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Abstract

In this paper, we analyse the sources of time variation in consumer inflation across ten Central and Eastern European (CEE) countries and five sectors (durables, semi-durables, non-durables, food, and services) in the period 2001-2013. With a multi-level factor model we decompose product-level HICP inflation rates into the following components: CEE region wide, sector, country, country-sector, and idiosyncratic. The outcomes indicate that region-wide and country specific components of inflation are more persistent than sector and product-level components, which is in line with similar studies for core EU countries. Two region-wide factors explain about 17% of variance in monthly price changes, whereas the other common components explain below 10% each. The results are at odds with empirical evidence on the importance of sectoral price shocks in developed economies and the volatility-persistence puzzle. This difference may be related to the conclusion that the first region-wide factor is associated with common disinflationary processes that occurred in CEE economies in 2000s, whereas the second one reveals significant correlations with global factors, especially commodity prices and euro area price developments.

JEL: C38, C55, E31, E52, F62

Keywords: product-level inflation, CEE economies, multi-level factor model

1. Introduction

The literature of the past two decades suggests that there is a high degree of comovement in inflation rates across countries. One of the popular explanation of this stylized fact is a globalization effect, which is responsible for weakening of the relationship between inflation and domestic economic activity (Borio and Filardo, 2007). In consequence, a growing synchronization of price changes is observed among the countries which are strongly connected in terms of trade and financial market. With the increased economic openness the vulnerability to common external shocks, coming from commodity prices (including oil), exchange rates, stock prices or interest rates on sovereign debt also increases. The literature that deals with these issues usually analyses inflation at the aggregate level. Ciccarelli and Mojon (2010) find that nearly 70% of inflation volatility in 22 developed OECD countries in the period 1960-2008 is driven by a global factor. Hence, they claim that inflation is a global phenomenon. Hakkio (2009) examines various inflation measures for the OECD countries and states that "the commonality of (…) inflation rates reflects the commonality of the determinants of inflation". Beck et al. (2006) conduct similar analysis at the regional level in euro area countries. They conclude that common euro area and country specific factors are explaining a substantial part of inflation with idiosyncratic regional variability playing a minor role.

There is also a strand of literature on price determination, which attempts to reconcile high persistence of inflation observed at the aggregate level with microeconomic evidence suggesting that sectoral and individual prices are transient and volatile (see Bils and Klenow, 2004 for micro-evidence). This is a volatility-persistence inflation puzzle which is at odds with microeconomic foundations of many sectoral New-Keynesian DSGE models (see discussion in Maćkowiak, Moench and Wiederholt, 2009). The potential explanation of the puzzle[1] is provided by Maćkowiak and Wiederholt (2009) in a rational inattention model. In this model representative firms being under information processing constraints rationally allocate more attention to idiosyncratic shocks than to aggregate ones, which are usually less volatile and more persistent. Boivin, Giannoni and Mihov (2009) claim that distinguishing between sector specific and aggregate sources of price fluctuations is a key point in understanding the volatility-persistence puzzle.

Most of the inflation decomposition studies relies on a static representation of dynamic factor model (e.g. Ciccarelli and Mojon, 2010, Boivin et al., 2006, and Maćkowiak et al. 2009). With such an approach idiosyncratic residuals may capture sector, geographical, country specific components and also other measurement errors. To handle this problem some authors use two-level factor model to decompose inflation into common (global) and sector or geographical factors at different levels of aggregation (e.g. Krusper, 2012, or Altissimo et al., 2011). Multi-level factor models are becoming more and more popular in the literature. Starting with the study of Kose, Otrok and Whiteman (2003) on commonality of business cycles new estimation methods in a dynamic factor setup have been proposed like sequential least squares and canonical correlation analysis (see Breitung and Eickmeier, 2014), with Bayesian analysis at the front (Moench, Ng and Potter, 2013). A comprehensive approach for decomposition in a multi-level factor model with an overlapping data blocks, we use, is the one proposed by Beck et al. (2011).

We argue that CEE countries on their road to the European Union have experienced similar inflationary pressures of economic (common market) and political origin (nominal convergence criteria). They all have experienced an economic transformation in the period of 1990s and they are strongly linked to the EU common market, which

[1] Other popular explanations are aggregation bias or structural break in the mean of inflation during the sample period (see Beck et al., 2011).

makes us believe that they share some similarities in price dynamics not only at the regional level, but also at the sectoral level. Nowadays these small open economies are still converging with an objective to join euro area in a far or near future or they have joined EMU already.[2] In spite of some differences between CEE countries in terms of trade openness, economic structures, exchange rate regimes etc. we provide evidence that there are common components in inflation dynamics across countries and sectors.

The existence of, both, global and domestic common factors driving inflation in CEE countries has already been advocated by several authors (e.g. Maćkowiak, 2006; Stavrev, 2009; Krusper, 2012; Alexova, 2012). Most of these studies analyse inflation at the aggregate level, without looking deeper into the sectoral determinants of price changes. We claim that in some sectors there are similar vulnerabilities to market integration and globalization effects. In other sectors there are possibly relevant differences stemming from institutional matters like price-setting behaviours (including the scope of market and price administration).

The empirical research on commonality in disaggregated inflation rates is scarce. Monacelli and Sala (2009) looks for the contribution of the international components that are responsible for the product-level inflation in 4 major OECD countries. Choueiri et al. (2008) analyses disaggregated CPI indices for 25 countries of the European Union. With the exception of Stavrev (2009) the other studies of sectoral or product-level price changes usually deal with price comovements in the developed countries like US (Boivin et al., 2009; Maćkowiak et al., 2009) or the euro area (Beck et al., 2011; Kaufmann and Lein 2013). Interestingly, when analysing disaggregated price indices common factors become less important than in the case of the aggregate analysis (cf. Boivin et al., 2009, Beck et al., 2011).

[2] See article of Staehr (2010) on divergent patterns of EMU entrance across countries.

In the paper we decompose COICOP product-level HICP inflation rates of ten CEE countries into aggregate, country, sector and country-sector specific common components, and into idiosyncratic components. We also document the volatility-persistence puzzle in components of HICP and provide economic discussion on the possible sources of comovements among them. The novel contribution of our approach to the analysis of sectoral inflation rates relies also in a unique product-level decomposition. Our method is related to iterative non-parametric PCA-based method of Beck et al. (2011), as we decompose common factors from overlapping data blocks, but with a different hierarchical structure of the factor model.

From our decomposition we find that all common factors explain about 36.5% of monthly inflation at a product level. Among them the most important are two CEE region-wide factors that contribute to about half of the total variance explained (17%). Regional component is very persistent, which is generally in line with similar studies for core EU countries, but the degree of persistence is more than 3 times bigger than in core EU or in OECD countries. Sectoral components (i.e. sector specific and country-sector specific) are on average less persistent than macroeconomic components (i.e. country and CEE region-wide) and as volatile as the latter. The results partly support the view that firms, when setting the price, pay attention to both macroeconomic and sectoral factors, although macroeconomic ones seem to be relatively more important in CEE countries than in developed ones.

The second aim of our research is the interpretation of the forces behind unobserved common factors. The outcomes indicate that the first CEE region-wide factor is associated with disinflationary processes in CEE countries, whereas the second regional factor reveals correlations with global factors, especially commodity prices and euro area price developments. Euro-area and U.S business cycle conditions are related to the country specific factors in Bulgaria, three Baltic countries and Poland. As the sector specific factors are concerned, prices of food and other non-durable goods strongly depend on the commodity markets. Prices of services reveal the moderate correlation with unemployment. Surprisingly, there is hardly no influence of the changes in the global or domestic economic activity on the prices of durable and semi-durable goods. One of the possible explanation is the globalization effect, which leads to price decreases regardless of the phase of the business cycle.

2. The Hierarchical Model

In most of the studies, in which global components of inflation are extracted (Ciccarelli and Mojon, 2010) or the aggregation volatility-persistence puzzle is documented (Boivin et al. 2009), the decomposition of inflation to sectoral and global components is based on a simple framework of a first-order factor model. The simple specification is suitable to introduce the dynamic relationship between common factors and observables (like in a FAVAR approach by Monacelli and Sala, 2009), but it has a major drawback. It implicitly assumes no hierarchical structure in the data in terms of commonalities within a country or inside a sector. Hence, in this type of factor analyses common sources of variability originating from sector or country specific factors are not properly treated leaving interpretations of idiosyncratic terms dubious.

The datasets with sectoral and geographical dimensions should be better analysed with a higher order hierarchical unobserved common factor models. Simple second-order factor models have been already used in the analyses of regional inflation rates – e.g. Beck et al. (2006) and Krusper (2012) leading to the following decomposition of sectoral inflation rates, $\pi_{c,r,t}$, in a country c and a region r:

$$\pi_{c,r,t} = \lambda_{c,r}^{a} f_t^{a} + \lambda_{c,r}^{r} f_t^{r} + u_{c,r,t}, \qquad (1)$$

where f_t^a represents global (aggregate) common factors, f_t^r – factors specific to a subset of countries (e.g. CEE) or regions in a given country r and $u_{c,r,t}$ is an idiosyncratic white-noise component.

Different sets of dimensions $\{c, r\}$ in $\pi_{c,r,t}$ are applied in the literature depending on the focus of the research and the data availability. For example, Krusper (2012) in a panel of HICP inflation rates for EU27 is interested in a regional component of inflation for 10 CEE countries, hence he defines c as a country, and r as a region. In another second-order factor study Beck et al. (2006) analyse regional overall HICP inflation rates in NUTS region c of EMU country r.

As a multi-level factor model augments an original specification of an approximate factor model by Stock and Watson (2002) a two-step method of principal components (PC) is usually applied to estimate orthogonal factors common at an aggregate level and factors common at a lower level of aggregation. In the first step orthogonal aggregate common factors $\hat{f}_t^a$ are extracted by PC and then they are used as regressors to calculate OLS residuals ($\hat{u}_{c,r,t} = \pi_{c,r,t} - \lambda_{c,r}^{OLS} \hat{f}_t^a$). In the second step, in order to extract the lower-level common factors ($\hat{f}_t^r$), PC is run separately on a subset of $\hat{u}_{c,r,t}$ belonging to the group r. Finally, to obtain estimates of factor loadings ($\lambda_{c,r}^a, \lambda_{c,r}^r$) and idiosyncratic terms ($u_{c,r,t}$), OLS regression of $\pi_{c,r,t}$ on a set of estimated factor scores $\{\hat{f}_t^a, \hat{f}_t^r\}$ is performed.

In our study we analyse sectoral COICOP product-level data on HICP inflation rates in 10 CEE countries. Although the data set in our study is also overlapping in terms of sectoral and geographical (countries) dimensions, it is the sectoral (not geographical as in Beck, et al. 2011) dimension which is defined at superior (5 broad groups: durables, semi-durables, non-durables, food and services) and subordinate (mostly 4-digit COICOP) level. Formally, we apply the following static representation of a multi-level factor model offering the following economic interpretation for the common factors:

$$\pi_{c,s,i,t} = \alpha_{c,s,i} f_t^a + \beta_{c,s,i} f_t^s + \gamma_{c,s,i} f_t^c + \delta_{c,s,i} f_t^{cs} + e_{c,s,i,t}, \qquad (2)$$

where:

f_t^a are k_a aggregate (regional CEE-wide) factors, which are common to all items (i) in a dataset and which are potentially related to common EU trade policy, or other external developments like shocks to commodity prices, global financial crisis,

f_t^s are k_s factors specific for sector s (group of goods like durables, semi-durables, non-durables, food, and services), which are potentially related to sectoral policy (e.g. Common Agricultural Market), shocks in oil market, changes to consumption patterns, geographical proximity or differences in exchange rate pass-through effects on tradables and non-tradables,

f_t^c are k_c country-specific factors representing such events in country economic policies as VAT changes, currency depreciation, etc.,

f_t^{cs} are k_{cs} country and sector-specific factors that affect only prices in a sector s in a country c (like energy prices in Poland, or food prices in Romania),

$\alpha_{c,s,i}, \beta_{c,s,i}, \gamma_{c,s,i}, \delta_{c,s,i}$ are respective factor loadings specific for each product-level item,

and $e_{c,s,i,t}$ represent idiosyncratic terms.

We identify orthogonal common factors from overlapping cross-sections (geographical and sectoral) using disaggregated information. The novel contribution of our approach to the analysis of sectoral and country inflation rates relies in a unique decomposition of product-level HICPs. Another important distinction is an interpretation of sector-specific factors at this level of inflation disaggregation. Firstly, our sectors are much broadly defined than in other studies. Secondly, the information on the comovements comes from the product-level HICP inflation rates. According to our knowledge this level of disaggregation was not analysed with an overlapping third-order hierarchical factor model until now.

In estimation we follow a non-parametric (based on principal components) method of Beck et al. (2011), which in a multi-sequential iterative version is capable of treating the overlapping data blocks in an appropriate way.[3] Yet, we apply the estimation method to a different dataset structure. To this extent an iterative estimation procedure has been adapted which consists of the following steps. In the first step we estimate CEE region-wide factors obtained from the whole data set by the method of principal

[3] The small samples properties of this method were tested by the authors – see Monte Carlo experiments in Beck et al. (2011). Breitung and Eickmeier (2014) also find that under a relatively big importance of higher order factor (as in our case) two-step PC estimator delivers good efficiency when compared to its non-Bayesian competitors.

components (PC) and extract idiosyncratic components as the part of price variability not explained by CEE region-wide factors (these are OLS residuals of regressing $\pi_{c,r,s,t}$ on factors f_t^a). From these residuals (demeaned across countries) in the second step we estimate sector-specific factors by PC method in each subset of sectoral data separately.[4] In the third step the OLS residuals from regressions of inflation rates on the estimated CEE region-wide and sector-specific factors $(\hat{f}_t^a, \hat{f}_t^s)$ are used to distinguish country-specific factors $(\hat{f}_t^c)$ in each country data subset separately. In the final step one obtains country-sector specific factors $(\hat{f}_t^{cs})$ running PC on residuals from the second step separately in each data subset of a given country in a given sector. Finally, we also propose an extraction of common CEE region-wide components from final residuals, separately for each COICOP category and give the discussion on their interpretations.

The number of factors may be established by the cumulative percentage of variance explained by factors or with more formal information criteria (Bai and Ng, 2002). The decomposition of lower-order factors, however, is conditional on the number of factors extracted at higher order level. Selecting more than one factor at each level also poses serious identification problems. Usually the orthogonality condition is used but it is not guaranteed by iterative procedure. As a result, the more of the higher level factors one extracts, the less variability is left for explaining lower-level factors. Consequently, the sequential top-down estimation method, as well as other competitors based on an asymptotic inference (see Breitung and Eickmeier 2014), are more efficient in extracting higher-order factors than lower-order ones. Thus, in the empirical part of the study we select only one common factor for each lower-level factor and we perform sensitivity

[4] The necessary modification in the iterative procedure compared to the two-step approach of Beck et al. (2011) is iteration between steps of obtaining different lower order factors. Our method is different in the second and the third step. Instead of country-specific factors we estimate sector-specific factors first. Because of relatively small number of items in overlapping country and sector cross-sections we repeat the lower-order factor extraction procedure (from step 2 to step 3) until convergence.

analysis to the selection of the number of aggregate factors (see Appendix 2). The possible correlation between extracted common factors may be also a good diagnostic tool of estimation problems.

3. Data

We analyse components of monthly Harmonized Index of Consumer Prices (HICP) from 10 Central and Eastern European (CEE) countries: Bulgaria (BL), Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI) for the period Jan. 2001 - Sept. 2013. These are all emerging market economies that have entered the EU in the sample period (BL, RO in January 2007, the others in May 2004). The selection reflects the choice of many authors interested in disentangling common- and country-specific factors across new EU members (see Stavrev, 2009; Krusper, 2012).

To capture the co-movements in inflation rates across countries and sectors we employ the price indices at the disaggregation level up to four COICOP (Classification of Individual Consumption According to Purpose) digits, which we call, in short, product-level data. When analysing sector-specific factors we group these HICP components into 5 exclusive categories (named sectors for convenience). These are services, food (which includes beverages, alcohol and tobacco), and three non-food good categories: durables, semi-durables, non-durables. The distinction between semi-durables and non-durables originates from Eurostat NACE Rev. 1 classification and is defined by differences in a way (semi-)durable goods are used ('repeatedly or continuously over a period of time considerably more than one year') and their expected lifetime (for semi-durables it is shorter than for durables).

The original database consists of 94 product-level categories. There are a few categories of the consumption basket with a missing values at the beginning of the sample due to the late acquisition of good quality data. We omit some COICOP categories with market prices observed only in a few of 10 CEE countries (like combined passenger transport or maintenance and repair of other major durables for recreation and culture). We also skip another 51 time series with zero monthly price changes in more than 25% of the sample periods. These are mainly administered prices, although different item categories are referred under this name in different countries and across time. The administered prices are fixed for a considerable period of time between price decisions of country-specific regulator, hence they are not suitable for correlation analysis. Finally, we employ a balanced panel of 776 HICP-component series (from 74 components in Estonia to 82 in the Czech Republic) over 154 consecutive months (see Table 1). The selected product-level HICP components are seasonally adjusted (SA) by a Tramo/Seats automatic procedures. We provide the results for month-over-month (mom) COICOP indices as a base case and for year-over-year (yoy) data as the robustness check (see Table 8, Appendix 2). Due to high kurtosis the data are corrected for outliers by winsorizing non-typical observations beyond 5^{th} and 95^{th} deciles.

Table 1 Descriptive statistics of monthly product-level inflation rates by sector

	Durables	Semi-durables	Non-durables	Food	Services	Total
Descriptive statistics (inflation in terms of logarithmic mom changes)						
No of observations	114	129	129	149	255	776
Mean	-0.180	0.109	0.402	0.373	0.428	0.174
Median	-0.055	0.097	0.259	0.227	0.271	0.185
St. dev.	1.093	0.893	1.692	1.836	1.874	1.622
Skewness	-0.549	0.686	1.812	1.606	-0.473	0.688
Kurtosis	23.352	84.364	37.980	42.993	520.487	327.430
AR1	0.193	0.032	0.127	0.250	0.139	0.147

Source: own calculations

A substantial heterogeneity is observed in the sample among monthly price changes across different sectors (see Table 1). Services and non-durables are the sectors with the highest average price changes, above 0.4% per month, next comes food sector with inflation below 0.4% and semi-durables – about 0.1%. The lowest average monthly inflation is recorded for durables and it is negative (ca. -0.2%). This ordering of average inflation rates from durables to non-durables is an interesting stylized fact in our sample, however, its explanation is beyond the scope of our study. Unsurprisingly, sectors with highest inflation are also those with highest price volatility (see Table 1).

There are significant differences in distribution of monthly inflation rates across countries. Countries with high average inflation rates are also characterized by high inflation persistence measured by the parameter of a first-order autoregressive (AR1) process on seasonally adjusted data. Romania is a clear example of this stylized fact with an inflation persistence estimated at 0.7 and the Czech Republic with non-persistent changes in inflation. The important extreme case is also Slovenia with volatile (2.1%, as measured by standard deviation of mom changes) and non-persistent inflation (see Table 2). The descriptive statistics (in mom terms) are generally in line with the volatility-persistence puzzle when compared to the aggregate data (see Table 4 in Appendix 1). The median of standard deviations of the aggregate HICP across countries is 0.4 pp. versus 1.5 pp. at the product-level. On the other hand, persistence measured by the median of first-order autoregressive coefficient is three times bigger at the aggregate level than at the product level (0.34 versus 0.13).

Table 2 Descriptive statistics of monthly product-level inflation rates by countries

	BG	CZ	EE	HU	LT	LV	PL	RO	SI	SK
Descriptive statistics (inflation in terms of logarithmic mom changes)										
No of obs.	77	82	74	78	80	76	78	78	75	78
Mean	0.306	0.094	0.313	0.337	0.182	0.281	0.172	0.622	0.218	0.194
Median	0.182	0.107	0.230	0.290	0.089	0.191	0.155	0.314	0.168	0.162
St. dev.	1.721	1.281	1.865	1.360	1.571	1.788	1.415	1.402	2.116	1.509
Skewness	4.191	9.515	2.408	-1.038	2.519	2.715	4.153	11.006	-11.262	3.029
Kurtosis	89.4	435.7	69.4	104.6	136.8	45.3	289.4	450.1	757.4	106.1
AR1	0.257	0.020	0.089	0.113	0.157	0.045	0.321	0.717	-0.046	0.189

Source: own calculations.

4. Results

In this section we present the empirical results with a disclaimer that they are conditional on, both, the factor model structure and the estimation method applied.[5] The results are presented for two CEE-wide regional factors (base case) which are selected after the analysis of dominating eigenvalues on the scree plot (see Figure 3 in Appendix 2). The lower-order factor decomposition (by sectors and countries) is conditional on the selection of aggregate factors and on the cross-sectional breakdown of the dataset.[6] As a robustness check we briefly discuss differences to the decomposition with three aggregate factors (see Table 7 in Appendix 2) and the decomposition of year-over-year price indices (Table 8 in Appendix 2).

We start with a common factor decomposition to describe the fraction of variance explained by common components, their volatility (in terms of standard deviation), and persistence (first order autoregressive coefficient) in the full dataset. Then we present similar decomposition at country and sectoral breakdown to point out some important differences in subsamples. Next, we perform a correlation analysis of aggregate factors. The last part of this section offers a preliminary analysis of sector-specific components at the product level.

[5] Particularly, the decomposition of unobserved factors and loadings at the upper (aggregate) level depends on usual PC restrictions (e.g. orthonormal factors), which are hard to be justified on economic grounds. Although there is a rotational indeterminacy of common factors (i.e. factors are identified up to a rotation by a non-singular matrix), PC-based decomposition is unique in terms of common and idiosyncratic components as long as the number of factors is known or fixed with some statistical criteria (see Bai, Ng 2013). Therefore, we do not interpret aggregate factors and their loadings separately, except for a preliminary correlation analysis.

[6] Nevertheless, sector, country, and country-sector specific single factors are identified up to a sign and variance (a local identification). The iterative estimation procedure guarantees that the ordering of lower level factors does not influence the decomposition.

Factor decomposition

In this part we are interested in a decomposition of product-level inflation rates according to a multi-level factor model (2). We name the decomposition with two aggregate factors obtained with PC iterative method described in Section 3 as the base case. The summary results are presented in Figure 1 and Table 3. The first aggregate factor explains 10.8% of variation in prices at the product level, whereas the second one explains 6.5%[7]. If we select the decomposition with three aggregate factors instead of two, the contribution of country and country-sector specific components (altogether) diminishes by 4 pp.[8] The contribution of CEE region-wide component varies considerably between different countries and sectors. It is the most prominent factor in Romania (explaining 55% of price variability), and the least important for Estonia (10%), the Czech Republic (8%) and Slovenia (6%). For the other countries the fraction of explained variance is between 13% (Poland) and 18% (Bulgaria). The CEE region-wide component explains from 11% of variance in food and non-durable sector to 24% in services being the most important price determinant in each of them (c.f. Table 5 and Table 6 in Appendix 1).

[7] With each consecutive aggregate factors ordered by eigenvalues of correlation matrix the explained part would be lower than 3% which is below the fraction of variance explained by sector-specific factors (3.1%) if two aggregate factors are assumed. See Figure 3 in Appendix 2.

[8] With the base case country specific and country-sector specific components explain, respectively, 6.5% and 9.6% of overall time variation in a panel, and in the three aggregate components 4.1% and 8.0% respectively.

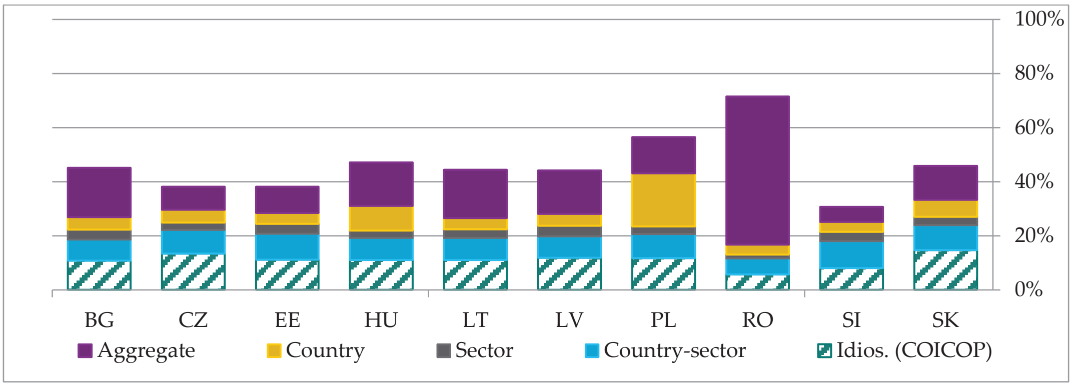

Figure 1 Factor decomposition by countries (base case, variance of HICP log-changes in mom terms). Source: Own calculations.

In the base case all estimated factors explain 36.5% of variance of product-level price dynamics (mom), which is a relatively low number (see Table 3). The most important are two aggregate (CEE region-wide) factors that contribute to about half of the total variance explained (17.3%), less important are country (6.5%) and sector specific (3.1%) components. The country-sector specific components explain on average 9.6% of time variation in full data set, which is more than country specific and sector specific components altogether. The average figures give the overall view on big contributions of regional and country factors in explaining inflation dynamics. There are, however, groups of products that are highly dependent on the sector specific and country-sector specific shocks with about 50% of variance being explained by a single factor. For example, these are liquid fuels in euro-pegged countries Slovenia, Bulgaria and Slovakia strongly dependent on sector specific shocks, or garments in Czech Republic and Hungary clearly dependent on their own country-sector specific factors. It seems that the interpretation of country-sector specific component may be troublesome. It may be interpreted as a domestic part of sector specific price variation being the result of sector-oriented economic policy or a particular structure of a domestic economy. Equivalently, it may be understood as a sectoral component which is country specific because inflation rates are calculated in terms of domestic currency and because they are under the influence of country–wide regulations (like fiscal policy). We will follow the second interpretation calling sector and country-sector specific components as the components of sectoral origin. Following this interpretation the overall contribution of sectoral factors is 13% on average, which is lower than the contribution of CEE region-wide factors, but it is still a considerable explained part of mom inflation rates.

Table 3 Descriptive statistics of volatility, persistence and fraction of variance explained by three-level factor model decomposition (log monthly changes)

	Aggregate	Country	Sector	Country-sector	Idiosyncratic	Idios. (COICOP)
			Volatility (St. dev.)			
Mean	0.187	0.120	0.120	0.180	0.578	0.221
Median	0.152	0.077	0.047	0.105	0.402	0.129
Min	0.002	0.000	0.000	0.000	0.025	0.000
Max	0.799	1.380	3.176	2.295	4.691	3.788
St. dev.	0.139	0.143	0.267	0.232	0.619	0.351
			Persistence (AR1)			
Mean	0.974	0.630	0.315	0.199	0.071	0.148
Median	0.975	0.680	0.331	0.204	0.058	0.121
Min	0.968	-0.145	0.071	-0.240	-0.543	-0.285
Max	0.980	0.880	0.551	0.705	0.673	0.628
St. dev.	0.004	0.267	0.180	0.213	0.179	0.211
			Variance explained			
Mean	0.173	0.065	0.031	0.096	0.647	0.109
Median	0.089	0.027	0.010	0.053	0.679	0.075
Min	0.000	0.000	0.000	0.000	0.030	0.000
Max	0.910	0.545	0.557	0.576	0.990	0.628
St. dev.	0.207	0.094	0.067	0.109	0.222	0.111

Source: own calculations.

The fraction of the variance explained is hard to compare with the results of other studies because of the differences in the methods applied by the researchers or differences in the level of data aggregation. Stavrev (2009) in an analogous data set of product-level inflation rates across ten CEE countries in the period 1998-2008 finds that first dynamic (not static) regional CEE-wide factor extracted with generalized dynamic factor model (GDFM) of Forni et al. (2000) explains about 65% of overall variance in yoy terms. This result is not directly comparable to our result of 17% for mom price changes and 32% for yoy changes, as in GDFM specification the explanatory power stems from the lag polynomial on common factor of an infinite lag order and our specification with overlapping geographical and sectoral structures is static. In Beck et al. (2011) the variance explained by common factors in 52 regions of 5 EMU countries is about 53%, but they apply HICP indices at higher level of sectoral aggregation (11 sectors in their paper compared to 83 four-digit COICOP groups in our sample).

Our decomposition is useful in describing the nature of shocks to consumer price changes at the product level. The magnitude of CEE region-wide shocks with average mom volatility estimated at 0.19 pp. seems to be important source of inflation next to country-sector specific disturbances (0.18 pp.) – see Table 3. Then country and sector specific factors are characterized with a similar magnitude of volatility in price changes (0.12 pp.). Although there are 10 different countries and 5 different sectors under research, the sample is much more heterogeneous in terms of shock decomposition across sectors than across countries (with a standard deviation of volatility at 0.27 and 0.14 pp., respectively). We also find that despite thorough procedure of data preparation (including winsorizing) still idiosyncratic shocks play a major role in price dynamics at the product level with a median of standard deviations at 0.4 pp. per month.[9]

[9] The result does not depend significantly on the number of factors selected at the aggregate level or yoy data used instead of monthly SA indices. The only difference in decomposition of HICP inflation in yoy terms is a bigger fraction of variance explained by CEE-wide factors and bigger volatility of CEE-wide components than volatility of any other common component, except for idiosyncratic one (see Table 8 in Appendix 2).

Not only the magnitude of shocks to inflation but also their persistence i.e. for how long they persist is of big value to the results of shock decomposition. The most persistent are CEE region-wide shocks. The first-order autocorrelation of the aggregate component hits the point of 0.97, which means it is almost a non-stationary part of variation extracted from the full sample. The number of cross-section units in the data panel guarantees that the results are not spurious but they are still remarkably high. Also the country components are very persistent on average (with a median AR1 coefficient at 0.68). It is a homogenous result among CEE countries, except for Slovenia, where the persistence of country specific component is close to 0. The results on persistence are generally in line with similar studies for core EU countries (Beck et al. 2011), but the degree of persistence is more than three times bigger. In line with many other studies of inflation at sectoral and product level (e.g. Beck et al. 2011) common aggregate factors exhibit high persistence, but unlike in other studies common aggregate components are as volatile as any other components of country or sectoral origin. From the factor decomposition the only component which is more volatile than the aggregate one is the idiosyncratic component.

At the end we also extract the part of variance common to price changes at a given four-digit COICOP group in a full sample of countries. This common component (Idios. COICOP in Figure 1 and Table 3) explains 1/6 of idiosyncratic price changes which is a bigger contribution than the contribution of a sector specific component. It is also the most volatile and non-uniform component of product-level inflation.

CEE region-wide factors

We investigate into the nature of common factors by a correlation analysis with the most important macroeconomic processes in, both, nominal (consumer prices – HICP and producer prices – PPI, exchange rates, commodity prices) and real terms (economic activity indicators: industrial output, unemployment rates, PMIs).

The results indicate that the first factor may be associated with the disinflationary processes that occurred in 2000s in some of CEE economies that led to a downturn in inflation expectations. It can be seen, both, in lowering inflation in such CEE countries like Bulgaria and Romania[10] and in some of HICP components for several CEE countries. This disinflationary process can be attributed to several factors. One factor is an inflation targeting strategy which lowers inflation expectations. The other are structural reforms conducted in the 90., which led to the change in the price setting behavior of the firms. This process is also attributed to the globalization (Pehnelt 2007). Its main face in CEE region is a relocation of production to the countries with relatively lower labor costs, which is visible in the case of such consumption goods as garments, footwear, equipment for recording, photography, recording media etc. Inflation dynamics in those HICP components was either negative or in a downward trend. This phenomenon is pointed out by Allard (2007) who evaluate the effect of the globalization in Poland. According to this research globalization lowered prices in Poland by 0.5 to 1 percentage point annually during 1995-2003 (more than in advanced economies), which was possible by lowering the mark-ups. Moreover, Allard states that this process will diminish after 2003 in line with the growing openness of the countries. The shape of the first factor may support the course of globalization process in CEE countries stated by Allard (2007).

The second factor can be recognized as a price reaction in the CEE countries to the changes in the global economy, especially euro-area (EA) inflation, what we interpret as an imported part of the country inflation in the region (see Figure 2). The second factor fluctuates, similarly like HICP in the euro area, around zero level up to the end of 2006, then it rises as the global commodity prices picked up and in 2009, with the

[10] When eliminating Romania from the sample we would receive similar results – two comparable common factors, but in a reversed order of importance and with slightly lower part of overall variance explained.

beginning of the financial crisis, it declines. Subsequently, starting from the beginning of 2010, it rises again, and from mid-2011 is in a downward trend. Besides, it also correlates with the unemployment in EA, production in EA and global PMI, therefore we may state that not only global inflation factors drive inflation in CEE countries, but also other macroeconomic processes, in particular real business cycle. However, this reaction occurs mostly via price developments in EA.

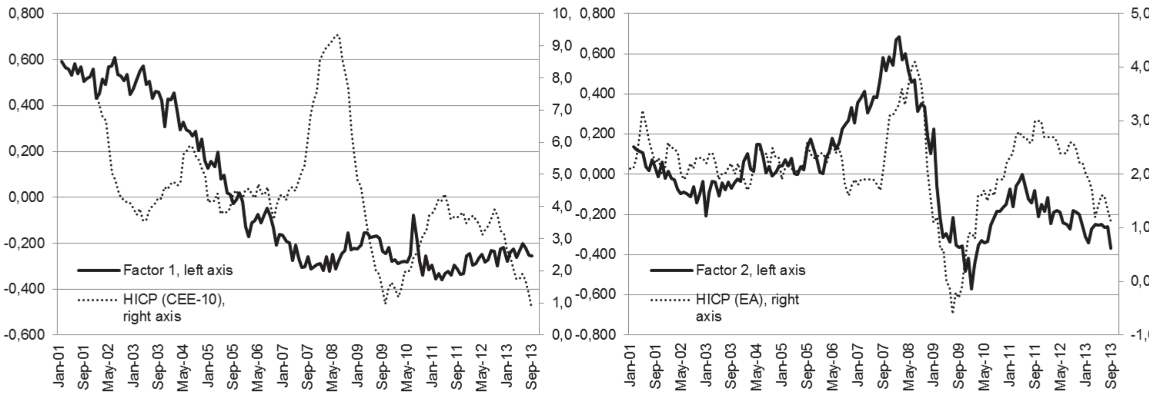

Figure 2. First (left panel) and second (right panel) CEE region-wide factor compared to yoy HICP for the CEE-10 (left panel) and Euro area (right panel)

Country specific factors

Correlations of the country specific factors for most of the countries show that one of the most important local determinant of inflation is the unemployment in a particular country, but for Bulgaria, three Baltic countries and Poland it is also the unemployment rates in the euro area and US. Moreover, this factor is also correlated with domestic core inflation i.e. HICP net of food and energy. It seems that, as expected, country specific factors are influenced mostly by the domestic variables, however external factors are not negligible.

Furthermore, some of the CEE countries like Estonia, Lithuania and Slovakia exhibit linkages with the global economy, measured by the PMI global index. Interestingly, Slovakia appears as a country strongly linked with the global commodity market, especially with the price developments of the energy and industrial commodities. One possible explanation is that it is a small country which experience quite high inflow of foreign direct investments. As a matter of fact, Slovakia experienced one of the highest inflow of the FDI (in relation to the GDP) among the CEE countries.

In general, countries with higher GDP per capita, higher productivity and economy's openness have on average higher volatility and lower persistence of the country factor (which is especially visible in the case of the Baltic countries). This outcome can be attributed to the fact that prices in those countries are more flexible (are changed more often than in e.g. in the euro area, compare results for Estonia obtained by Dabušinskas and Randveer, 2006). For small open economies quick adjustment to changing external economy is important factor that helps to maintain the competitiveness of the domestic companies. This higher elasticity of the domestic firms may steam from the lower menu costs. In contrast, companies in the big countries, especially those with the big domestic markets like Poland, can afford not to adjust so quickly to changing environment due to the domestic demand.

Additionally, in our research we check whether exchange rate regime plays a role. Countries with the fixed/pegged exchange rate (like Baltic countries or SI, BG) exhibit higher volatility of country specific components, what suggests that floating exchange rate and independent monetary policy may to some extent act as a shock absorber and prevent against sharp movements in price indices in the period of global perturbations.

Sector specific factors

Developments of food prices in countries of the CEE region are driven by the changes of the global commodity prices and also by domestic conditions. On one hand, growing importance of the world commodity markets and the increasing openness of the CEE economies causes stronger price reaction to the movements of the commodity prices. On the other hand, recent research on the sensitivity of the HICP components to the output gap in Poland provide evidence that more than half of food indices react to the changes in the domestic output gap (see Hałka and Kotłowski, 2013). Similar observation is valid for other non-durable goods, which include mainly the energy products. The prices in this sector are strongly determined by the developments of energy commodity prices (i.e. oil, gas and coal). The factors of second importance are producer prices (PPI) and unemployment in the euro area. Quite strong correlation with the PPI may be spurious, because PPI is strongly influenced by changes on the commodity market. However, the correlation with the economic conditions of the euro area proves that EA is an important partner for this sector.

The services group, according to the expectations, reveal the highest correlation with the unemployment, especially with the unemployment in the analyzed countries, though it is not a strong one. Services are rather a heterogeneous group which consists of components influenced by strong competition (like communication or insurance services) or administered to certain extent (like services related to dwellings). Such components hardly react to changes in external or domestic economy (compare Hałka and Kotłowski, 2013). Growing competitiveness and price deflation in some markets are common for the economies in transition.

Surprisingly, there is hardly no influence of the changes in the global or domestic economic activity on prices of durable and semi-durable goods. It is probably due to the fact, that HICP components that encompass this groups are goods which prices are influenced by the globalization process. Moreover, some of these goods are also under strong impact of the technological developments (e.g. telephone equipment). Both factors, globalization and technological development, entail lowering of prices no matter what is the phase of the business cycle.

5. Conclusions

In this paper we apply a new method of multi-level factor model to decompose the sources of time variation in a product-level inflation in each of 10 CEE countries. We decompose the inflation rates into CEE region-wide, sector, country and country-sector specific components.

We find that two regional factors explain about 17% of variance in monthly price changes. The contribution of regional component varies considerably between different countries and sectors. It is the most distinct determinant of inflation in Romania (explaining 55% of price variability), and the least important for Estonia (10%), the Czech Republic (8%) and Slovenia (6%). When the sectoral breakdown is concerned, the CEE-wide component explains on average from 11% of variance in food and non-durable sector to 24% in services being the most important price determinant in each of them. Less important are country (6.5%), sector specific (3.1%) and country-sector specific (9.6%) components. There are however single COICOP groups (liquid fuels, garments), where the contribution of the two latter sectoral factors exceeds 50% of variance in mom terms.

We also find the evidence that the regional component is very persistent (0.97 in terms of AR1) and the country component is quite persistent too (0.68), which is generally in line with similar studies for core EU countries. On the other hand, the average standard deviation of aggregate and country-sector specific components (about 0.2 pp. per month) is about twice as the volatility of country and sector-specific components. In general, high volatility of macroeconomic components relative to sectoral ones is a puzzling result in our study, which puts into the question the explanations provided by the model of rational inattention.

Moreover, our research shows that product-level price changes in CEE countries are more heterogeneous in terms of shock volatility across five sectors (e.g. services vs.

durable goods) than across ten countries. Such outcome may indicate the growing level of economic integration in CEE region. We find that inflation in different sectors is driven by very different forces; e.g. inflation in services is determined by unemployment rate, whereas in durable goods is influenced by the external inflationary processes such as globalization, level of inflation abroad. It means that sectoral shocks influence prices dynamics more than country specific shocks and each sector may react with a different scope and momentum to global disturbances.

The results also indicate that the first CEE-wide factor may be associated with the disinflationary processes that occurred in CEE countries, whereas the second regional factor reveals correlations with the global factors, especially commodity prices and euro area aggregate HICP inflation. Additionally there is a higher volatility of the country specific factors for countries with fixed exchange rate. Such outcome may mean that floating exchange rate serves as a shock absorber and hampers the volatility of the national prices.

As the sector specific factors are concerned prices of food and other non-durable goods (mostly energy goods) strongly depend on the commodity markets. Prices of services reveal the highest correlation with the unemployment in the analyzed countries, though it is not a strong one. Surprisingly, there is hardly no influence of changes in the global or domestic economic activity on prices of durable and semi-durable goods. Probably, it is due to the fact, that HICP components that encompass these groups are influenced by the globalization process, which leads to the price decreases regardless the phase of the business cycle.

We leave two interesting questions for the further research. The first one is whether there are some similarities between CEE and euro area countries in terms of product-level inflation rates and the second is on the stability of this relationship over time.

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Appendix 1 Decomposition results of the base case with two aggregate factors

Table 4 Descriptive statistics of all-item HICP country indices (log monthly changes, SA)

	BG	CZ	EE	HU	LT	LV	PL	RO	SI	SK
Descriptive statistics (inflation in terms of logarithmic mom changes)										
Mean	0.388	0.178	0.330	0.378	0.252	0.402	0.217	0.718	0.290	0.308
Median	0.308	0.153	0.320	0.353	0.199	0.414	0.204	0.557	0.291	0.263
St. dev.	0.556	0.328	0.404	0.501	0.432	0.381	0.252	0.633	0.372	0.401
Skewness	0.637	1.831	0.533	0.506	1.099	-0.031	0.368	1.240	-0.074	1.877
Kurtosis	4.7	12.8	5.8	3.6	5.8	6.1	3.3	4.2	2.9	14.0
AR1	0.341	0.227	0.411	0.595	0.347	0.233	0.401	0.652	0.211	0.280

Source: Own calculations.

Table 5 Volatility, persistence and variance explained by estimated factors, cross-country breakdown (log monthly changes)

	BG	CZ	EE	HU	LT	LV	PL	RO	SI	SK
Volatility (St. dev.)										
Aggregate	0.221	0.106	0.199	0.157	0.232	0.291	0.092	0.277	0.152	0.148
Country	0.112	0.082	0.154	0.134	0.131	0.145	0.086	0.081	0.161	0.104
Sector	0.162	0.085	0.169	0.090	0.126	0.168	0.071	0.067	0.178	0.101
Country-sector	0.201	0.126	0.217	0.135	0.166	0.228	0.095	0.127	0.256	0.154
Idiosyncratic	0.620	0.436	0.801	0.482	0.648	0.793	0.345	0.367	0.845	0.479
COICOP	0.232	0.189	0.281	0.193	0.253	0.317	0.152	0.133	0.252	0.212
Persistence (AR1)										
Aggregate	0.973	0.974	0.973	0.975	0.974	0.971	0.976	0.978	0.975	0.975
Country	0.698	0.635	0.621	0.660	0.690	0.592	0.883	0.849	-0.135	0.658
Sector	0.381	0.382	0.381	0.382	0.380	0.380	0.386	0.378	0.374	0.377
Country-sector	0.297	0.260	0.202	0.080	0.092	0.049	0.378	0.523	-0.021	0.367
Idiosyncratic	0.119	0.037	0.024	0.070	0.049	-0.010	0.139	0.234	-0.053	0.095
COICOP	0.153	0.146	0.149	0.148	0.147	0.148	0.151	0.148	0.144	0.148
Variance explained										
Aggregate	0.183	0.085	0.098	0.161	0.178	0.161	0.134	0.548	0.056	0.125
Country	0.046	0.047	0.040	0.090	0.041	0.044	0.196	0.036	0.037	0.062
Sector	0.037	0.028	0.037	0.027	0.032	0.039	0.029	0.015	0.034	0.032
Country-sector	0.078	0.087	0.095	0.082	0.082	0.079	0.089	0.060	0.100	0.092
Idiosyncratic	0.656	0.753	0.731	0.639	0.665	0.678	0.551	0.340	0.773	0.687
COICOP	0.107	0.134	0.112	0.110	0.110	0.118	0.117	0.056	0.080	0.147
Squared loadings at two aggregate factors										
Aggregate 1	0.059	0.051	0.023	0.112	0.065	0.020	0.074	0.484	0.031	0.081
Aggregate 2	0.180	0.053	0.104	0.063	0.174	0.208	0.084	0.043	0.032	0.058

Source: Own calculations.

Table 6 Volatility, persistence and variance explained by estimated factors, cross-sector breakdown (log monthly changes)

	Durables	Semi-durables	Non-durables	Food	Services
			Volatility (St. dev.)		
Aggregate	0.204	0.128	0.171	0.218	0.199
Country	0.116	0.076	0.136	0.180	0.096
Sector	0.094	0.069	0.263	0.169	0.060
Country-sector	0.183	0.124	0.235	0.252	0.106
Idiosyncratic	0.533	0.400	0.651	0.952	0.434
COICOP	0.199	0.128	0.265	0.406	0.146
			Persistence (AR1)		
Aggregate	0.976	0.975	0.973	0.974	0.974
Country	0.180	0.613	0.615	0.620	0.624
Sector	0.169	0.081	0.518	0.577	0.435
Country-sector	0.252	0.105	0.267	0.308	0.226
Idiosyncratic	0.952	0.009	0.081	0.124	0.066
COICOP	0.406	0.027	0.125	0.316	0.122
			Variance explained		
Aggregate	0.166	0.182	0.111	0.113	0.239
Country	0.059	0.065	0.067	0.056	0.069
Sector	0.022	0.024	0.061	0.043	0.015
Country-sector	0.111	0.090	0.093	0.097	0.058
Idiosyncratic	0.640	0.638	0.668	0.689	0.619
COICOP	0.107	0.098	0.119	0.134	0.097
			Squared loadings at two aggregate factors		
Aggregate 1	0.175	0.209	0.102	0.111	0.403
Aggregate 2	0.084	0.116	0.113	0.150	0.537

Source: Own calculations.

Appendix 2 Robustness analysis

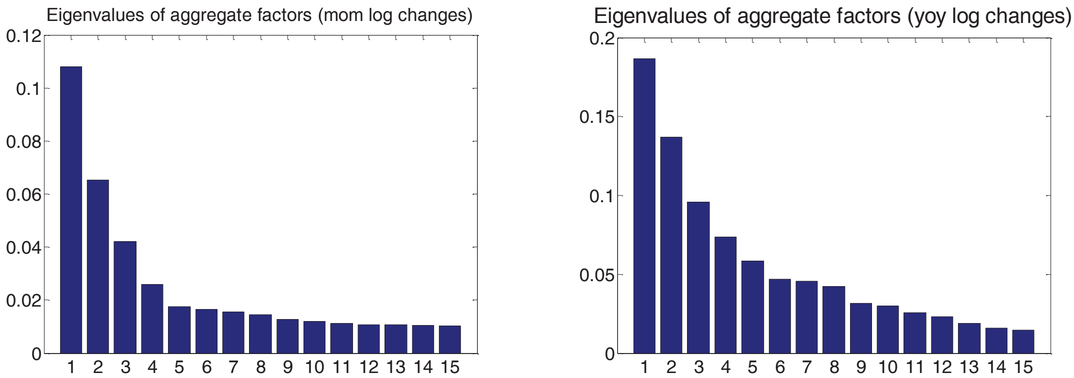

Figure 3 Scree plots of correlation matrix in a balanced panel of product-level HICPs

Source: Own calculations

Table 7 Volatility, persistence and fraction of variance explained by components of factor model decomposition with three aggregate factors (monthly log changes)

	Aggregate	Country	Sector	Country-sector	Idiosyncratic	COICOP
			Volatility (St. dev.)			
Mean	0.214	0.109	0.129	0.172	0.568	0.215
Median	0.177	0.068	0.043	0.094	0.392	0.123
Min	0.007	0.000	0.000	0.000	0.021	0.000
Max	1.083	1.305	3.390	1.800	4.514	3.474
St. dev.	0.150	0.139	0.293	0.224	0.601	0.331
			Persistence (AR1)			
Mean	0.960	0.423	0.470	0.190	0.056	0.139
Median	0.968	0.507	0.625	0.208	0.045	0.108
Min	0.907	-0.169	0.157	-0.282	-0.550	-0.302
Max	0.984	0.832	0.629	0.613	0.690	0.657
St. dev.	0.020	0.279	0.194	0.206	0.172	0.195
			Variance explained			
Mean	0.210	0.041	0.034	0.080	0.630	0.105
Median	0.128	0.020	0.009	0.043	0.661	0.081
Min	0.001	0.000	0.000	0.000	0.024	0.000
Max	0.916	0.310	0.634	0.588	0.989	0.529
St. dev.	0.216	0.052	0.076	0.095	0.221	0.103

Source: Own calculations.

Table 8 Volatility, persistence and fraction of variance explained by components of factor model decomposition (yoy log changes)

	Aggregate	Country	Sector	Country-sector	Idiosyncratic	COICOP
			Volatility (St. dev.)			
Mean	0.062	0.031	0.024	0.031	0.063	0.027
Median	0.029	0.014	0.009	0.015	0.035	0.013
Min	0.000	0.000	0.000	0.000	0.003	0.000
Max	0.414	0.225	0.199	0.234	0.336	0.253
St. dev.	0.086	0.040	0.033	0.039	0.062	0.034
			Persistence (AR1)			
Mean	0.991	0.971	0.955	0.927	0.779	0.889
Median	0.991	0.972	0.951	0.940	0.818	0.898
Min	0.986	0.949	0.935	0.727	-0.187	0.760
Max	0.997	0.990	0.969	0.976	1.142	0.959
St. dev.	0.004	0.013	0.012	0.045	0.148	0.041
			Variance explained			
Mean	0.323	0.126	0.058	0.115	0.378	0.097
Median	0.267	0.070	0.028	0.063	0.343	0.054
Min	0.000	0.000	0.000	0.000	0.010	0.000
Max	0.935	0.766	0.578	0.658	0.975	0.742
St. dev.	0.247	0.148	0.082	0.127	0.233	0.113

Source: Own calculations.

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