectors.

We analyze the following:

- The factors that determine the inflation of traded and nontraded goods in the Balassa-Samuelson framework.
- Persistency of traded and nontraded inflation in the countries of the region
- Frequency of price changes of market services and manufactured goods
- Persistency of wages in the traded and nontraded sectors
- Features of disinflationary periods in the region

After that, we decompose the traded and nontraded inflation by several methods to show which factors could have made the difference.

- Simple grouping of the items in the traded and nontraded basket. For the nontraded, they are grouped to food-intensive, fuel-intensive and other. For the traded, they are grouped to durable and nondurable goods.
- Decomposition into cost-factors. For this we use a cost-based inflation forecasting model.
- Decomposition into factors using principal component analysis.

## 2. 4. Underlying inflation indicators

The main goals of the chapter:

- overall analysis of the underlying indicators on Hungarian data, that is consistent with international practices (using seasonally adjusted, short-based indices)
- using a dynamic factor model to construct an underlying indicator on Hungarian data

- considering explicitly the revision arising from seasonal adjustment when evaluating the indicators – as far as we know this is a novelty even in an international context

In the chapter we collect the standard indicators used in the international literature, we elaborate some evaluation criteria, then we evaluate the indicators according to the criteria.

The evaluation critera we used are:

- smoothness
- short-term forecasting ability
- low revision

We paid particular attention to use always real time data that is we solve the problem of revision.

# 3. Results

We review results separately for chapters.

## 3. 1. Analysis of price rigidity based on micro data

For the analysis we used shop-level data that the Hungarian CSO uses for the construction. We used data only for some items. These are dairy products and various bakery products, we worked with a total of 46 items. Apart from descriptive analysis we tried to evaluate the results against the background that these results are consistent with time dependent or rather with state dependent pricing models.

For time dependent models the timing of price changes is exogenous. The two well-known models are Taylor [1980] and Calvo [1983]. In Taylor's model every shop can change the price of a product with the same frequency and at regular periods. In Calvo's pricing model the probability of price changes is fixed (but do not happen in regular periods).

For state dependent models timing of price changes is endogenous. Among them the mostly known are menu-cost models where there is a fixed cost of changing prices that is independent from the size of the price change.

A specific menu-cost model is the so-called (S,s) pricing model where price changes take place when the difference between the actual and the optimal price reach a certain threshold. Optimal price means the price that would maximize profit if price changes would not incur a cost.

We got the following empirical results:

1. We first examined the measures of price rigidity. Basically there are two different measures that characterize price rigidity: the frequency of price changes and the duration of unchaged prices. The simpler measure is the frequency of price changes. We got the results from our data that the monthly frequency of price changes is 24.7 percent. Filtering out price changes due to sales we got 22.2 percent.
2. In international comparison we can say that the frequency of price changes that we got for Hungarian data is higher than in the euro area while is close to the figure for the United States. Namely, in the euro area the average frequency of price changing for the processed food is 13.7 percent monthly (Dhyne et al. [2005]), while in the US for food items it is 25.3 percent.
3. The other type of measure of price rigidity is the duration of unchanged prices. The newly changed prices have a duration of 3.8 months. In the case when the expected duration of unchanged prices differs significantly between products, then the duration of new prices is not a proper way to show the extent of price rigidity. This is because the products with longer unchanged price periods take part in the average with fewer spells. To avoid this problem we get a better measure of rigidity if the spells are averaged weighted with their own length (or duration). Following this method we got 8.1 month as a measure of price rigidity.

4. 62 percent of the price changes are price increases while 38 percent are price decreases. That means that there are half as much more increases than decreases.
5. Relative frequency of price increases and decreases are similar in Hungary to the euro area and to the United States: 40 and 45 percent of the price changes are decreases, respectively (Dhyne et al. [2005], Klenow-Kryvstov [2005]).
6. Prices that increase, increase by 12.1 percent on average in a month. Prices that decrease, decrease by 11.8 percent on average.
7. These numbers are representative in an international context: in the euro area 8 and 10 percent is the size of the price increase and the price decrease on average, respectively (Dhyne et al. [2005]), while for the United States Klenow-Kryvtsov [2005] show the average absolute value of price changes which is 13 percent.
8. That means individual prices (same shop, same product) relatively rarely change, but if they change then the size of change is significant.
9. Very small price changes exist but are relatively rare. More precisely: 95 percent of price increases were bigger than 1.5 percent, and 95 percent of price decreases were bigger (in absolute value) than 1.5 percent. Small price decreases are especially rare.
10. The existence of small price changes at all, is inconsistent with (S,s) pricing model as smaller price changes than a certain threshold cannot happen in the model (in turn, too small threshold does not generate the observed price rigidity). Problem can be solved with a version of (S,s) model where menu-cost is time-variable.
11. The standard deviation of the frequency of price changes between months is 8.2 percentage point. This is almost the same as the standard deviation of the

frequency of price changes between *products*. This could mean that heterogeneity between periods is similarly important as heterogeneity between products. So probability of a price change cannot be considered constant in time, contrary to the conclusion from the basic models of Taylor [1980] and Calvo [1983]. At the same time, time-dependency of price changes cannot be ruled out completely as seasonality can be observed in the time series of the frequency of price changes.

12. Synchronization of price changes between shops is on a low level. Synchronization within shops also can be rejected. This staggered price changes is always consistent with time dependent models, and is usually consistent with menu-cost models (if there is some heterogeneity).
13. More frequent price increases are coupled with smaller size of these increases while more frequent price decreases accompany smaller size of these decreases (in absolute value). This result can be consistent with Calvo and (S,s) pricing models as well.
14. The probability of price changes is negatively depend on the duration of unchanged prices, that is the so-called hazard function is decreasing, and this is not entirely explainable by heterogeneity. This means prices that are unchanged for a longer period of time, the probability of a change is lower. This cannot be explained by any simple theoretical model. However decreasing hazard can be a result of a heterogeneous Calvo-pricing where different products have different probability of price changing. But even if we control for heterogeneity there is some evidence for decreasing hazards. Campbell and Eden [2006] argue that decreasing hazards mean that for some of the prices that were changed recently,

the shop could not set it properly. The shop quickly discovers it and changes the price again. In turn if a price was set properly then it remains unchanged for a longer period.

15. The time elapsed since the last price change does not correlate positively with the size of the price change when it finally takes place. This contradicts the conclusion of the Calvo model.
16. According to menu-cost models a high relative price (in absolute value) has a high probability of change. We could show that based on our data, furthermore the probability of price change is asymmetric consistently with the (moderately) positive inflation.
17. Relative prices with higher absolute value are coupled with bigger price changes: price increase for a negative relative price and price decrease for a positive relative price. For relative prices with zero value the size of price changes is zero on average. However the size of price changes are smaller than needed for the new relative price to be zero.

## 3. 2. A semi-structural pricing model

In this chapter we estimate a simple semi-structural econometric model based on the (S,s) pricing model. The goal of the analysis to get an estimate for the menu-cost, or more precisely for the thresholds in the (S,s) model. Another goal is to separate the price changing decision from the factors that affect the “optimal” price.

The model is the following:

$$p^*_{st} = a^{time}_t + a^{shop}_s + x'_{st}\beta + \varepsilon_{st}$$

$$p_{st} = p_{st-1}\text{, if } | p^*_{st} - p_{st-1} | \leq c_{st}$$

$$p_{st} = p^*_{st}\text{, otherwise.}$$

where

$p_{st}$ is the price observed in the shop *s* in the time period *t*,

$p^*_{st}$ is the optimal frictionless price in the s shop in the t time period (unobservable),

$a^{time}_t$ is the fixed-effect on the optimal price between shops (in time *t*)

$a^{shop}_s$ is the fixed-effect on the optimal price between time periods (in the shop *s*)

$x_{st}$ are various explanatory variables that have an impact on the optimal price

$\varepsilon_{st}$ is the unobserved heterogeneity that changes between periods and shops (idiosyncratic shocks)

$c_{st}$ defines the interval where there are not price changes. This can vary in time and by shops.

Distributional assumptions:

$$\varepsilon_{st} \sim i.i.d.N(0, \sigma^2_\varepsilon)$$

$$c_{st} \sim i.i.d.N(c_0, \sigma^2_c)$$

The parameters of the above model are estimated using maximum likelihood estimation. The estimations are performed separately by products. The likelihood function is the following:

$$L(\mathbf{a}^{time}, \mathbf{a}^{shop}, \sigma_\varepsilon, c_0, \sigma_c) = \prod_s P(\mathbf{p}_s \mid \mathbf{a}^{time}, \mathbf{a}^{shop}, \sigma_\varepsilon, c_0, \sigma_c),$$ and

$$P(\mathbf{p}_s \mid \mathbf{a}^{time}, \mathbf{a}^{shop}, \sigma_\varepsilon, c_0, \sigma_c) = P(p_{s1} \mid p_{s0}) P(p_{s2} \mid p_{s0}, p_{s1}) \cdots P(p_{sT} \mid p_{s0}, p_{s1}, \ldots p_{s,T-1}) P(p_{s0})$$

where the conditional probabilities are also conditioned on the estimated parameters (without notation).

The MLE was performed for 10 selected products.

We got the following results:

1. The more frequent price changing is accompanied with lower menu-cost ( $c_0$ ).
2. We got a negative but not significant correlation between the frequency of price change and the volatility of the estimated common factor ( $a_t^{time}$ ).
3. The time-series of the common factor usually follows the time-series of the average prices but it is more volatile.

In the second chapter the optimal price was approximated by a specially performed averaging (that was called normalization). Now we know the common factors and we can calculate with an optimal price produced by another way: using the common factor and the shop fixed-effects we can estimate the latent optimal price. The results are in line with the conclusion from the second chapter:

4. Higher relative prices (in absolute value) have a higher probability to change.
5. Probability of price changing grows more slowly to the positive side.
6. There is significant probability of price change even if the relative price is zero or close to zero.
7. This significant probability of price change can be explained by shop-specific time-variant shocks (idiosyncratic shocks)
8. The size and sign of price changes are consistent with the conlusions from menu-cost models: negative relative prices tend to increase, positive relative prices tend to decrease; relative prices with a larger absolute value tend to

change by a larger value; average size of price changes assure that the new price will be close to the optimal price.

## 3. 3. Inflation persistence in the traded and nontraded sector

It is typical for most catching-up countries that the levels and sometimes the dynamics of inflation for services and manufactured goods are significantly different. Therefore to understand properly the factors behind changes in the price level it is helpful if inflationary processes are analyzed not only on an aggregated level but on sectoral level, too.

In the chapter we overview the in Hungary what the main features of market services and manufactured goods sector in the point of view of price developments, and what can cause the difference between sectors. We show that the price and wage setting characterizing the sectors does not imply significantly different inflation persistence in the two sectors. It is seemingly contradicted by the fact that from 2004 until mid 2008 nontraded inflation was surprisingly stable despite of several supply and demand shocks that impacted the sector.

First, we analyzed the long-term development of the traded and nontraded inflation in Hungary in the framework of the Balassa-Samuelson mechanism.

In the framework of Balassa-Samuelson the nontraded inflation determined relatively to the traded sector inflation. The mechanism is based on the assumption of wage equalization between the two sectors. If wages in the two sectors grow by an equal rate then nontraded inflation corresponds to the sum of the traded inflation and the productivity growth differential between the two sectors.

However based on the research of the recent years we cannot say that the size of the Balassa-Samuelson effect is greater for all the catching-up countries than for the developed countries.

We got the following empirical results:

1. For the EU countries we compare the productivity growth differential between the traded and the nontraded sector and the differential in inflation for the period between 1996 and 2006. For most countries the explanatory power of productivity differential is weak for the inflation differential. It is interesting that for Hungary productivity differential explains well the observed inflation differential.

Beside of the question of longer-term development of inflation it is also important to examine the dynamics of inflation in the two sectors. We characterize the persistence of traded and nontraded inflation by fit an AR(1) model on the time-series, and the coefficient of the autoregressive term  shows the strength of persistence.

2. Based on the results, on the full and on a shorter sample, we cannot say that the Hungarian nontraded inflation would be more persistent than the traded inflation, on the contrary, and it proves to be true for international data, too. We also cannot say that these persistence numbers would be huge compared to countries in the region. It is true, however, that persistence is higher than in the euro area.

Stickiness of market services inflation and manufactured goods inflation can also be characterized by the volatility of the time series. To examine this, we filtered the trend out of the time series (using HP filter) and we calculated the standard deviation of monthly and quarterly changes.

3. For the full sample that we analyzed (1997-2009) Hungarian nontraded inflation is somewhat more volatile than traded inflation, but between 2004-2008 traded inflation has a standard deviation which is 30 percent larger than for nontraded inflation. In international comparison we cannot say a robust statement about the relative volatility of inflation in the two sectors, but the average standard deviaton (for EU-27 and EA-15 groups) is larger for nontraded than traded inflation.
4. Analyzing micro data show a somewhat different picture about the flexibility of traded and nontraded prices. Studies on the CPI database (monthly collected, individual prices in different shops) showed that among sectors the prices of the nontraded sector changes the most rarely. However difference compared to the traded goods is not significant and most of the products' prices are changed at least once a year in the nontraded sector, too.

One of the causes of inflation persistence can be the persistence of wages. This can be more important for the service sector as the proportion of wage cost is very high in total cost.

5. Examining the time series on macro level there were not any notable differences between the sectors, and wages in the nontraded and traded sector were not only similar in persistence but typically they moved together closely (apart from the last period that begins in 2008).

Factors that determine the wage developments in the nontraded and traded sectors do not differ significantly between the two sectors:

6. First, among institutional factors we can mention the regulation of minimum wages that the most significant obstacle of the adjustment of wages in Hungary. The number of employees that are affected by this regulation are somewhat higher in the service sector than in the manufacturing sector. According to the survey "Bértarifa" in 2006 in manufacturing 10.1 and in market services 15 percent of full-time employees' monthly average wages were close to the minimum wage.
7. Trade union coverage is low in both sectors. The wage negotiations happen on firm level both in the manufacturing and in services. This helps to adjust to idiosyncratic shocks.
8. The proportion of flexible wage components to the total wage is similar in both sectors. Flexible wage components usually help to adjust to short-term shocks.
9. Frequency of wage setting is also similar in the two sectors.
10. Wage adjustment can be easier if fluctuation is higher in a sector. Empirical results show that the wage setting for newly hired employees is an important option to adjust for the firms. However significant differences are not present in this regard between the traded and nontraded sector.

Potential asymmetries in the price adjustments of the different sectors can appear more pronounced in periods when the economy is hit by larger-than-average shocks:

11. Regional disinflationary experiences show that inflation persistence does not differ considerably in the traded and the nontraded sector. However when

disinflation was primarily caused by the strengthening of the exchange rate then nontraded inflation typically lagged behind the decrease in traded inflation.

In Hungary market services inflation showed a surprising stability through a longer period: between 2004 and mid 2008. We argue in the following that this observed stability was due to the fact that the effects of the shocks that hit the sector were at opposite direction. To demonstrate this, we decompose the sectoral inflation time series in several ways.

12. First, we regrouped the items in the market services and manufactured goods groups into subcategories. For nontraded, CPI items can be grouped to oil-intensive (taxi, trucking), to food-intensive (food at restaurants, food at workplace, buffet, espresso coffee) and to the "other" categories. While the inflation of the first two categories was significantly volatile, the inflation of the "other" category was stable around a 6 percent level.
13. Traded goods can be traditionally categorize into durable and nondurable groups. Understanding the dynamics of traded inflation, however this grouping does not help too much as the inflation of the two subgroups are strongly correlated. At the same time it is worth to notice this strong co-movement of the two categories and the inflation differential which was quite stable on the long-run.
14. We examined also the decomposition of traded and nontraded inflation with a cost-based inflation forecasting model. We decomposed nontraded inflation into the inflationary impacts of different cost-factors. It is important to highlight the effect of the unit labor cost and energy cost among other costs. The contribution of these two factors was significantly time-variant. Based on the model

decomposition we can say that the individual factors developed in such a way that jointly their effect resulted a stable nontraded inflation around 6 percent despite individual effects were quite volatile in time. We also decomposed traded inflation in the same way to compare with the results for nontraded inflation. We can state that albeit the effect of the cost-factors are different in the two decompositions but volatility of the effect of cost-factors are significant in both sectors.

For the analysis of traded and nontraded inflation principal component analysis is another tool. The essence of the method is to use only statistical tools looking for components that explain the largest possible variance in the items time-series. For this exercise we used the 26 items in nontraded sector and the 48 items in traded sector. We used year-on-year inflation.

15. The first principal component explains 53 percent of the variance of the items in nontraded sector. Basically it is correlated with all items positively and strongly. For this reason we can consider the first principal component as a kind of underlying inflation process.
16. Other principal components with significant explanatory power have a feature that they were volatile during the period, and with half of the items the correlation is positive, with half of the items the correlation is negative. This means that these components explain the difference in dynamics between items.
17. Special attention is paid to the third most important component which is correlated with retail trade sales, thus it can show the effect of aggregate demand on nontraded prices.

18. The first principal component explains 49 percent of the variance of the items in the traded sector. As for nontraded, it is also true for traded sector that most of the items are strongly and positively correlated with the first principal component. So the first principal component in this case can also be understood as an average inflation tendency for traded sector.
19. For the other principal components we can say also in the case of traded sector, that they explain heterogeneity in the inflation of different items within the sector, and they were volatile in time. The fourth principal component co-moves with the HUF exchange rate changes. Also can be observed that exchange rate changes shows their effect in prices with a couple of quarters lag.
20. Based on the principal component analysis we can say that the nontraded category is somewhat more homogenous than the traded one. The difference however is not significant; the first principal component explains half of the variance in both categories.
21. A résztételek inflációját magyarázó főkomponensek többsége a vizsgált időszakban számottevően ingadozott, emiatt aggregált szinten sem valószínűsíthető túlzott perzisztencia. Most of the principal components that explain the inflation of the items were considerably volatile in the analyzed sample, so on an aggregate level is also not probable that persistence was strong.

In sum, we can say that although nontraded inflation between 2004 and mid 2008 was unusually stable, but that cannot be explained by sector specific features. Decomposition of the nontraded inflation shows that individually shocks would resulted in a volatile nontraded inflation. However these shocks appear in such a way that jointly they caused a stable inflation.

## 3. 4. Underlying inflation indicators

For economic analysts who follow current economic processes it is an important task to analyze the development of inflation while it has essential importance for central banks. For this reason it is important to form a robust picture about inflationary processes and take an interest in indicators that can show the underlying inflation and support inflation forecasting.

The goal of the chapter is doing an overall analysis of underlying indicators on Hungarian data that is in line with international practices (using seasonally adjusted, short-based indices). It is a novelty that we use a dynamic factor model on Hungarian data to construct an underlying indicator. We explicitly consider the revision arising from seasonal adjustment, as far as we know it is new even in an international context.

We think that the methodology introduced in the chapter can be useful in other areas, where it is important to uncover underlying processes of aggregate variables.

In this chapter we base our methods on usual practices of central banks. In the practices of central banks indicators are called underlying inflation (or core inflation) indicators that temporary effects, outliers are filtered out from with various methods. Such effects are for example tax changes, products or services with volatile inflation. These indicators are expected to be forward looking, that is they should have short-term forecasting ability.

We categorize the indicators into the following groups:

- *Case-by-case filtered indicators*. It can be applied when it is known that an outlier impacts inflation in an exact time period and its effect is also roughly known.
- *"Ex-food and energy" type indices*. Some fixed, volatile items are excluded from the consumer price index.
- *Limited influence estimator*. Among the items in the consumer basket we exclude the most extreme ones in every time period. So the most important difference compared to the "ex-food and energy" that the excluded items can change from period to period. Such indicators are the trimmed mean, median, weighted median. The logic behind the method is that it is a meaningful way to filter out outliers in every time period.
- *Changing the weights*. The method calculates the weighted average of items in the consumer basket not with traditional, consumption weights, instead it uses other weights. The most popular method multiplies the original weight with the reciprocal of the standard deviation of the item. Using these weights to construct the index is the so-called Edgeworth-type index. The idea is that items with more volatile inflation get a smaller, items with more stable inflation get a larger weight than the original weights.
- *Time series methods.* The moving-averages and various one-variable trend-filtering methods like the Hodrick-Prescott (HP) filter are in this category.
- *Using cross-sectional and time series information together.* Dynamic factor models are in this category that get to be more and more popular.

Underlying inflation indicators are evaluated by some defined criteria. The following criteria were considered:

- Smoothness.
- Short-term forecasting ability
- Low revision

We analyzed the following indicators:

- *CORE_VAI*. The traditional underlying inflation of the MNB (the central bank of Hungary). This is the seasonally adjusted core inflation filtered from the effect of indirect tax changes, and usually calculated in month-on-month (or quarter-to-quarter). The core inflation is an "ex-food and energy" type index that excludes the unprocessed food, fuel, market energy, and regulated prices (that includes regulated energy prices such as town gas, district heating, electricity).

- *Trimmed mean*. Items (or more exactly their logarithmic changes) are sorted in every period (that is by cross-sections) separately by size, and some of the largest and smallest values are dropped from the weighted average. The amount that is to be dropped are determined by a fixed α (and β) number that shows how much should be sum of the weights of the dropped smallest (and largest) items.

- *Unweighted median.*
- *Weighted median.*
- *Edgeworth-weighted index.* The method is what we already wrote down above, that is the weighted average is calculated not with consumption weights but they are changed in the way that more volatile items get a smaller, more stable items get a larger weight.

- *HP trend.* We chose the Hodrick-Prescott filter as a time-series method, and the trend we got with HP is the underlying indicator to be analyzed.

- *Dynamic factor model.* This is a method based on the dynamic factor decomposition of Cristadoro et al. [2002]. The idea of the method is to get the common factors of the CPI items and approximate CPI with them. In this way the individual shocks that impact only on a few items are filtered out. The model is called dynamic because lags of the factors are also considered not just contemporaneous values (as in the static factor model). So cross-sectional and time series information are also used in the model.

Apart from CORE_VAI, every indicator is constructed from seasonally adjusted price index of items from the consumer basket.

We got the following results:

1. First we examined the smoothness of the indicators. We calculate this with two different measures: standard deviation and autocorrelation. Based on standard deviation the three best indicators are the dynamic factor model, the median and the trimmed mean (these have the lowest standard deviation). The problem with it is that smoothness is usually meant as the lack of high frequency volatility, while standard deviation includes low frequency, long-run waves. For this reason size of autocorrelation seems to be a better criterium. Based on it the three best underlying indicators are the HP trend, the dynamic factor model and the Edgeworth index. Their smoothness is less than the smoothness of the year-on-year headline inflation (according to autocorrelation).
2. After that we analyzed the revision property. That shows how much the indicators change retrospectively as the new data comes. The indicators that use exclusively cross-sectional information (all apart from HP trend and dynamic factor model) could be revised only because of seasonal adjustment. We took

into account how the revised numbers fluctuated across the full time interval (average standard deviation of revision) and what the difference is between the first and last revised numbers for a certain period (average absolute total revision). The average standard deviation of revision is best for the Edgeworth index, the median and the trimmed mean. HP trend performed pronouncedly bad. Analyzing the average absolute total revision we can say that the best are the Edgeworth, the median and the trimmed mean. Largest is the total revision of the HP trend and the dynamic factor model, but the later is significantly lower.

Then we examined how much the indicators are forward looking in different ways: in sample (correlation with the inflation of the next 6 months), forecasting ability was evaluated and we looked at how they can forecast turning-points. Finally we analyzed their bias. In this context bias means that a simple graphical exercise – whether the indicator is under or above the current headline inflation – how strongly indicates that inflation will decrease or increase in the future.

In each analysis we took into account the problem of revision, this means that we worked with real time data. For example for the forecasting we calculated seasonally adjusted data based only on data known in the estimation sample.

We got the following results:

3. Analyzing correlation with inflation of the next 6 months we got that the dynamic factor model is the most forward looking indicator. The Edgeworth index and the trimmed mean also perform well. The CORE_VAI is not among

the best performing indicators, so based on this criterium, there are better underlying indicators than CORE_VAI.

4. We examined forecasting ability based on an autoregressive equation for inflation where the indicator was also an explanatory variable. According to our findings it is very hard to give better forecast than the pure autoregressive benchmark model which does not include the indicator. The starting point in time also influences the results (January 2000 or January 2002, because CORE_VAI and dynamic factor model could be evaluated only from 2002). We can say that on shorter forecast horizon than one year CORE_VAI performs well, however it seems to be robust that the Edgeworth index was among the best on every horizon and for both starting point. We can also conclude that HP trend and the dynamic factor model were the worst on shorter forecast horizons than one year, while they were the best on the one year horizon. We emphasize that the factor model was the only model (for the sample starting from January 2002) that could produce better forecast than the benchmark.
5. It is an important criterion evaluating the indicators, whether they can indicate the turning points in inflation. And if the answer is yes, how much earlier, than the year-on-year headline inflation. Since there are only a few turning points and the sample period is short, hence we evaluated the indicators based on "eye-balling" technique. We can say that all the indicators show the turning points and during these periods they co-moved. An exception could be the CORE_VAI. It seems in mid 2007 it overreacted the food and energy shock, while in the Autumn of 2008 it exaggerated the decrease in inflation relative to the other indicators.

6. Finally we analyzed the bias about the forward looking behavior of the indicators. This is because it is an appealing property of an underlying indicator if it give the path that the inflation will converge on the long run. So if it is higher than the yearly index of inflation in a period then inflation should increase in the future, and if underlying inflation is lower than inflation then inflation should decrease. This property gives an easy way to evaluate underlying processes, since it is enough to show the inflation and the underlying indicator on one figure. We found that HP trend and the dynamic factor model were more biased than the other indicators.

In sum we got the following findings:

- We found better underlying inflation indicators than the CORE_VAI according to more criteria.
- Edgeworth index is among the best indicators according to all the criteria.
- The indicator constructed by the dynamic factor model has a revision that is slightly high. Despite this, out-of-sample forecasting performance is outstanding on a one year horizon, and it is the most smooth time series after the HP trend. However it is biased in the sense that a higher (lower) value of it than inflation does not mean that inflation will increase (decrease).
- Using the HP trend as an underlying inflation indicator is not recommended because its revision property is bad, and it has a significant effect on the indicator's forward lookingness.
- The median, weighted median performed similar while the trimmed mean was slightly better if we take into account all the criteria.

- It is an important lesson that revision should be taken into account in the analysis as it can significantly change the results.
- If we want to get a robust picture about inflationary processes, maybe a minimum-maximum range of the indicators can be the best as it shows the uncertainty also. The range should not include HP trend and the dynamic factor model. The former proved to be a problematic underlying indicator, while the later has significantly different movements than the other indicators.

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