Measuring and Explaining Inflation Persistence: Disaggregate Evidence on the Czech Republic*

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Abstract: The paper provides an empirical analysis of inflation persistence in the Czech Republic using 413 detailed product-level consumer price indexes underlying the consumer basket over the period from 1994:M1 to 2005:M12. Subject to various sensitivity tests, our results suggest that raw goods and non-durables followed by services display smaller inflation persistence than durables and processed goods. Inflation seems to be somewhat less persistent after the adoption of inflation targeting in 1998. There is also evidence for the aggregation bias, that is aggregate inflation is found to be more persistent than the underlying detailed components. Product characteristics explain variation in the estimated inflation persistence to a certain extent. Inflation is more persistent in the Czech Republic than in Eurozone: we find that Czech inflation rates are integrated of order one, while for Eurozone relevant research suggests that inflation is fractionally integrated, i.e. follows a process of order between zero and one.

Keywords: inflation dynamics, persistence, inflation targeting
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1. Introduction

Sensitivity of aggregate inflation to various macro-economic disturbances has been traditionally in the focus of attention of monetary authorities. Indeed, the transmission of monetary policy actions to prices depends on a number of factors, including *inter alia* the degree of nominal rigidities. Consequently, in the last 20 years or so, there has been substantial research investigating the macroeconomic consequences of nominal rigidities for the working of an economy in response to various shocks and for the design of policy rules. The result of this effort has been a number of micro-founded models with price or wage stickiness, which predict various types of inflation dynamics. Nevertheless, two standard models in their original version, Calvo (1983) and Taylor (1980), imply no role for backward-looking dimension of inflation. These models while assuming price stickiness do not imply inflation stickiness.

It is however a well documented empirical regularity that inflation tends to adjust only sluggishly to its mean in spite of serially uncorrelated shocks (i.e. inflation persistence).[1] Because the original Calvo (1983) model typically cannot match the empirical persistence of inflation, several other models addressed this issue by introducing lagged value of inflation into a new Keynesian Phillips curve. The rationale behind the inclusion of lagged values differs across the models. Except simply assuming the rule of thumb behavior (Gali and Gertler, 1999), Fuhrer and More (1995) suggest that relative wage structure might be a reason for the backward-looking nature of inflation. Mankiw and Reis (2002) stress the significance information processing lags in price setting mechanisms. Besides, Erceg and Levin (2003) and Orphanides and Williams (2003) explain persistence with adaptive learning of agents in response to changes in monetary policy regime. In consequence, the ability of monetary policy to anchor long term inflation expectations induces agents to rely on past inflation, to a lesser extent. In this regard, Sargent (1999) studies extensively the interactions between the conduct of monetary policy and inflation persistence. Nimark (2005) suggests that optimal price setting with firm specific marginal cost rationalizes the link between past and current inflation. Calvo, Celasun and Kumhof (2002) show that in the environment of high steady state inflation, firms choose not only their today's price, but also set the rate at which they

[1] Assuming Gali and Gertler (1999) hybrid New Keynesian Phillips curve specification for inflation dynamics, Angeloni *et al.* (2006) distinguish between various sources of inflation persistence and label them accordingly. They define *intrinsic inflation persistence* as the persistence originating in past inflation, *extrinsic inflation persistence* as the persistence related to inertia in output gap and *expectation-based inflation persistence* as the persistence rooted in the deviations from rational expectations due to e.g. learning.

will update prices in future (firm-specific inflation rate). Under a monetary policy shock, some firms will not reset their inflation rate (and prices) and this gives rise to inflation inertia.

Recent empirical research has shown that inflation persistence is generally much lower than previously thought (e.g. Cecchetti and Debelle, 2006). This is mainly associated with two factors. First, inflation persistence indeed declined in the 1990s, as compared to the 70s and 80s (O'Reilly and Whelan, 2004). Second, greater care in econometric work has been undertaken. Levin and Piger (2004) find that inflation persistence falls considerably, when accounting for structural breaks. Next, the stability of monetary policy regime and central bank credibility helps to anchor long-run inflation expectations and reduces the extent of backward-looking behavior. Levin *et al.* (2004) find that adoption of explicit inflation target significantly reduces the extent to what economic agents use backward-looking information in terms of their inflation forecasting and thus puts a downward pressure on the persistence of inflation.

There are various reasons, why it is vital to study inflation persistence at the disaggregated level. Disaggregated analysis generally uncovers smaller inflation persistence across the individual/sectoral price indexes compared to the aggregate inflation. This suggests that inflation persistence observed at the aggregate level may arise due to aggregation bias (Granger, 1980 and Zaffaroni, 2004) and due to a fact that idiosyncratic shocks will tend to disappear when aggregating a substantial number of series (Altissimo *et al.*, 2004). Disaggregate analysis is also fruitful for understanding which components of various price indexes exhibit greater inflation persistence.

Additionally, several studies have raised the issue which factors are behind the fact that inflation process is relatively persistent. Cournede *et al.* (2005) argue that lower responsiveness of inflation to output developments in the euro area in comparison to the U.S. is caused by more rigid structural policy settings and relate it to trade barriers in the European services sector. Analogously, European Commission (2004) points out that low competition in services enhances its inflation inertia. On the other hand, studies employing disaggregate data such as Lunnemann and Matha (2005) for several EU countries and Clark (2006) for the U.S. find little evidence that services would display greater inflation persistence than goods. Similarly, Coricelli and Horvath (2006) also report the results for Slovakia that inflation inertia in services sector is lower than for goods and provide an explanation, why services,

where the degree of competition is typically lower, may in fact exhibit smaller persistence. The argument is based on Calvo (2000), who shows that greater competition may actually slow down the adjustment to shocks. This all aforementioned issues gives further impetus for individual or sectoral level analysis of inflation persistence.

One of interesting applications of inflation persistence analysis at the disaggregate level is provided by Cutler (2001). Cutler constructs an alternative measure of core inflation – persistence-weighted core inflation. The measure is constructed in the way giving greater weights to items exhibiting greater inflation persistence. Using UK data, Cutler finds that this measure outperforms in terms of ability to predict headline inflation some other standard measures of core inflation such as those using trimmed mean or weighted median or those excluding food and energy prices[2].

In addition, it is noteworthy that there is still very little evidence on price setting in the New EU Member States (NMSs). Typically, few available studies focus either on aggregate inflation dynamics or examine price setting in the single market (Ratfai, 2006). More detailed evidence on price setting is provided by Konieczny and Skrzypacz (2005) analyzing about 50 products in Poland. Among other things, they show that more intense search is associated with smaller price dispersion. Coricelli and Horvath (2006) give evidence on the empirical stylized features of price setting behavior in Slovakia using large micro-level dataset underlying Slovak CPI.

Therefore, a novel contribution of this study lies in exploring inflation persistence on the disaggregate level in the Czech Republic, using rich data collected by the Czech Statistical Office, which cover about a thousand of product categories over 1994-2005. Furthermore, our study goes beyond a simple statistical description of the data and makes an attempt to identify the determinants of inflation persistence. Of particular interest is the examination of the so-called "services inflation persistence puzzle", namely that more labor intensive categories such as services often exhibit smaller persistence, as compared to goods (see e.g. Altissimo *et al.*, 2004, Clark, 2006, Coricelli and Horvath, 2006). Finally, we construct 'persistent-weighted' core inflation in line with Cutler (2001) and propose 'persistent expenditure weighted' core inflation measure, that combines information on the persistence of individual

[2] Notice that in general the forecasting ability of persistence-weighted measures of inflation may depend on the monetary regime and the degree of inflation persistence. For discussion, see Smith (2004, 2005).

product and its weight in CPI basket, with an objective to assess its predictive performance (ability to capture inflation trends) compared to other alternative approaches for core inflation measurement.

The paper is organized as follows. After this introduction to the subject and overview of the key literature, the second section describes how inflation persistence could be measured in practice, formulates the research hypotheses and explains the estimation methodology. The third section presents the data set used in the study. The forth section provides the results. The last section concludes and draws policy implications.

2. Estimating inflation persistence

The literature generally applies two statistical approaches in estimating inflation persistence, those parametric and non-parametric. A parametric approach is more extensively applied in the empirical studies (Cecchetti and Debelle, 2006; Clark, 2006; Levin and Piger, 2004 or Levin, Natalucci and Piger, 2004). As advocated by Andrews and Chen (1994), the best scalar measure of persistence is the sum of autoregressive coefficients in the dynamic equation for inflation:

$$\pi_t = \mu + \sum_{j=1}^{K} \alpha_j \pi_{t-j} + \varepsilon_t, \qquad (1)$$

where π_t stands for year-to-year inflation rate, μ and α_j are parameters, and ε_t is the white-noise disturbance. The lag length *K* is determined based on information criteria. Typically, $\sum_{j=1}^{K} \alpha_j$ is interpreted as the measure of inflation persistence. Specification (1) may be labeled as naïve, because it does not account for potential structural breaks. However, recently a number of studies apply various tests for structural breaks (e.g. Cecchetti and Debelle, 2006; Levin and Piger, 2004).

A non-parametric approach has been recently put forward by Marquez (2004). This approach builds on the idea that less persistent inflation is more likely to cross its long-run mean of inflation rate (possibly the time-varying mean). Dias and Marquez (2005) derive finite sample and asymptotic properties of this non-parametric measure. They also conduct Monte Carlo simulations and find that the bias of the estimate of persistence based on non-parametric approach is smaller for any sample size, as compared to the parametric measure from the

equation (1). Besides, they argue that the non-parametric measure is more robust to structural breaks. Nevertheless, the properties of this measure are investigated only for covariance stationary processes.

Despite the potential attractiveness of the above described approaches, in our case we find that most of individual inflation rates follow an I(1) process. For such a case, properties of the non-parametric approach have not been investigated yet. Analogously in the case of parametric measure, it is well-known that the non-stationarity of variables would result in spurious regression. Therefore, we do not report these measures and propose a different measure of the persistence of inflation.[3]

Given non-stationarity of inflation series, we opt for an examination of the degree of inflation persistence using the complementary unit root and stationarity tests. Namely, we use the augmented Dickey-Fuller test (Dickey and Fuller, 1981), Phillips-Perron test (Phillips and Perron, 1988) and KPSS test (Kwiatkowski et al., 1992).

For the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, the probability of rejection the null hypothesis of a unit root will be reported. The probability can vary from 0 to 1. Higher values correspond to more persistence. For example, probability higher than 0.10 means that the null of a unit root cannot be rejected at the 10% significance level. For the KPSS stationarity test, the t-statistic will be reported.[4] Higher values of t-statistic increase the probability of rejecting the null hypothesis of stationarity and hence characterize more persistence in the underlying series.

The number of lags in the aforementioned tests is determined according to the Akaike information criterion. Given the relatively short time series, we do not test for structural breaks, as the time coverage is not large. However, we address the sensitivity of results by estimating persistence first for the whole sample and then using data only after the introduction of inflation targeting in 1998. It is also vital to note that we use year on year inflation rates for the following reasons. Other possibilities such as using month on month and quarter on quarter changes of price level are associated with seasonality, which may

[3] A straightforward application of the non-parametric method to our data does not bring any meaningful insight: the degree of persistence across all sectors is found to be very similar.
[4] Note that p-values are not available for KPSS test.

contaminate true extent of persistence. Besides, these two aforementioned changes are typically not monitored by economic subjects such as households or unions. Most importantly, central banks set their inflation targets in year on year changes of price level. In addition, Aron and Muellbauer (2006) claim that year on year inflation rates also capture the dynamics of month on month inflation[5].

The main research questions we want to address thus are the following:

1. *What is the distribution of inflation persistence across the sectors in the Czech Republic? Does this distribution change over time? What is the relation between aggregate CPI inflation persistence versus that of the individual or sectoral components?*
2. *Are there any sectors with consistently greater inflation persistence (e.g. services or regulated prices)? Is there difference between inflation persistence in tradables and non-tradables? What are the determinants of inflation persistence?*
3. *Is 'persistence-weighted' core inflation a useful predictor of future headline inflation?*

3. Data

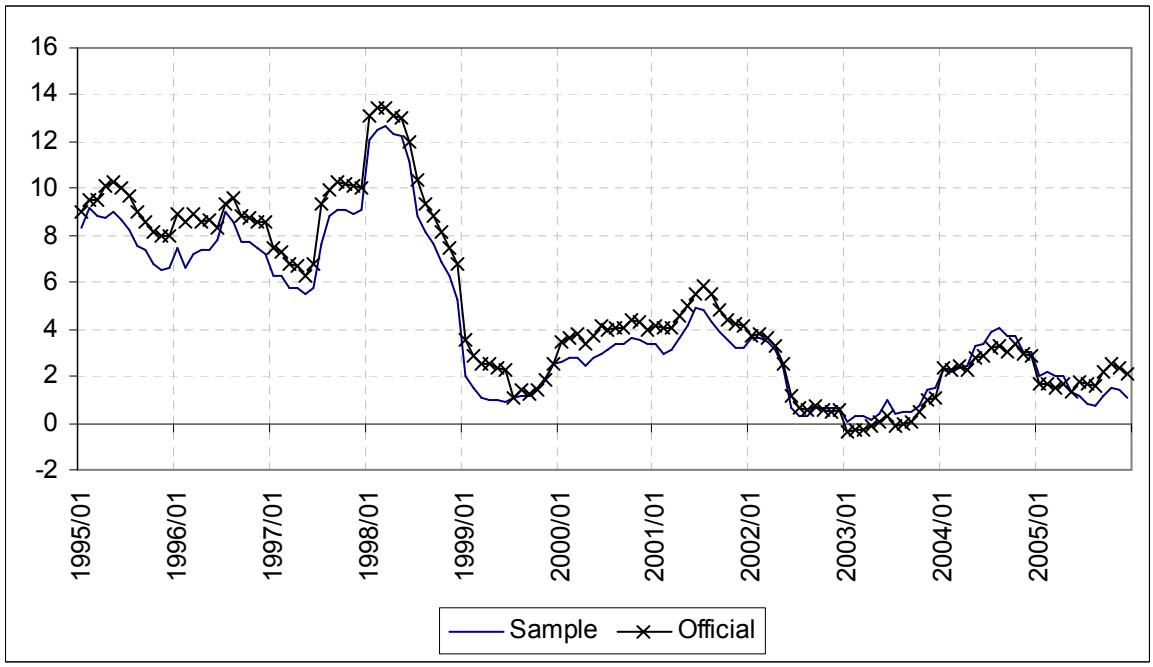
The Czech Statistical Office distinguished 1022 narrowly defined products that entered the consumer basket between 1994 and 2005 on a monthly frequency. Nevertheless, prices of many products have not been tracked over the whole sample period. Typically, the whole consumer basket includes about 700 products at a given date. As a result, we were able to identify 413 individual products for which the underlying consumer price indexes are available for the whole period spanning from 1994:M1 to 2005:M12. The selected 413 products represent 64% of the CPI basket for the year 2005. As a benchmark, we construct sample inflation as weighted average of 413 individual price indices (year-to-year percentage changes of).

Figure 1 shows official CPI inflation and our sample inflation over 1995-2005, at monthly frequency. High similarity between the two series suggests that our sample of 413 products is fairly representative in terms of inflation dynamics. On average, annual CPI inflation in the

[5] Nevertheless, for the purpose of sensitivity checking, we replicate our analysis on month to month inflation rates (The results are available upon request). We find that in such case inflation exhibit less persistence compared to the yearly base. Similar observation was pointed at by the Altissimo *et al.* (2006): the same series is found less persistent if considered in quarter on quarter changes compared to year on year changes.

Czech Republic was about 4.3% over the period 1994-2005. Prior to 1998, inflation fluctuated around 10%, while successful disinflation policy resulted in average inflation on the order of 3% during 1999-2005.

Figure 1. Official CPI inflation and sample inflation, 1995-2005



To facilitate interpretation, the individual 413 products are further grouped into several broader categories according to their characteristics (in line with Czech National Bank internal classification of products for reporting sectoral inflation rates). These are: tradables, non-tradables, durables, regulated good, services, non-regulated services, raw goods and processed goods. The products are also classified into 12 main categories according to so-called classification of individual consumption by purpose (COICOP). These categories are food and non-alcoholic beverages; alcoholic beverages and tobacco; clothing and footwear; housing, water, gas, and electricity; furnishing and maintenance of housing; health care expenses; transport; communications; leisure and culture; education; hotels, cafés, and restaurants; and miscellaneous goods and services.

4. Results

In the first part, we perform product-specific estimates of inflation persistence employing unit root (ADF, PP) and stationarity (KPSS) tests. Then we examine the effect of aggregation on inflation persistence and analyze whether inflation persistence changes over time. The second

part is devoted to the assessment of the determinants of inflation persistence. Finally, we evaluate the predictive ability of the persistence-weighted core inflation.

4.1 Inflation Persistence Estimates

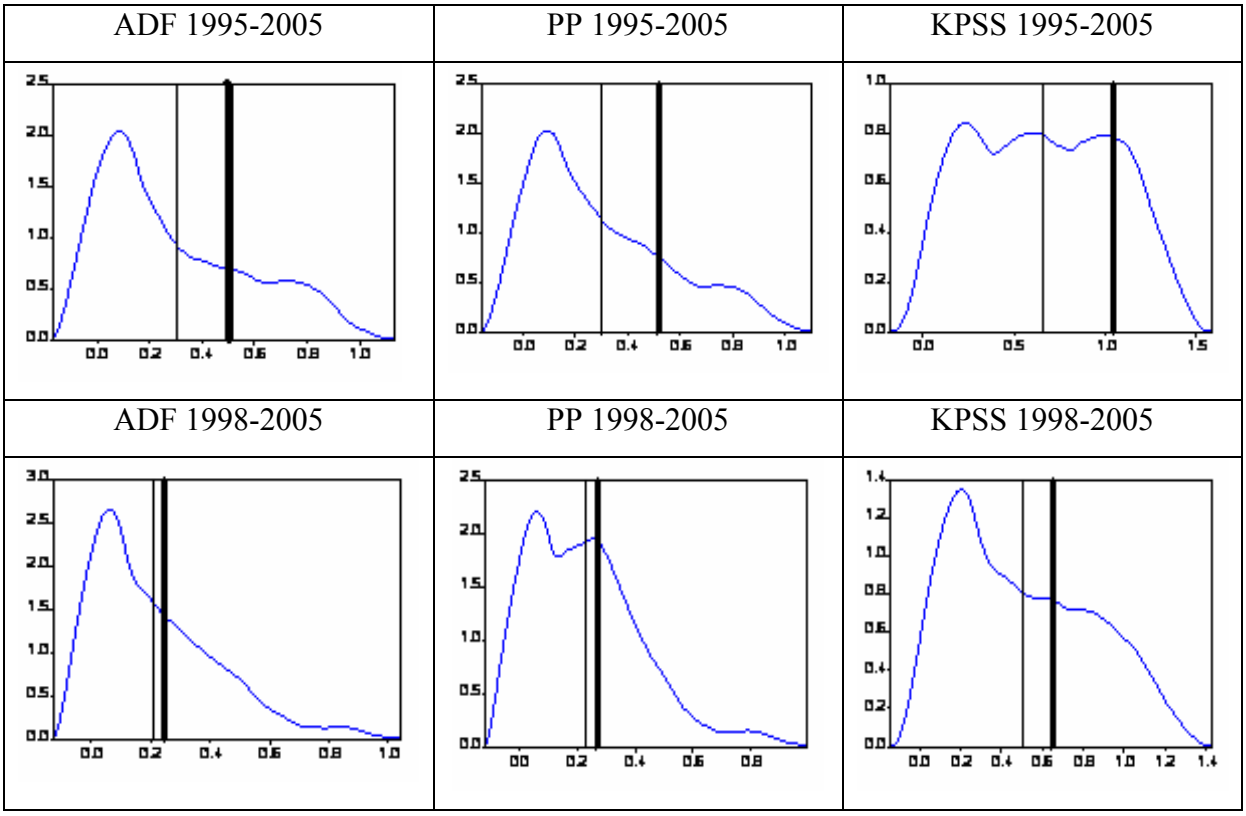
Overall distribution of inflation persistence across product categories is summarized on Figure 2 below. The degree of persistence is depicted on the horizontal axis, while the vertical axis displays the kernel density. Several stylized facts follow from Figure 2.

All three tests suggest that aggregate inflation exhibits significantly higher persistence than inflation measured on the disaggregate levels for the whole sample as well as for the 1998-2005 sub-period[6] (e.g. the results of Altissimo *et al.*, 2004 and Clark, 2006 also indicate this discrepancy). Generally, there are two possible explanations for this phenomenon. First, Granger (1980) showed that the cross sectional aggregation of (even simple) time series may result in complex, often more persistent processes (i.e. aggregation bias). Tipicallly, the aggregation bias is likely to be greater, when there is large heterogeneity of product-level inflation persistence. As a result, the estimated persistence of aggregate inflation may change due to changes in sectoral heterogeneity. Second, it may also reflect that idiosyncratic shocks vanish due to aggregation.

One can also observe a noticeable reduction in overall CPI inflation persistence for the sub-period period 1998-2005, while sample aggregate inflation persistence has decreased rather marginally (see the lower part of Figure 2). We find that it was the persistence of tradables (especially durable goods) inflation rather than those of non-tradables that declined after the adoption of inflation targeting.

[6] The results are valid regardless whether the sample aggregate inflation is constructed using the mean, weighted mean or the median.The gap between aggregate inflation and the disaggregate components average is different from zero at the 1% significance level, as suggested by the t-test. However, this significance may be overestimated since the conventional t-test is applied to the test statistics, not to the raw data.

Figure 2. Distribution of inflation persistence across 413 products and aggregation bias



Notes: Vertical bold lines denote persistence of aggregate CPI inflation; simple vertical lines represent a mean of disaggregate inflation persistence. Horizontal axis characterizes the level of inflation persistence (higher values mean more persistence). For all displayed measures of persistence, higher values mean more persistent inflation. For the **ADF** and **PP** unit root tests, the probability of rejection the null hypothesis of a unit root is reported. The probability can vary from 0 to 1. Higher values correspond to more persistence. For example, probability higher than 0.10 means that the null of a unit root cannot be rejected at the 10% significance level. Standard deviations are shown in parentheses. For the **KPSS** stationarity test, the t-statistic is reported. Higher values of t-statistic increase the probability of rejection the null hypothesis of stationarity and hence characterize more persistence in the underlying series.

Similar evidence of aggregation bias is observed when comparing inflation persistence for aggregate CPI and nine sectors (see Table 1 and Table 2). Overall, the results in Table 1 and 2 indicate that inflation persistence in the Czech Republic is much higher compared to the Eurozone members. While for Western European countries there are relatively few cases of pure I(1) process on sectoral and even aggregate levels (European Central Bank, 2005), and while the results of stationarity and unit root tests are often inconclusive[7] (Gadea and Mayoral, 2006), the results for the Czech Republic are much more clear-cut. Czech inflation follows a unit root process for most of the sectors. Moreover, in the Czech case the results of unit root and stationarity tests are quite similar on the sectoral level (test performance on the product level is assessed in the next paragraph). For example, considering the period from

[7] In other words, Gadea and Mayoral find that many sectoral inflation series are fractionally integrated, i.e. follow a process between I(0) and I(1).

1995 to 2005 (Table 1), the results of unit root and stationarity tests give the same picture: 10 out of 11 sectors exhibit a unit root process at the 10% significance level; raw goods (line 8) is the only sector which is stationary at the 10% level, as supported by both unit root (ADF/PP) and stationarity (KPSS) tests. This similarity between unit root tests and stationarity test gives strong support for I(1) behaviour of sectoral inflation. Note that these results are obtained assuming no trend in inflation. Incorporation of time trend in inflation dynamics (e.g. accounting for the inflation target) could be further investigated.

Table 1. Inflation persistence, yearly inflation, 1995-2005 (132 obs.)

Sector	No. of products	Sample weights	Measures of persistence		
			ADF	**PP**	**KPSS**
Tradables	314	0.61	0.31 (0.29)	0.31 (0.27)	0.69** (0.39)
Non-tradables	99	0.39	0.24 (0.21)	0.22 (0.20)	0.55** (0.30)
Services	94	0.39	0.24 (0.22)	0.22 (0.20)	0.56** (0.30)
Non-regulated services	71	0.28	0.24 (0.21)	0.22 (0.19)	0.57** (0.30)
Regulated	28	0.11	0.23 (0.21)	0.23 (0.20)	0.51** (0.29)
Durables	174	0.37	0.43 (0.29)	0.42 (0.28)	0.88*** (0.34)
Non-durables	158	0.44	0.14 (0.18)	0.16 (0.16)	0.44* (0.29)
Raw goods	42	0.11	0.07 (0.13)	0.09 (0.11)	0.24 (0.19)
Processed	371	0.89	0.32 (0.28)	0.31 (0.26)	0.70** (0.36)
Total product level	41	1	0.29 (0.28)	0.29 (0.26)	0.66** (0.38)
Aggregate inflation	1	1	0.48	0.49	1.03***

Notes: Durables do not include regulated prices, while processed goods include it. For all displayed measures of persistence, higher values mean more persistent inflation. For the **ADF** and **PP** unit root tests, the probability of rejection the null hypothesis of a unit root is reported. The probability can vary from 0 to 1. Higher values correspond to more persistence. For example, probability higher than 0.10 means that the null of a unit root cannot be rejected at the 10% significance level. Standard deviations are shown in parentheses. For the **KPSS** stationarity test, the t-statistic is reported. Higher values of t-statistic increase the probability of rejection the null hypothesis of stationarity and hence characterize more persistence in the underlying series. *, **, and *** denote the 10%, 5% and 1% asymptotical significance levels for rejection of the stationarity hypothesis. Standard deviations are shown in parentheses.

Table 2. Inflation persistence, yearly inflation, 1998-2005 (96 obs.)

Sector	No. of products	Sample weights	Measures of persistence		
			ADF	**PP**	**KPSS**
Tradables	314	0.61	0.20 (0.21)	0.23 (0.19)	0.51** (0.34)
Non-tradables	99	0.39	0.23 (0.20)	0.23 (0.17)	0.46* (0.29)
Services	94	0.39	0.25 (0.20)	0.23 (0.17)	0.47** (0.29)
Non-reg. serv.	71	0.28	0.28 (0.19)	0.26 (0.16)	0.47** (0.27)
Regulated	28	0.11	0.12 (0.16)	0.13 (0.16)	0.46* (0.32)
Durables	174	0.37	0.25 (0.24)	0.26 (0.23)	0.69** (0.32)
Non-durables	158	0.44	0.18 (0.15)	0.21 (0.13)	0.28 (0.20)
Raw goods	42	0.11	0.12 (0.14)	0.15 (0.13)	0.16 (0.12)
Processed	371	0.89	0.22 (0.21)	0.24 (0.19)	0.54** (0.33)
Total prod. lev.	413	1	0.21 (0.20)	0.23 (0.19)	0.50** (0.33)
Aggr. inflation	1	1	0.26	0.27	0.63**

Notes: as for Table 1.

In addition, both inflation persistence and dispersion have decreased for the post-1998 period, when inflation targeting regime was adopted. Vega and Winkelried (2005) find that inflation targeting helps in reducing the volatility of inflation, however the effect on inflation persistence is rather ambiguous. On the other hand, the results of Levin *et al.* (2004) indicate that inflation targeters exhibit smaller inflation persistence. In this regard, while we find that there are 319 categories out of 413, for which we cannot reject the null of unit root based on ADF test in the 1995-2005 sample at the 5% significance level, there are 300 respective categories in 1998-2005 (note that for the PP test these are 338 and 322 categories, respectively). In case of the KPSS test, we reject the null of stationarity at the 5% significance level for 270 categories over 1995-2005 and 207 categories for 1998-2005, respectively. These results suggest that inflation persistence may be somewhat lower after the adoption of inflation targeting regime in 1998, however this should be taken with caution, as the power of the tests may decrease for the shorter sample.

On the three-digit product level, a link between various tests is illustrated in Figure A1 in the Appendix. P-values of the ADF and PP tests are closely related, the corresponding correlation coefficient is equal 0.94 for 1995-2005 and 0.87 for 1998-2005. Correlation between unit-root tests and the KPSS test for stationarity is fairly high (0.63-0.67) for 1995-2005, and much lower (0.31) for 1998-2005. Such a difference over the two periods may be due to the following reasons. First, as the number of observations decrease, tests loose their power to reject the null hypothesis – that of a I(1) process for the ADF/PP tests, and of I(0) process in

case of the KPPS. Second, as inflation itself has decreased over time, it becomes more difficult to distinguish whether the series follow an I(0) or I(1) process; the series may become fractionally integrated, as it is the case for disaggregate inflation in West European countries (see Gadea and Mayoral, 2006). In other words, rising differences between unit root and stationarity tests may capture the effect of structural changes in the Czech Republic.

4.2 Explaining inflation persistence

Once the disaggregate estimates of inflation persistence are obtained, we put them to the test whether there are any significant determinants. In particular, we analyze the ability of product characteristics to explain the variation in persistence across 413 individual products. In addition, we put to a test so-called "service inflation persistence puzzle": Several studies have uncovered that (labor-intensive) services that are typically not subject to international competition, surprisingly display smaller persistence than goods (see e.g. Altissimo et al., 2004, Clark, 2006, and Coricelli and Horvath, 2006). Thus, our results will add a piece of evidence on this "service inflation persistence puzzle".

One hypothesis to explain a variation in inflation persistence is that it differs across sectors. Concerning sectoral categories, raw goods indeed demonstrate the lowest inflation persistence (and the lowest dispersion) among ten sectors considered. Non-durables are the second category with the lowest persistence and dispersion of inflation. Apart from aggregate inflation, sectors with the highest inflation persistence (and also dispersion) are durables, followed by processed goods and tradables.

It is interesting to note that services are typically non-tradable and more labor-intensive, i.e. their prices are set in a less competitive environment than as for goods. Naturally, incentives for price revision for services should then be weaker and thus the convergence to frictionless equilibrium slower. Consequently, one would expect that services prices should display greater inertia. However, our results as well as empirical evidence do not support for this reasoning. We find that inflation in services exhibits lower persistence, although for the post-1998 period this difference diminishes and becomes sensitive to the choice of the test. Similarly, Clark (2006) for the U.S. as well as Coricelli and Horvath (2006) for Slovakia report smaller inflation persistence in services than for manufacturing using micro level data.

Lunnemann and Matha (2004) find that in about 5 out of 15 EU countries the persistence in services inflation is smaller than the respective persistence of overall HICP.

In this regard, Coricelli and Horvath (2006) propose an explanation for the finding that services inflation is often found to exhibit smaller persistence than goods. Typically, it is assumed that higher competition increases the incentives for price revisions and the market has a tendency to adjust faster. On the other hand, Calvo (2000) shows that greater degree of competition may increase the inertia, rather than decrease it. This is because when markets are highly competitive, it is more likely that individual prices will not diverge a lot from the average (firms "follow the pack"), otherwise it would push the firm out of market. In other words, the degree of strategic complementarity among price setters increases with higher competition and individual pricing decisions will be more affected by the average strategy in the market. Consequently, greater competition reduces price dispersion; however, it does not have to decrease persistence.

Next, we study to what extent we are able to explain the cross-sectional variation in inflation persistence by price dispersion controlling for product characteristics. Price dispersion can be interpreted as the measure of market competition. Consequently, this allows us to test if competition is indeed negatively related to inflation persistence. We measure price dispersion as the standard deviation of price indexes within an individual COICOP category normalized to one at the initial period. The resulting COICOP-specific measure of price dispersion is obtained by averaging the standard deviations over time.

First, simple pair-wise correlations are illustrated in Table 3. Particularly strong correlations are detected for the categories of durables and raw goods followed by non-regulated services, and regulated products. We also find a significantly negative correlation between our measure of price dispersion and inflation persistence. This is robust to a measure of inflation persistence as well as sample period.

Table 3. Correlation matrix – Inflation persistence and product characteristics

	1995-2005			1998-2005		
	ADF	PP	KPSS	ADF	PP	KPSS
Price dispersion	-0.26	-0.28	-0.32	-0.08	-0.09	-0.27
Durables	0.43	0.44	0.50	0.15	0.14	0.49
Goods	0.09	0.13	0.13	-0.09	0.00	0.04
Non-Durables	-0.43	-0.40	-0.46	0.07	0.00	-0.06
Non-Tradables	-0.10	-0.15	-0.15	-0.14	-0.09	-0.52
Processed goods	0.27	0.27	0.37	0.15	0.14	0.35
Raw goods	-0.27	-0.27	-0.37	-0.15	-0.14	-0.35
Regulated products	-0.06	-0.05	-0.09	-0.12	-0.13	-0.02
Services	-0.09	-0.13	-0.13	0.09	0.00	-0.04
Services – non regulated	-0.08	-0.13	-0.11	0.15	0.08	-0.05
Tradables	0.10	0.15	0.15	-0.07	0.00	0.06

Note: Correlation coefficients greater that 0.08 in absolute terms are significant at 5% level.

Next, we present our results on determinants of inflation persistence in Table 4. The results suggest that greater price dispersion, a measure of competition, is associated with smaller inflation persistence. We report both OLS and GMM estimates to check the robustness of the results. While OLS may be subject to endogeneity bias, GMM is known that it may give the biased results for a smaller sample. Next, we also control for the product characteristics (two products with high correlation with inflation persistence) and present the results for two sample periods. We utilise here the KPSS test based estimates of inflation persistence. The results using ADF and PP tests to measure the inflation persistence are presented in Table A.2 in the Appendix. Appendix also contains Table A.1, where we study the impact of product characteristics on inflation persistence. We find that raw goods exhibits smaller inflation persistence, while durables display significantly greater persistence. There is rather weak evidence that inflation in services sector exhibit smaller persistence.

Table 4 – Determinants of inflation persistence

	1995-2005			1998-2005		
	KPSS	KPSS	KPSS	KPSS	KPSS	KPSS
Price dispersion	-1.25***	-1.25***	-2.13***	-0.91***	-3.91***	-1.45***
	(0.18)	(0.55)	(0.58)	(0.17)	(0.74)	(0.54)
Non-durables			-0.24***			-0.27***
			(0.06)			(0.05)
Raw			-0.27***			-0.17***
			(0.09)			(0.06)
Adj. R-squared	0.11	---	---	0.07	---	---
Estimation method	OLS	GMM	GMM	OLS	GMM	GMM
Sargan test (p-value)	---	0.1	0.1 (0.75)	---	0.2 (0.65)	0.9 (0.33)
Observations	413	413	413	413	413	413

Note: Heteroscedasticity robust standard errors are shown in parentheses. The list of instruments for price dispersion is as follows: non-regulated services and regulated prices dummies.

To support further our results that competition is likely to be negatively related to inflation persistence, we present the determinants of price dispersion. Here we expect that non-tradables, as they are not subject to international competition, will exhibit greater price dispersion. Controlling for other product characteristics, the results in Table 5 indicate that the degree of non-tradability of product, as captured by the services dummy, is positively linked to price dispersion.

Table 5 – Determinants of price dispersion

Services - no regulated	0.06***	0.07***	0.08***
	(0.01)	(0.01)	(0.01)
Non-durables			0.04***
			(0.01)
Raw		0.03***	0.03***
		(0.01)	(0.01)
Regulated			0.16***
			(0.02)
Adj. R-squared	0.06	0.06	0.22
Estimation method	OLS	OLS	OLS
Sargan test (p-value)			
Observations	413	413	413

Note: Heteroscedasticity robust standard errors are shown in parentheses.

4.3 Predictive ability of persistence weighted core inflation

In order to improve inflation forecasts, there has been developed a number of core inflation measures to capture underlying inflation trends. Generally, the measures remove or reweigh the most volatile categories of inflation such as energy prices. Smith (2004) notes that core inflation measures typically exploit cross-sectional information, while time-series information has been much less noted. In line with this, we construct a measure of core inflation, I_t^{core}, based on product-level inflation rates persistence giving a greater weight to categories exhibiting greater persistence and examine its predictive ability in comparison to other measures of core inflation as well as various inflation forecasts. Our persistence-weighted core inflation, $\pi_t^{core,PW}$, is based on Cutler (2001) and is constructed as follows:

$$\pi_t^{core,PW} = \sum_{i=1}^{413} \theta_i \Delta p_{t,i}$$

where θ_i denotes i-th product inflation persistence (normalized such that $\sum_{i=1}^{413}\theta_i = 1$)[8] and $\Delta p_{t,i}$ is i-th product yearly inflation rate in time t. As an alternative indicator, we combine information on the persistence of individual product, θ_i , and the weight of a given product in CPI basket in the following way,

$$\pi_t^{core,PEW} = \sum_{i=1}^{413} \xi_i \Delta p_{t,i}$$

where ξ_i is the simple average of θ_i –individual inflation persistence– and w_i is the sample weight of i-th product in the CPI basket, when θ_i and w_i is normalized such that $\sum_{i=1}^{413}\theta_i = 1$ and $\sum_{i=1}^{413} w_i = 1$. Consequently, we label $\pi_t^{core,PEW}$ as the persistence expenditure weighted core inflation.

We will undertake a simple exercise here to evaluate the predictive ability of persistence weighted core inflation vis-à-vis other (core) inflation measures. Namely, we compare it with net inflation, median net inflation (median net individual inflation rate), and so-called adjusted inflation (net inflation minus food, beverages and tobacco) over the horizon of 6, 12 and 18 months. The mean square error (MSE) will be used to measure the forecast quality:

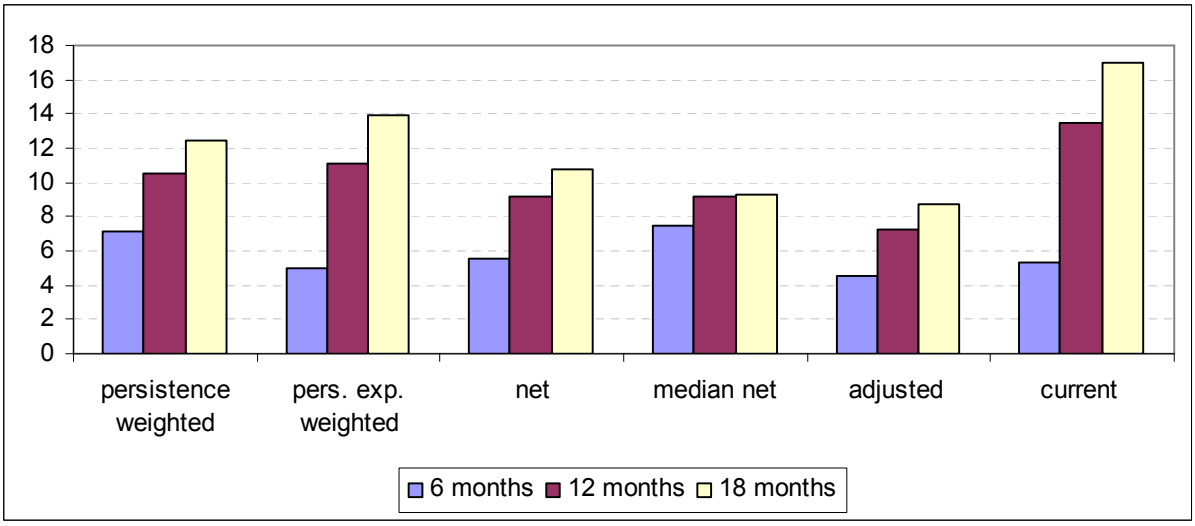
$$MSE = 1/T \sum_{t=1}^{T} \left(\Pi_{t+h}^{CPI} - \Pi_t^{CORE,i} \right)^2,$$

where T is the number of observations, h is time horizon in months and $\Pi_t^{CORE,i}$ is the selected core inflation measure.

Figure 3 depicts the predictive ability of aforementioned core inflation measures. The results indicate that adjusted inflation exhibits the smallest MSE and thus is the best predictor out of considered core inflation measures. Net inflation, median net inflation and persistence weighted core inflation, $\pi_t^{core,PW}$, do not perform particularly well. Current inflation and persistence weighted core inflation, $\pi_t^{core,PW}$, are relatively good predictors of inflation 6 months ahead, but their predictive ability worsen substantially over the longer time horizon.

[8] We used persistence measure based on the ADF test on 1995-2005 data.

Figure 3. Predictive ability of core inflation measures, 1995-2005



5. Conclusions

In this paper, we have presented evidence on disaggregate inflation persistence in the Czech Republic, exploring data from 413 individual narrowly defined products and 9 broader sectors from 1995:M1 to 2005:M12. The results suggest that inflation persistence has decreased since 1998 onwards. A somewhat similar observation of falling rather than rising inflation persistence in the Eurozone countries over the past decade is reported by the Eurosystem Inflation Persistence Network (IPN)[9]. However, inflation persistence in the Czech Republic still remains relatively high compared to that in the Eurozone countries. Therefore, inflation targeting regime seems to be associated with smaller inflation persistence, albeit this effect is rather weak.

Second, the results unambiguously point at the presence of aggregation bias, that is aggregate inflation is more persistent than the mean of disaggregated components. This result is robust to the choice of the disaggregating level (413 components or 9 sectors) and the weighing scheme (simple mean, median, or weighted mean), to the choice of the estimation technique (unit root ADF, PP or stationarity KPSS tests), and to the choice of the period (whole horizon versus the post-98 period).

Third, we identify that sectoral structure may explain the estimated variation in inflation persistence. In particular, products belonging to the raw goods category exhibit smaller than

[9] The summary of IPN findings is provided by the Altissimo *et al.* (2006).

sample average persistence, while durables have higher than average persistence. Concerning the "services inflation persistence puzzle", there is evidence that (labor-intensive) services are characterized by smaller persistence than goods for our 1995-2005 sample. However, the results are sensitive to the choice of the estimation techniques and the period, i.e. using shorter sample over 1998-2005 we do not find robust differences in terms of persistence of goods and services.

Lastly, we construct persistence weighted core inflation measure and evaluate its predictive ability in comparison with other available measures of core inflation, over the sample 1995-2005. Generally, we find that adjusted inflation (headline inflation excluding regulated prices, fuel and food prices and changes in indirect taxes) is the best predictor of future inflation trends in our set of core inflation measures over the horizon of 6, 12 and 18 months. For the 6-month horizon, our proposed measure - persistence expenditure weighed core inflation - may be viewed as good predictor as adjusted inflation for a 6-month horizon, but its predictive ability worsens over the longer time periods.

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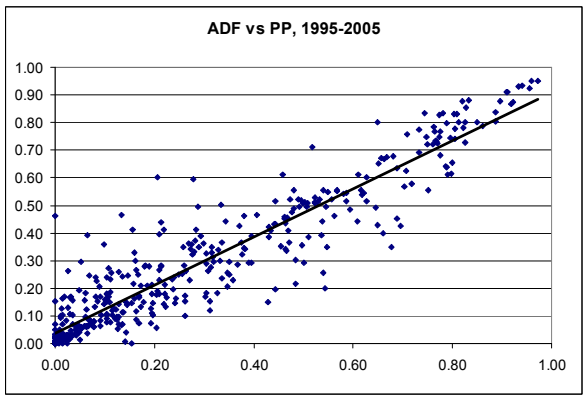
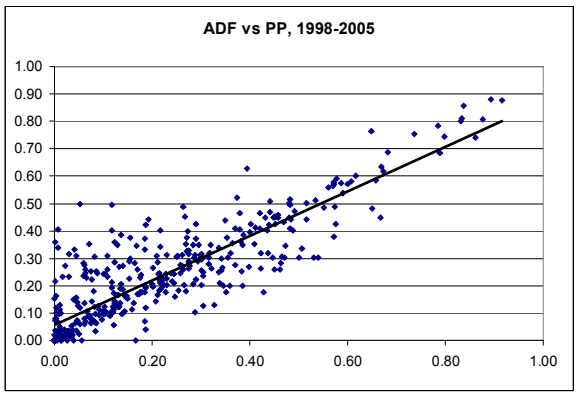
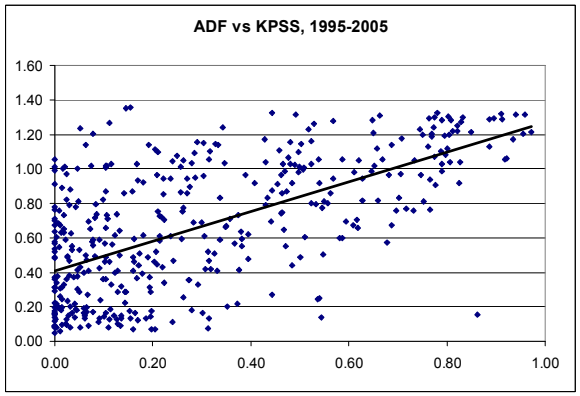
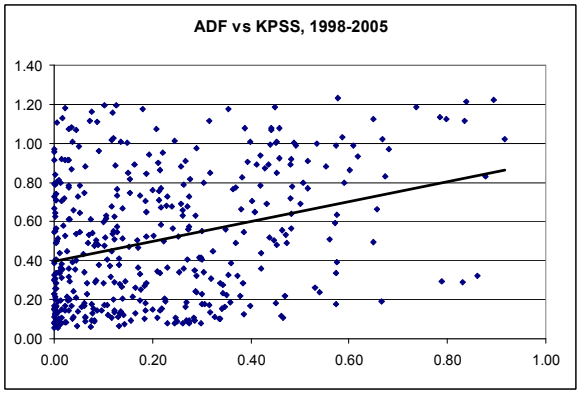
APPENDIX

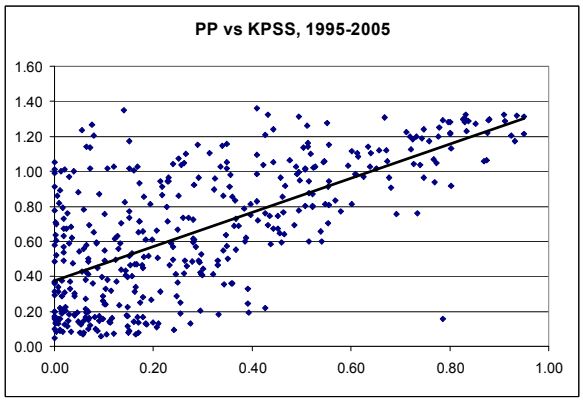
Figure A.1 - Link between ADF, PP, and KPSS tests (based on 413 product groups)

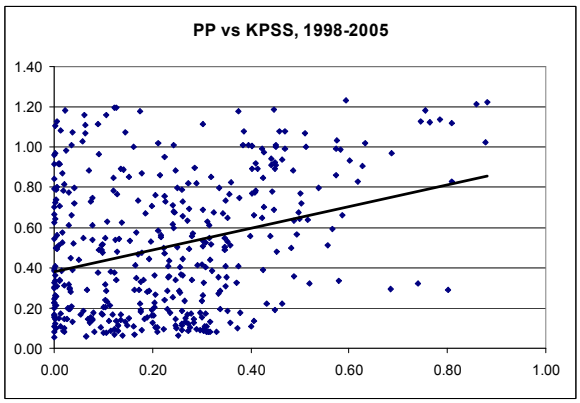












	1995-2005
corr(adf,pp)	0.94
corr(adf,kpss)	0.63
corr(pp,kpss)	0.67

	1998-2005
corr(adf,pp)	0.87
corr(adf,kpss)	0.31
corr(pp,kpss)	0.31

Notes: For the **ADF** and **PP** tests, the probability of rejection the null hypothesis of a unit root is employed. The probability can vary from 0 to 1. Higher values correspond to more persistence. For example, probability higher than 0.10 means that the null of a unit root cannot be rejected at the 10% significance level. For the **KPSS** stationarity test, the t-statistic is used (shown on vertical axes). Higher values of t-statistic increase the probability of rejection the null hypothesis of stationarity and hence characterize more persistence in the underlying series. Critical values for the KPSS t-statistics are 0.739 (1% level), 0.463 (5% level), and 0.347 (10% level).

Table A.1 – Determinants of inflation persistence, Product Characteristics

	1995-2005			1998-2005		
	ADF	PP	KPSS	ADF	PP	KPSS
Non-Durables	-0.222***	-0.20***	-0.31***	-0.06***	-0.04**	-0.30***
	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)
Raw	-0.17***	-0.16***	-0.36***	-0.07***	-0.07***	-0.26***
	(0.03)	(0.02)	(0.05)	(0.03)	(0.02)	(0.03)
Services - no regulated	-0.01	-0.05*	-0.06	0.09***	0.04*	0.02
	(0.03)	(0.03)	(0.04)	(0.03)	(0.02)	(0.04)
Regulated	0.01	0.01	-0.05	-0.06*	-0.08***	0.08
	0.05	(0.04)	(0.06)	(0.04)	(0.03)	(0.06)
Adj. R-squared	0.22	0.23	0.32	0.07	0.05	0.29
Estimation method	OLS	OLS	OLS	OLS	OLS	OLS
Observations	413	413	413	413	413	413

Note: Heteroscedasticity robust standard errors are shown in parentheses.

Table A.2 – Determinants of inflation persistence, ADF test

	1995-2005			1998-2005		
	ADF	ADF	ADF	ADF	ADF	ADF
Price dispersion	-0.73***	-0.75***	-1.30***	-0.17*	-0.32*	-0.46**
	(0.14)	(0.29)	(0.29)	(0.1)	(0.19)	(0.54)
Non-durables			-0.18***			-0.03*
			(0.03)			(0.02)
Raw			-0.12***			-0.02
			(0.02)			(0.03)
Adj. R-squared	0.07	---	---	0.01	---	---
Estimation method	OLS	GMM	GMM	OLS	GMM	GMM
Sargan test (p-value)	---	1.4 (0.24)	3.3 (0.07)	---	12.3 (0.0)	12.3 (0.0)
Observations	413	413	413	413	413	413

Note: Heteroscedasticity robust standard errors are shown in parentheses.

Table A.3 – Determinants of inflation persistence, PP test

	1995-2005			1998-2005		
	PP	PP	PP	PP	PP	PP
Price dispersion	-0.73***	-0.80***	-1.31***	-0.17*	-0.48***	-0.54**
	(0.14)	(0.25)	(0.26)	(0.1)	(0.18)	(0.17)
Non-durables			-0.15***			-0.01*
			(0.02)			(0.02)
Raw			-0.11***			-0.02
			(0.03)			(0.03)
Adj. R-squared	0.08	---	---	0.01	---	---
Estimation method	OLS	GMM	GMM	OLS	GMM	GMM
Sargan test (p-value)	---	1.6 (0.20)	0.4 (0.52)	---	11.4 (0.0)	11.5 (0.0)
Observations	413	413	413	413	413	413