Whose Inflation Is It Anyway?

The Inflation Spillovers Between The Euro Area and Small Open Economies.

Aleksandra Halka*

Narodowy Bank Polski

Karol Szafranek†

Narodowy Bank Polski, Warsaw School of Economics

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Abstract

For the last two years inflation has been systematically falling across countries in the European Union and lately it exhibits rising deflationary pressures. Recent studies suggest that apart from global determinants influencing the broad inflation measures, e.g. the plummeting commodity prices, core inflation components are subjected to the rising influence of globalization. Our analysis focuses on two aspects: the extent of the HICP components infected with deflation and the spillovers of headline, core, non-energy goods as well as services inflation between the euro area and distinguished small open economies. In order to answer the question of inflation broadness we calculate the percentages of HICP components which dynamics fall into certain thresholds and introduce a simple measure - the Discrepancy Index showing the relative strength of deflationary and inflationary groups. To address the problem of quantifying the inflation spillovers across distinguished economies we use the Diebold and Yilmaz (2012) spillover indices. Results indicate that the share of deflationary groups for most countries has been consistently rising since 2010 with the Discrepancy Index approximating its all-time lows in the fourth quarter of 2014. Simultaneously we show that the volatility spillover index for non-energy industrial goods and services inflation has lately risen considerably with the measure for headline inflation remaining elevated and for core inflation dropping. The euro area remains a net volatility transmitter in most cases.

JEL: C32, C53, E31, E37

Keywords: inflation, spillovers, VAR, disaggregation, small open economy, euro area

I. Introduction and literature review

For the last two years inflation has been systematically falling in most countries with the euro area or CEE not being an exception. Moreover, over the last few months strengthening deflationary processes have been observed in many economies, among others in Poland but in the eurozone as well. This common for many economies development of the lowering of headline inflation is somewhat surprising as it coincides with the economic recovery, however muted. Simultaneously similar developments can be observed with the core inflation measures. Some researchers explain the headline inflation lowering only by the positive supply shock

*Electronic address: Aleksandra.Halka@nbp.pl; Postal address: ul. Swietokrzyska 11/21, 00-919 Warszawa; Telephone number: +48 22 185 28 37

†Electronic address: Karol.Szafranek@nbp.pl; Postal address: ul. Swietokrzyska 11/21, 00-919 Warszawa; Telephone number: +48 22 185 22 80

that economies face due to the lowering commodity prices from mid-2014. However, when investigating components of the inflation indices we can spot that not only food and energy prices are low and declining, but also prices of the other components.

Until the outbreak of the financial crisis inflation has been low and stable. This was often attributed to the fading influence of the domestic economic performance on inflation in many both developed and emerging economies. Growing linkages between countries through incorporating emerging economies into the global supply chains as well as liberalization of the international trade entailed increasing globalization, which resulted in the price movements tightening between countries and further disinflation and thus acting as a positive supply shock. Moreover globalization process applies not only to goods, but due to the technological development also to services. This phenomenon described as the flattening of the Phillips curve was proved by the outcomes of several researches, among others: Borio and Filardo (2007), Kuttner and Robinson (2010) as well as IMF (2014).

The importance of global factors shaping the inflation developments across countries is emphasized in many works. Borio and Filardo (2007) when studying the flattening of the Phillips curve argue that apart from the domestic factors, global factors play an important and growing role. They observe weakening relationship between domestic economic conditions and the inflation rate and conclude that the importance of the global output gap has risen between the 1980s and the 2000s. Moreover, they suggest that exchange rate pass-through becomes weaker, what is proved in estimates for Poland by Lyziak et al. (2014). Ciccarelli and Mojon (2010) find that nearly 70% of inflation variability is driven by the common, global factor. However, they also state that it is not clear whether it is a common global factor or whether domestic monetary policy in the OECD countries has become similar and synchronized. Anyhow, the presence of the globally shared determinant seems even more convincing in 2014-15, when a divergence in monetary policy of the US, Europe and Japan as well as some emerging markets is observed.

By and large, the researchers rather agree on the importance of common, global factors shaping inflation across countries. 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". By using a measure of "uniqueness" he shows that industrial economics hit with the same shock are characterized by correlated cyclical inflation rates. Similar results are obtained by Aastveit, Bjørnland, and Thorsrud (2011), who examine the influence of global and regional factors on the main macroeconomic variables (e.g. GDP, investment, inflation, employment) for small open economies. They conclude that foreign – world and regional – shocks explain ca. 50-70% of the analyzed variables total variability in 4 countries, but when accounting for additional shock – the oil shock – the variability explained is even bigger.

Contrary to the conclusions drawn above, Ball (2006) believes that globalization did not influence the structure of the Phillips curve or the long-run level of inflation. He suggests that changes of the import prices may have some effect on inflation, but only when they are abrupt. Further, Rogers (2007) finds, that price convergence in the euro area is influenced more by the "real" factors like VAT harmonization, decline in the income dispersion between the countries rather than by the trade flows or exchange rate stability.

Nevertheless globalization is surely one of the determinants that contributes to the observed low inflation. Another one is the current decline in the commodity prices. Interestingly, though a drop of oil and food commodity prices has been observed since the middle of 2014, the lowering and convergence of the inflation rates among European countries has been witnessed even earlier. This low inflationary pressure may be due to the encountered after the global crisis structural change in the economic process. Question may arise whether the European economy enters a prolonging period of anemic recovery when inflation will stay muted for several years. This view resurrected the hypothesis of secular stagnation first introduced by Alvin Hansen in 1938 (Hansen, 1939) that now gains renew attention (CEPR, 2014). However, whereas the concept seems unrealistic for the US experiencing a robust growth, Crafts (2014) argues that in Europe, and especially in the euro area, the risk of the secular stagnation to materialize is much higher due to unfavorable demographics, underperforming productivity growth, high public debt as well as ECB's reluctance to commence appropriate policy actions.

Putting the issue of secular stagnation aside, low inflation in many countries, especially in small and open economies, like the Czech Republic, Poland or Sweden may be imported from the bigger ones, like the euro area. This question was raised by Iossifov and Podpiera (2014). Using Phillips curve framework they analyze the spillovers effects of the low inflation from the euro area on the non-euro area countries. They distinguish between inflation targeters (like Poland, Sweden) and rigid exchange rate countries (like the Czech Republic). Their findings show that spillovers of the core inflation in the euro area to the variance of domestic countries for inflation targeters has increased since end-2011, especially in Poland. Moreover they also state that countries with pegged exchange rate tend to import more inflation (or deflation) and the higher share of the domestically consumed foreign value-added (e.g. the Czech Republic) the larger are the spillovers from the euro area. They confirm small, but positive influence of the euro area's inflation on the prices in Sweden. Similar tendencies have been observed in Asian countries. Osorio and Unsal (2013) state that inflation in countries in geographic proximity to the Chinese economy are affected by the inflation spillovers from China, both directly through the import prices and indirectly through the commodity prices.

In line with those results are also conclusions obtained by Auer and Sauré (2013). In their research conducted on the disaggregated producer prices for 21 OECD countries they conclude that growing international trade integration contributes to the increase of the price spillovers between the countries, hence making inflation more global.

Such low inflation poses a challenge for the policy makers. Firstly, because in many countries inflation is well below targets, what may induce negative economic consequences. Secondly, low level of inflation persists despite easing of the monetary conditions (QE in the US, in the UK, low interest rates, ZLB, in most of the European countries).

The aim of this research is to have a deeper insight how widely is low inflation in small open economies spread. We take into account the Czech Republic, Poland and Sweden, which are strongly connected with the euro area. Additionally we want to focus on the spillovers of the low inflation from the euro area into these economies.

In order to answer the question of the broadness of inflation we calculate the percentage of the harmonized index of consumer prices (HICP) components which dynamics is within certain thresholds (e.g. below zero), controlling for the weight of components in the consumption basket and then introduce a simple measure - the Discrepancy Index to show the relative strength of the distinguished extreme fractions. To address the problem of quantifying the spillovers of the inflation variation we use spillover measure proposed by Diebold and Yilmaz (2012) which is based on the forecast error variance decomposition in a generalized VAR framework. Although this method was developed to address the question of the spillovers in the financial markets, the authors stated that it can be used "to measure the spillovers in returns or return volatilities (or, for that matter, any return characteristic of interest)".

The rest of the paper is organized as follow. Section II is devoted to the description of the data and the methodology. In section III we describe the inflation evolution in the analyzed countries focusing mostly on recent developments. In particular we divide inflation indices into subcomponents and analyze if they display similar patterns. Section IV discusses the results of the calculated inflation spillover measures and section V concludes.

II. Data and methodology

In our study we employ the methodology of Diebold and Yilmaz (2012), hereafter DY, and construct a spillover index as well as additional spillover measures for different inflation indices of four distinguished economies. The spillover measures are based on the forecast error variance decompositions from a generalized vector autoregression.

Before incorporating the DY framework, in order to observe whether deflation is a widespread process in the economy – affects all goods and services in the country – we calculate the number of HICP categories which dynamics is within certain ranges. Then we express this number as a fraction of all categories and

normalize it from 0 to 1. We consider at most 94 categories[1] (HICP decomposed into 4 digits COICOP[2]) for each country for the y-o-y indices. We introduce three ranges: (1) $[-\infty \div 0)$ – to identify the fraction of HICP components actually facing deflation; (2) $[0 \div 4)$ – to identify the fraction of the aforementioned components with the dynamics that is considered neutral for the economy; in addition, financial markets do not regard the selected upper band as problematic supposing the cause of higher inflation dynamics is only temporary and does not lead to second round effects[3]; (3) $[4 \div \infty)$ – fraction of goods signaling more serious price developments that should be somehow addressed by the monetary councils otherwise it can lead to the beginning of more severe economic problems, like price-wage spiral. Finally, we introduce the Discrepancy Index (DI), which shows the difference between the fraction of components with "too high" inflation and fraction of goods with deflation interpreted by us as a relative strength of these two groups. We believe that in "normal" times this index should evolve around zero.

After studying the changing frequencies of groups with different inflation dynamics, we focus on measuring the dependencies in inflation measures between the euro area, Sweden, Poland and the Czech Republic. Firstly, by incorporating the HICP measure in the DY framework we look for the proof of importing inflation by small countries from the euro area. Secondly, we study the interdependence between the core inflation measured as HICP excluding energy and unprocessed food and suggest that the process of inflation convergence cannot be only attributed to global factors such as commodity prices but also the rising tradability of goods and services. Thirdly, we examine the transmission based on the inflation of non-energy industrial goods advocating the intensification of the globalization process as well as services inflation claiming the rising tradability of services.

We use monthly data on annual inflation of HICP, HICP excluding energy and unprocessed food, non-energy industrial goods and services for the euro area, Sweden, Poland and the Czech Republic. The data span the period January 1997 to December 2014 with the total of 216 observations for HICP and December 2000 to December 2014 for other inflation measures, with the total of 169 observations.

The DY spillover index is an extension of the Diebold and Yilmaz (2009) spillover index allowing not only to quantify the total spillovers but also to measure the directional spillovers due to the adoption of the generalized VAR framework of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998), hereafter KPPS. It eliminates the possible results dependence on the variable ordering (resulting from the Cholesky factor orthogonalization of VAR innovations). In order to adopt the DY methodology we start our estimating procedure by fitting a covariance stationary 4-variable VAR(p): $x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \epsilon_t$, where $\epsilon_t \sim (0, \Sigma)$ is a vector of independently and identically distributed disturbances. The moving average representation is $x_t = \sum_{i=1}^{\infty} A_i \epsilon_{t-i}$ with $N \times N$ matrices obeying the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \cdots + \Phi_p A_{i-p}$ with A_0 being the identity matrix and $A_i = 0$ for $i \leq 0$. Following DY we denote the KPPS H-step-ahead forecast error variance decompositions by $\theta_{ij}^{g}(H)$ for $H = 1, 2, \ldots$ and obtain (1):

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i^T A_h \Sigma e_j)^2}{\sum_{h=0}^{H} (e_i^T A_h \Sigma A_h^T e_i)} \tag{1}$$

where Σ is the variance matrix for the error vector ϵ, σ_{jj} is the standard deviation of the error term for the jth equation and e_i is the selection vector, with one as the ith element and zeros otherwise. Due to the fact that shocks to each variable are not orthogonalized, the contributions sum to the variance of the forecast error may not necessarily equal to 1. Therefore, DY normalize each entry of the variance decomposition matrix by

[1] For each country there are few not available series, like group "other insurances" for the Czech Republic or Sweden.

[2] The highest available disaggregation from the Eurostat. COICOP stands for Classification of Individual Consumption According to Purpose (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5)

[3] There is an ongoing debate if the target of 2% is not too low (Blanchard, Dell'Ariccia, and Mauro, 2010). E.g. Ball (2014) argues, that 4% target is not harmful for the economy, moreover it minimizes the problem of the zero lower bound policy which we are now facing. However there are other authors, who accept the problem of the zero lower bound (Coibion, Gorodnichenko, and Wieland, 2010), but suggest that instead of changing the target, central banks should adopt different monetary policy – price level targeting.

the row sum as (2):

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{2}$$

DY construct a total volatility spillover index (3) using the volatility contributions from the KPPS variance decomposition:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \cdot 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}} \tilde{\theta}_{ij}^{g}(H)}{N} \cdot 100 \tag{3}$$

DY underline that the use of generalized VAR framework enables them to learn about the direction of the volatility spillovers due to the insensitivity to the ordering of variables. Therefore additional measures are introduced such as, the directional volatility spillovers received by market i from all other markets j (4):

$$S_{i\cdot}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \cdot 100 = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \cdot 100 \tag{4}$$

directional volatility spillovers transmitted by market i to all other markets j (5):

$$S_{\cdot i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \cdot 100 = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} \cdot 100 \tag{5}$$

net volatility spillover from market i to market j (6):

$$S_{i}^{g}(H) = S_{\cdot i}^{g}(H) - S_{i\cdot}^{g}(H) \tag{6}$$

and the net pairwise volatility spillover between market i and j (7) as the difference between the gross volatility shocks transmitted from market i to market j and those transmitted from j to i:

$$S_{ij}^{g}(H) = \left(\frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{i,k=1}^{N} \tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{j,k=1}^{N} \tilde{\theta}_{jk}^{g}(H)} \right) \cdot 100 = \frac{(\tilde{\theta}_{ji}^{g}(H) - \tilde{\theta}_{ij}^{g}(H))}{N} \cdot 100 \tag{7}$$

In order to exclude the possibility of a small country's inflation influencing the inflation of a much bigger economy we impose zero restrictions on the parameter matrices Φ_i. In other words, in our framework we (*i*) do not allow for lagged inflation measures in the Czech Republic, Poland and Sweden to influence the current inflation measure in the euro area, (*ii*) reject the possibility of influencing the current inflation in Sweden by the lagged inflation in Poland and the Czech Republic, (*iii*) eliminate the chance of the lagged Swedish inflation measures influencing the Czech's and Polish ones. The lag order p of the VAR model is optimized by the Schwarz criterion (maximal lag is set to 13 in order to look for potentially significant base effects[4]). After fitting the optimal VAR model we incorporate the DY framework and compute the total spillover index as well as the directional volatility spillovers received by market i from all other markets j, directional volatility spillovers transmitted by market i to all other markets j, net spillovers and net pairwise spillovers. Having in mind the complexity of inflation processes and the unlikelihood of a single, fixed in time parameter properly reflecting the time-variant structure of the volatility spillovers in inflation across countries we estimate the spillover measures in the whole sample as well as in a seven-year rolling window. Whilst measuring the inflation interdependence between countries based on full sample provides us with a valuable description of the average spillovers interplay, estimating the volatility spillovers in a rolling framework enables us to assess the nature and spillover variability over time, evaluate the influence of the disinflation processes in the Czech Republic and Poland, measure the extent to which the global crisis changed the interconnectedness of inflation processes and finally equip us with conclusions regarding the convergence of inflation measures across countries.

[4]The results in the rolling window estimation suggest that the optimal lag structure should equal maximally 2 suggesting that the use of annual inflation measures does not incorporate the risk of long lag structure of the VAR framework.

Lastly, the computed volatility measures can be dependent on the forecast horizon (forecast error variance decomposition is defined as the proportion of the H-step ahead forecast error variance of variable i which is accounted for by the innovations in variable j in the VAR). For robustness check we perform a sensitivity analysis of the results to the choice of the forecast horizons. Therefore, in our base scenario we use forecast horizon H equal to 48 months and compute also the measures for forecast horizons equal to 24, 36, 60 and 72 months having in mind the high inflation persistence (Fuhrer, 2010). Then we use the maximal and minimal values of the spillover measures from models with different forecast horizon as the quasi confidence intervals to check for significance[5]. Results of the sensitivity analysis are put on the graphs as grey areas around the base scenario as well as in tables in square bracket.

III. Inflation developments

When analyzing inflation processes in our sample we can distinguish between countries that faced a disinflationary period (the Czech Republic and Poland) and countries where price development was relatively stable (the euro area, hereafter the EA, and Sweden). In Poland and the Czech Republic disinflationary process ended around 2001. Since then, with an exception for 2008 in the Czech Republic the HICP inflation stayed below 5%. Moreover, headline inflation in these economies was very volatile (in the whole sample over three times larger than in the EA or Sweden). On the contrary Sweden and the EA are stable, developed economies in which inflation in the whole period stayed below 4.5% and was relatively unchanging (compare Table 1). After the EU enlargement the inflation rates between the Czech Republic and Poland along with the EA has become more synchronized. Similar developments can be observed for core inflation (inflation excluding energy and unprocessed food) or services inflation.

Table 1: Summary statistics for the HICP, HICP excluding energy and unprocessed food, non-energy industrial goods inflation and services inflation

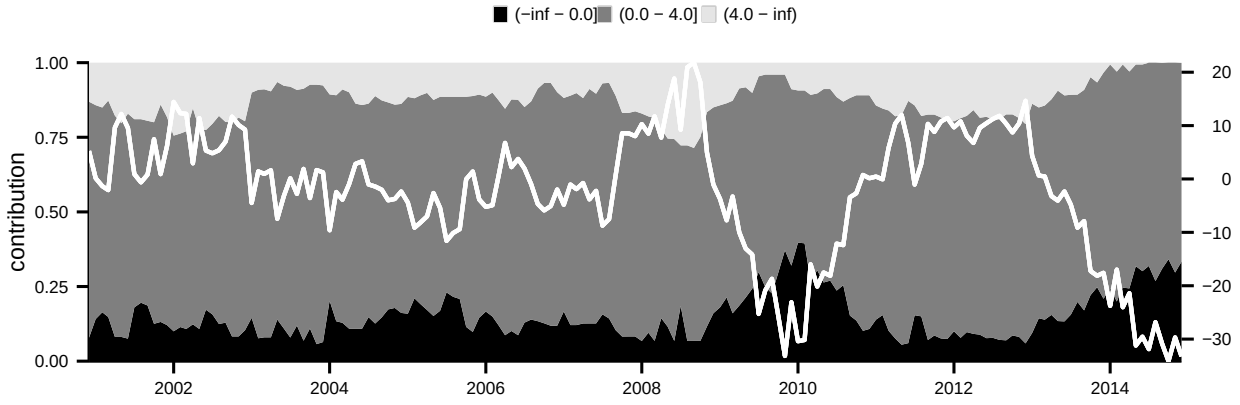
	HICP				HICP excluding energy and unprocessed food				Non-energy industrial goods				Services			
	1997:01 - 2014:12				2002:01 - 2014:12				2002:01 - 2014:12				2002:01 - 2014:12			
	EA	SWE	PL	CZK	EA	SWE	PL	CZK	EA	SWE	PL	CZK	EA	SWE	PL	CZK
Mean	1.9	1.5	4.5	3.0	1.7	1.2	2.2	1.8	0.7	-0.1	0.6	-1.1	2.1	2.0	3.1	3.2
Median	2.0	1.4	3.6	2.3	1.7	1.1	2.1	1.3	0.8	-0.2	0.3	-1.2	2.1	1.9	2.6	3.1
Std. deviation	0.8	0.9	4.1	2.8	0.5	0.7	1.5	1.5	0.4	1.0	1.6	1.1	0.6	0.7	1.7	1.9
Minimum	-0.6	-0.4	-0.6	-0.6	0.7	-0.1	0.1	-0.5	-0.2	-1.8	-1.8	-2.9	1.0	0.2	0.9	-0.1
Maximum	4.0	4.2	17.9	12.5	2.7	2.8	8.7	7.2	1.8	2.9	6.3	1.1	3.3	4.0	10.6	7.8
Range	4.6	4.6	18.5	13.1	2.0	2.9	8.6	7.7	2.0	4.7	8.1	4.0	2.3	3.8	9.7	7.9
Skewness	-0.3	0.6	1.3	1.4	-0.1	0.3	1.0	1.4	0.0	0.8	1.1	0.2	-0.1	0.3	1.7	0.6
Kurtosis	0.3	0.1	1.1	1.8	-0.9	-0.9	1.7	1.9	-0.4	0.2	1.2	-1.3	-0.9	0.2	3.3	-0.2

Whereas the aggregate inflation dynamics between countries has been converging (compare Figure 17), the price dynamics of non-energy industrial goods in each analyzed country displays different pattern (Figure 19). Whilst in the Czech Republic and Sweden have been visible long periods of negative inflation, in Poland these periods were much shorter, and in the EA there were hardly any. Moreover periods of high inflation in one country coincide with relatively low inflation in another. Particularly vivid example is year 2004 for Poland and the Czech Republic. During that time in Poland, due to VAT adjustment to the UE requirements, non-energy industrial goods inflation was high and in the Czech Republic it was in the negative territory (as a result of very low telephone and telefax equipment). At the same time in the EA non-energy industrial goods inflation was low and stable.

[5] We are fully aware that such construction cannot be interpreted as a confidence interval. However, the width of the interval suggest the sensitivity to different model specifications and the inclusion of zero by said quasi confidence interval can indicate that the relation is insignificant in the analyzed period.

Years 2013-2014 have shown declining inflation which turned into deflation in 2014 in many European countries. The majority of the economists attribute this process to the plummeting oil and food commodity prices. While this drop is observed since mid-2014 inflation has been declining since the beginning of 2012. The deflation or low inflation in 2014 in the European countries is mostly driven by negative dynamics of energy and food prices. However, core inflation (inflation excluding energy and unprocessed food) is also very low, well below 1% (with an exception of the Czech Republic, where it amounts to around 1%, compare Figure 18). The main driver of low core inflation is the inflation of tradables (goods) which is in negative territory in Poland, Sweden and the euro area. Again the Czech Republic is an exception. Czech's tradable's inflation is rising, and in mid-2014 reached positive numbers. This may be attributed to Czech National Bank decision regarding pegging the Czech koruna at the end of 2013.
After the outbreak of the crisis Sweden was importing low inflation. Firstly, Swedish krona has appreciated with the beginning of the euro area's crisis as a resulf of perceiving Swedish currency as a "save heaven". Secondly, major Swedish trading partners[6] were facing lowering inflation. Lower import prices induced higher competition on the domestic market and hence lowered Swedish inflation. In addition, inflation expectations in Sweden are declining what makes it more difficult for the Riksbank to achieve the inflation target. Similarly as in Sweden, in Poland this disinflationary trend is motivated by the import of low prices from abroad. However Polish exchange rate was relatively stable during last years. In all countries services inflation is positive, though it is relatively low fluctuating between 1% and 2% (compare Figure 20).
This inflation outlook suggests that nowadays we are facing widely spread lowering of inflation. Firstly, inflation has been declining because of plummeting oil and food prices since mid-2014. Secondly, non-energy industrial good in most countries face negative numbers as they are tradable and influenced by the globalization. Lastly, also services inflation is relatively low, when comparing to the previous years, what may steam from the growing importance of globalization coupled with a slow growth of the unit labor costs.
Having that in mind we look deeper into the HICP components of the analyzed countries and establish the percentage of HICP components within specified ranges. Figures 1– 4 illustrate these results.

Figure 1: The Discrepancy Index (white line, right axis) and the percentage of HICP components within the specified range for the EA



First of all, for the developed economies (the EA and Sweden) we observe that the fraction of goods with the dynamics within the optimal intervals (i.e. $0\% \div 4\%$) is relatively stable, with the significant drop before the onset of the financial crisis. However this drop is only temporal and abates within one year. On the contrary in the Czech Republic and Poland this fraction is far more volatile. This may indicate ongoing price convergence in those countries and a higher sensitivity of the price decision making to the external shocks in comparison with the developed economies.

[6] Almost 50% of the Swedish import is from the EA.

Figure 2: The Discrepancy Index (white line, right axis) and the percentage of HICP components within the specified range for Sweden

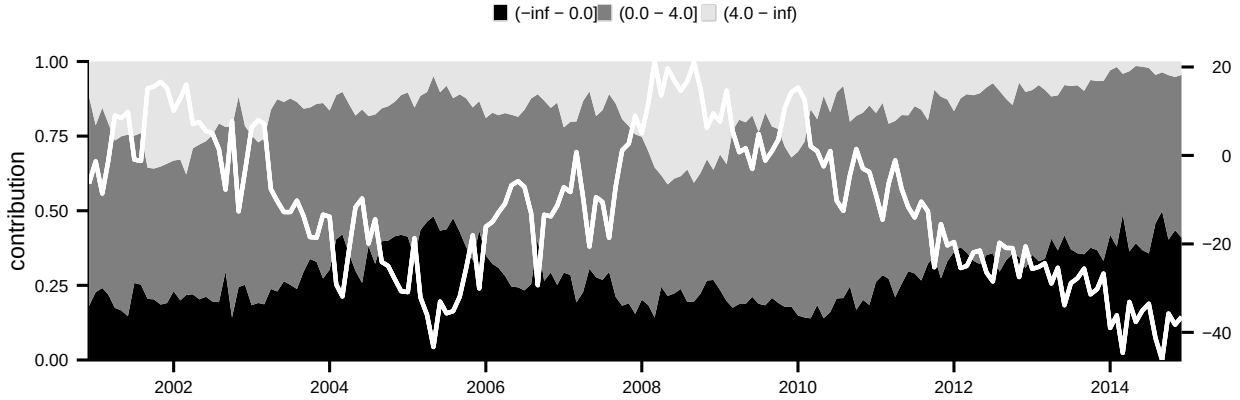


Figure 3: The Discrepancy Index (white line, right axis) and the percentage of HICP components within the specified range for Poland

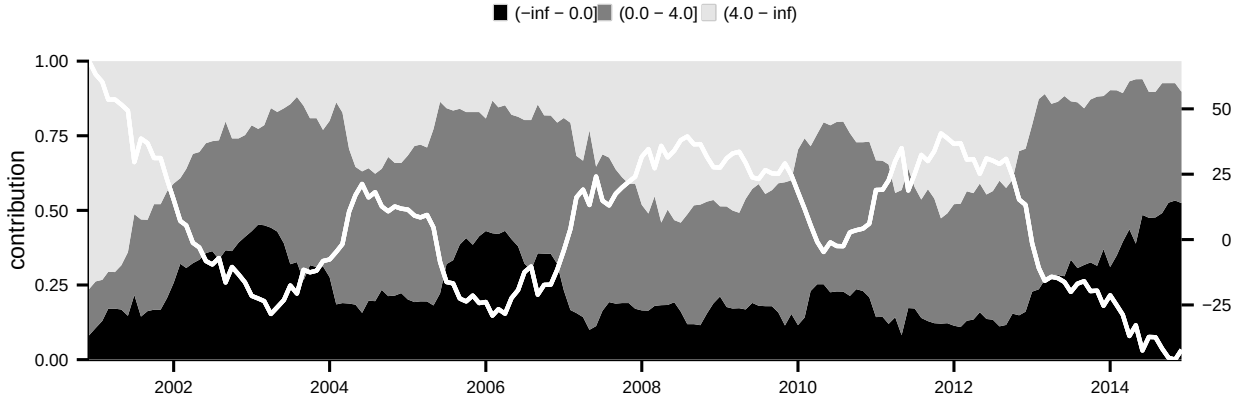
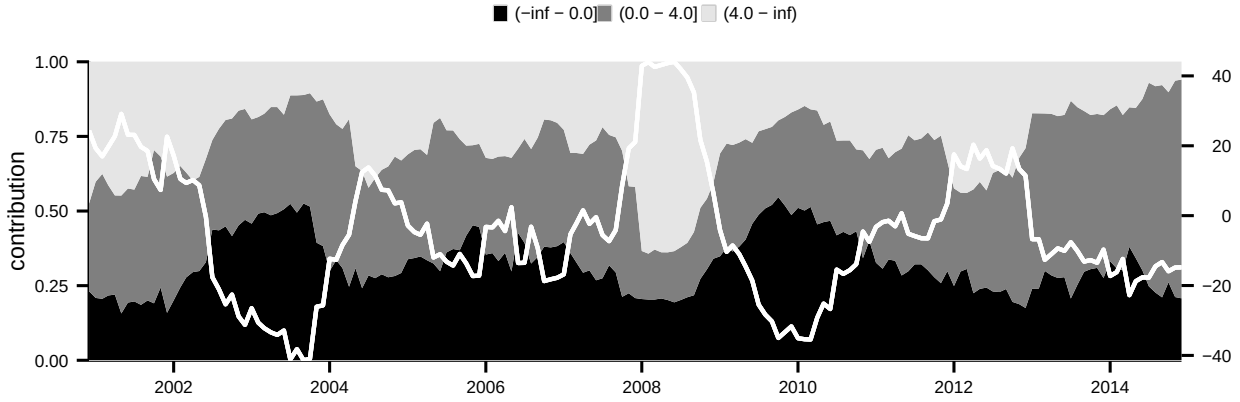


Figure 4: The Discrepancy Index (white line, right axis) and the percentage of HICP components within the specified range for the Czech Republic



Together with the gradual drop of inflation we can notice rising percentage of the components which dynamics is below zero. In the EA, Sweden and Poland the percentage of the components with deflation is the highest in Q4 2014 and amounts to, respectively, 33.3%, 41.0% and 52.4% suggesting rising deflationary pressures. Additionally, in all countries the percentage of the components above 4% is the lowest and the contributions of highly dynamic groups seem to be sharply falling recently. The results for the Czech Republic may be somewhat puzzling as the highest percentage of the components facing deflation was in 2009 and in 2014 a

negative trend of components experiencing deflation is observed. Nevertheless we have to take into account, that since 2009 the Czech's economy was facing several VAT rises[7]. This baffling behavior of inflation components in Czech Republic may be also attributed to the CNB's decision to introduce an asymmetric exchange rate which aim was to prevent Czech's inflation to fall below zero and to reach the target.
All in all, the fraction of the components with the dynamics above 4% in 2014 in all analyzed countries is the lowest in the history, with the EA having this number close to zero, Sweden approximately 5% and the Czech Republic and Poland around 10%. Such outcomes indicate that observed low inflation it these countries is widely spread across the whole economy.
The abovementioned observations are confirmed by the behavior of the Discrepancy Index (DI). On the verge of the financial crisis in all countries the DI heavily rose. However after the Lehman Brothers collapse its tendency was different among the distinguished countries. In the EA and the Czech Republic the DI fell below its initial values, what was in line with the changes of the commodities' prices. Afterwards it rose again and stabilized on the elevated level until 2012. In Poland due to a strong depreciation of the Polish zloty[8], the drop of the DI was not so significant. From 2012 on, the DI has been continuing its way down until the end of the 2014 in Poland and in the EA amounting to -42,2 and -33,2, respectively, while in the Czech Republic since 2013 it has stabilized around -15. In Sweden the pattern was somewhat different, as the DI after the onset of the financial crises started its way down and continues this trend systematically up to now achieving the level of -36,5.
The stable values of the DI since 2013 in the Czech Republic can be attributed to the CNB monetary policy, which, in order to prevent from the fall of the inflation below zero, introduced asymmetric exchange rate target (to prevent Czech koruna to appreciate). Although this policy helped to hold back further decline of the inflation, due to the plummeting of oil prices inflation in the Czech Republic is still very low (0,1% y-o-y in January 2015). However this unconventional policy helped to hamper the DI to fall deeper.

IV. Results

In this section we analyze the results of the model based on the DY methodology. In particular we focus on the whole-sample analysis informing about the average spillovers throughout the sample as well as the rolling-sample outcomes indicating the changing patterns of inflation spillovers.

IV.I. Average spillovers throughout the sample

We start the analysis of the results by exploring the outcomes on the whole sample summarizing the average volatility spillover behavior between the inflation measures for different measures. Tables 2–5 present the volatility spillover matrices estimated on the whole sample. The ijth element of each matrix presents the estimated contribution to the forecast error variance of the economy i coming from the innovations to the market j (equation 2). Consequently, the off-diagonal sum of elements in each row represents the directional spillovers from other countries to the country i (equation 4) and the off-diagonal sum of elements in each column represents the directional spillovers to others from the j economy (equation 5). The total spillover index, hereafter TVSI, is presented in the bottom-right corner (equation 3). On the basis of the volatility matrix one can easily compute net volatility spillovers as the difference between the directional spillovers transmitted to others and the directional spillovers received from others (equation 6) as well as the net pairwise volatility spillovers (for the ijth pair it's the difference between the jith and the ijth element of the volatility spillover matrix, equation 7). Lastly, to demonstrate the stability of the estimated conditional on the chosen horizon H minimal and maximal estimates from the models with different horizons are introduced in square brackets.

[7] By 1 pp. in 2010, by 1 pp. for the standard rate and 4 pp. for reduced rate in 2012 and in 2013 by 1 pp.
[8] Złoty depreciated by 50%, whereas Czech koruna by 25% and Swedish korona by 23%

Consider first what can be observed from Table 2 presenting the volatility spillovers of the HICP measure of the chosen economies. The TVSI amounts to somewhat 33,3% indicating that within the whole sample almost one third of the total forecast error variance in four countries comes from spillovers suggesting the intermediate interconnectedness of the chosen European economies. Not surprisingly, the EA is the net volatility transmitter over the full sample, although the difference is not significantly greater than zero (1,7%). Compared to low net volatility spillovers of the EA and Sweden (0,4%), Poland is quite big volatility transmitter (28,5%), with the majority of it received by the Czech Republic, which is consistent with the economic relations between these two countries.

Table 2: Volatility spillovers table for the HICP for the euro area, Sweden, Poland and the Czech Republic

	Volatility spillovers table: HICP				
	EA	SWE	PL	CZK	From others
EA	62.286	18.474	7.106	12.133	37.714
	[62.286 - 62.286]	[18.474 - 18.474]	[7.106 - 7.106]	[12.133 - 12.133]	[37.714 - 37.714]
SWE	16.816	72.820	3.822	6.541	27.180
	[15.713 - 17.065]	[72.517 - 74.203]	[3.719 - 3.843]	[6.365 - 6.575]	[25.797 - 27.483]
PL	3.085	1.639	88.179	7.097	11.821
	[2.682 - 4.555]	[1.576 - 2.028]	[85.083 - 89.682]	[5.694 - 8.333]	[10.318 - 14.917]
CZK	19.521	7.481	29.423	43.574	56.426
	[16.460 - 19.751]	[6.660 - 7.529]	[25.763 - 30.053]	[42.667 - 51.116]	[48.884 - 57.333]
To others	39.422	27.595	40.352	25.771	TVSI: 33.285
	[35.063 - 41.370]	[26.869 - 28.031]	[36.589 - 41.002]	[24.192 - 27.042]	[30.678 - 34.361]

Secondly consider the dependencies of the volatility spillovers measured on the core inflation indices, measured as the HICP excluding energy and unprocessed food, presented in Table 3. There is a notable discrepancy between the estimates for the HICP inflation and the core inflation measure. Firstly, we observe the lowest level of the TVSI among investigated measures amounting only to somewhat 11%. Secondly, the estimated contribution to the forecast error variance of the economy coming from the domestic innovations is in all cases predominant suggesting that core inflation is driven mainly by domestic factors rather than imported. As a result the directional volatility spillovers are very low in the whole sample with the EA, Sweden and the Czech Republic as volatility transmitters and Poland as a receiver. Moreover, both in the net terms as well as in net pairwise terms the contributions remain low. These low figures give us an incentive to further disaggregate the core inflation measure into non-energy industrial goods and services.

Table 3: Volatility spillovers table for the HICP excluding energy and unprocessed food for the euro area, Sweden, Poland and the Czech Republic

	Volatility spillovers table: HICP excluding energy and unprocessed food				
	EA	SWE	PL	CZK	From others
EA	92.093	7.245	0.000	0.662	7.907
	[92.093 - 92.093]	[7.245 - 7.245]	[0.000 - 0.000]	[0.662 - 0.662]	[7.907 - 7.907]
SWE	3.132	96.854	0.011	0.003	3.146
	[2.740 - 3.312]	[96.673 - 97.247]	[0.011 - 0.011]	[0.002 - 0.004]	[2.753 - 3.327]
PL	4.376	0.440	81.718	13.465	18.282
	[3.779 - 4.541]	[0.390 - 0.454]	[81.556 - 82.379]	[13.450 - 13.474]	[17.621 - 18.444]
CZK	2.432	0.163	12.480	84.925	15.075
	[2.403 - 2.522]	[0.161 - 0.170]	[11.849 - 12.518]	[84.790 - 85.494]	[14.506 - 15.210]
To others	9.940	7.848	12.490	14.131	TVSI: 11.102
	[9.009 - 10.375]	[7.801 - 7.869]	[11.860 - 12.529]	[14.115 - 14.139]	[10.697 - 11.222]

Consider now the volatility spillovers for the non-energy industrial goods inflation presented in Table 4. Basically, the diagonal elements for the EA, Sweden and the Czech Republic remain high suggesting a heavier impact of the domestic non-energy industrial goods variability. However, this is not the case for Poland as estimated contribution to the forecast error variance of the Polish economy coming from the domestic innovations is comparable to the one coming from the EA. This in turn advises the importing of the inflation

patterns from the EA by the Polish economy. Again, the EA is in the whole sample a net volatility transmitter to small open economies: Poland and the Czech Republic. The study of the net pairwise volatility spillovers suggest that the EA is a net volatility transmitter to other countries (with Sweden hardly departing from 0), Sweden is a minor volatility transmitter to Poland and the Czech Republic and Poland also receives volatility from the Czech Republic to a minor extent. Interestingly, the TVSI for the non-energy industrial goods is lower than for the headline inflation but higher than the core measure and amounts to somewhat 20%, which advocates the necessity of disaggregation of the core inflation.

Table 4: Volatility spillovers table for the non-energy industrial goods inflation for the euro area, Sweden, Poland and the Czech Republic

Volatility spillovers table: non-energy industrial goods inflation					
	EA	SWE	PL	CZK	From others
EA	96.449	2.425	1.118	0.007	3.551
	[96.449 - 96.449]	[2.425 - 2.425]	[1.118 - 1.118]	[0.007 - 0.007]	[3.551 - 3.551]
SWE	2.548	97.191	0.099	0.163	2.809
	[2.332 - 2.551]	[97.188 - 97.406]	[0.099 - 0.099]	[0.163 - 0.163]	[2.594 - 2.812]
PL	44.665	2.282	44.142	8.911	55.858
	[42.202 - 44.665]	[2.168 - 2.282]	[42.288 - 50.992]	[4.638 - 11.297]	[49.008 - 57.712]
CZK	14.274	1.385	0.187	84.155	15.845
	[13.043 - 14.278]	[1.351 - 1.385]	[0.169 - 0.231]	[84.131 - 85.416]	[14.584 - 15.869]
To others	61.487	6.092	1.404	9.080	TVSI: 19.516
	[57.578 - 61.487]	[5.944 - 6.092]	[1.386 - 1.448]	[4.808 - 11.467]	[17.434 - 19.981]

Finally we look at the spillover process between the services inflation among studied economies. The results are presented in Table 5. This time the diagonal elements are more consistent across countries but again the Polish economy is affected the most by its environment (the diagonal element is the lowest for Poland). Once again, the EA is a net volatility transmitter with Sweden and the Czech Republic receiving the most volatility. Moreover, in the net pairwise terms all countries import volatility from the EA. The relationship between Sweden and chosen CEE countries is negligible which is consistent with their weak economic connection. Once more, a positive relationship is established between Poland and the Czech Republic with the former mentioned receiving volatility from the latter. The TVSI is marginally higher than the one for non-energy industrial goods signaling the rising globalization of services. As it turns out, by aggregating the non-industrial goods and services into the core measure a valuable information regarding the spillovers between core inflation components is lost.

Table 5: Volatility spillovers table for the services inflation for the euro area, Sweden, Poland and the Czech Republic

Volatility spillovers table: services inflation					
	EA	SWE	PL	CZK	From others
EA	85.827	9.951	0.966	3.257	14.173
	[85.827 - 85.827]	[9.951 - 9.951]	[0.966 - 0.966]	[3.257 - 3.257]	[14.173 - 14.173]
SWE	22.249	76.268	0.132	1.350	23.732
	[19.747 - 22.488]	[76.020 - 78.881]	[0.101 - 0.135]	[1.272 - 1.358]	[21.119 - 23.980]
PL	2.718	0.444	70.130	26.707	29.870
	[1.254 - 3.031]	[0.251 - 0.482]	[69.818 - 72.359]	[26.137 - 26.707]	[27.641 - 30.182]
CZK	14.508	2.002	6.692	76.798	23.202
	[10.858 - 14.994]	[1.570 - 2.058]	[6.644 - 7.049]	[76.305 - 80.523]	[19.477 - 23.695]
To others	39.475	12.397	7.789	31.315	TVSI: 22.744
	[31.858 - 40.513]	[11.772 - 12.491]	[7.744 - 8.115]	[30.665 - 31.315]	[20.603 - 23.008]

Several conclusions are to be drawn from this section. Primarily, the total volatility spillover index and the directional spillovers are the highest for the headline measures suggesting quite robust interdependence of the inflation measures across investigated countries over the full sample. The TVSI is lowest for the core inflation measures signaling the importance of domestic factors shaping core inflation. However, even in these measure we observe some spillover effects, which is visible after the core measure disaggregation. Secondly, spillover

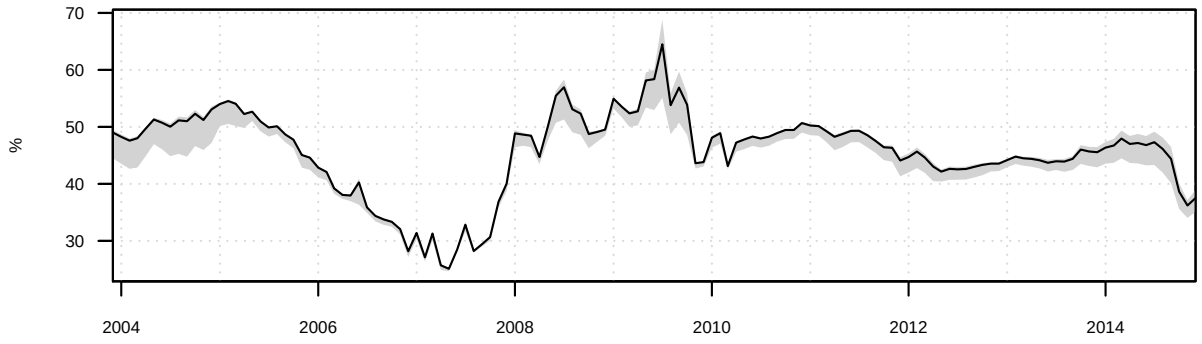
indices for non-energy industrial goods inflation and services inflation are close to each other showing some process of volatility transmission, however hesitant. Thirdly, in all cases the EA is a net volatility transmitter, which can be interpreted as importing the inflation by small economies and the Polish economy seems to be affected the most by other countries. Fourthly, the quasi confidence intervals are narrow suggesting the insensitivity of the results to the chosen horizon. Finally, in terms of net pairwise volatility spillovers all countries are connected with the EA, whereas there is no considerable connection between the chosen CEE countries and Sweden. Due to their proximity the Polish and Czech's economy are also more connected.

IV.II. Rolling-window spillovers estimates

Undoubtedly, 1997-2014 has been a period of rapidly changing economic environment. During that time inflation fluctuated considerably due to the presence of several important factors like the burst of the dot-com bubble and global slowdown of the early 2000s, robust economic growth preceding the outburst of the financial crisis in the US and the sovereign debt crisis in Europe, drastic commodity price swings as well as ongoing lethargic recovery of the European economy. In the background of the major macroeconomic events increased linkages between economies firmed as globalization of the economies advanced. Hence, the analysis of the single, fixed parameter may lack important information such considering the evolution and turbulence of the inflationary processes. Therefore, we produce the estimates in the rolling window and analyze the results here. We begin our analysis of the rolling window estimation by comparing the total volatility spillover indices for the selected inflation measures. Just for clarity we note that a point estimate of the rolling-window TVSI is attributed to the ending date of the period its calculated for.

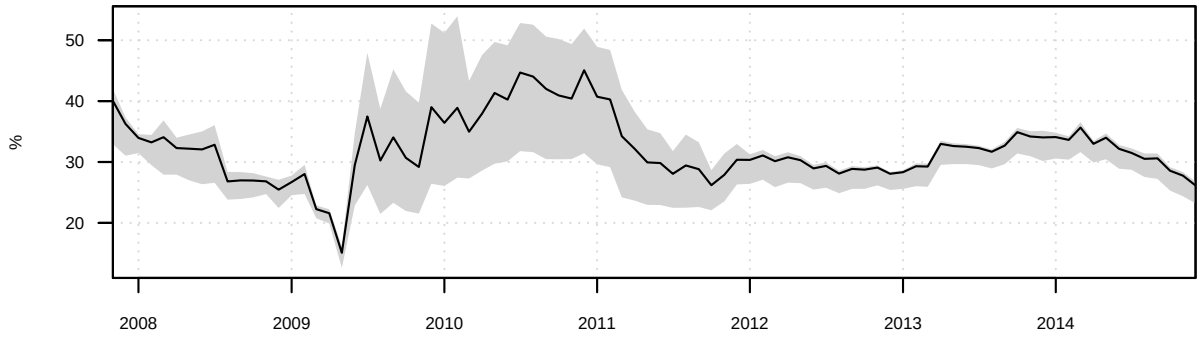
Consider first the rolling TVSI for the HICP across countries. When looking on Figure 5 one can easily distinguish four periods. During 2004-2005 the TVSI remained elevated around 50% but stable. In years 2006-2007 it systematically trends downwards achieving its minimum in the first half of 2007. On the verge of the financial crisis outburst it rises dynamically signaling major inflation interdependence between countries – around 65% of the forecast error variance came from spillovers in the second half of 2009. Duly noted should be also that the index remains elevated after the crisis oscillating in the channel between 40 and 50 per cent until the second half of the 2014, when it falls presumably due to the rising influence of the plummeting commodity prices. Moreover, the sensitivity to the chosen horizon is overall negligible, however the period of CEE's countries disinflation process and the period of global financial crisis are subjected to greater instability of estimates.

Figure 5: The rolling-window total volatility spillover index for HICP



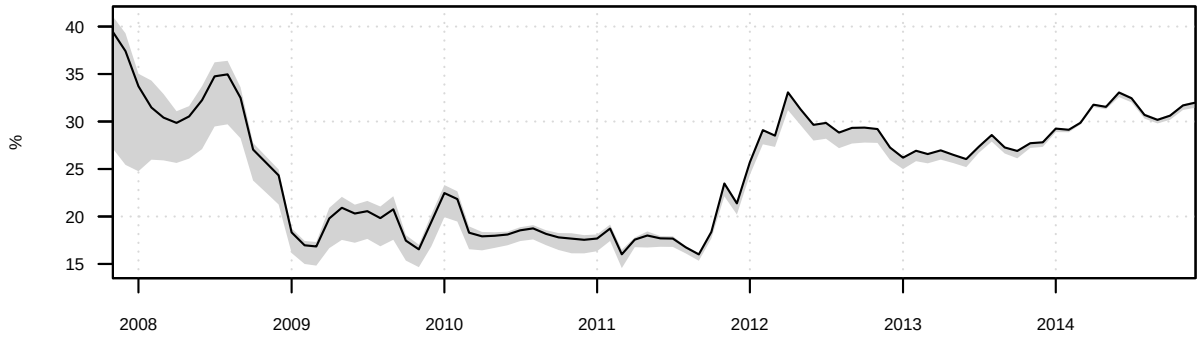
Consider now the rolling TVSI for the core inflation shown on Figure 6. The spillovers diminished significantly during the first year of the crisis to below 20% suggesting the rising importance of domestic factors shaping the core measure. However, the index rebounds in the second half of 2009 and remains elevated around its initial level until 2011. The proportion of the forecast error variance stemming from spillovers oscillates afterwards around 30% and has recently slightly dropped. Worth noticing is the rising sensitivity to the chosen horizon during the recession.

Figure 6: The rolling-window total volatility spillover index for HICP excluding energy unprocessed food



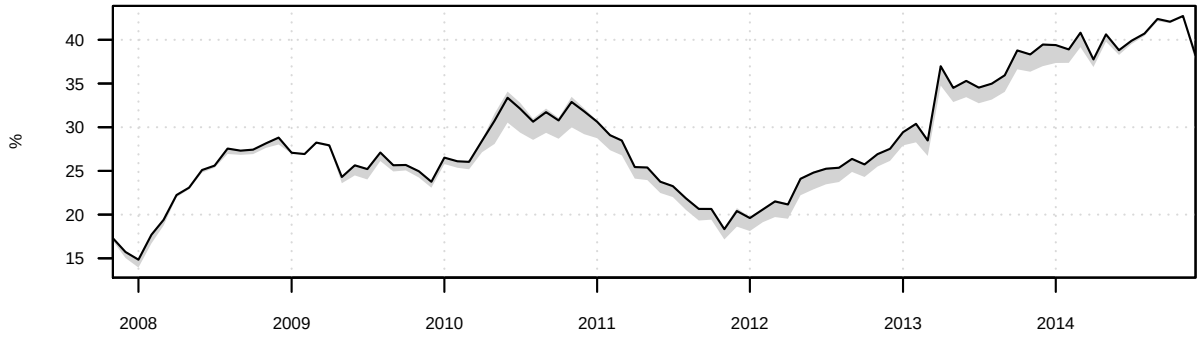
The faltering trade relations between countries during the financial crisis find their confirmation in the rolling TVSI for the non-energy industrial goods presented on Figure 7. The index diminishes substantially in 2008 to around 15% and remains in that area fluctuating until the second half of the 2012. Initially the sensitivity bands of the drop are widespread but they gradually tighten. The second half of the 2011 and the first half of 2012 brings revival to the international trade among countries with the TVSI doubling.

Figure 7: The rolling-window total volatility spillover index for non-energy industrial goods inflation



Lastly, presented on Figure 8 path of the TVSI for services seems to be especially interesting. The index establishes its minimum in the beginning of the 2008 and then more than doubles itself in 2010. It falls again in 2011 to its local minimum and rises significantly since then to somewhat 40% suggesting that now around 40% of the forecast error variance comes from spillovers. That in turn could be interpreted as the rising globalization of services.

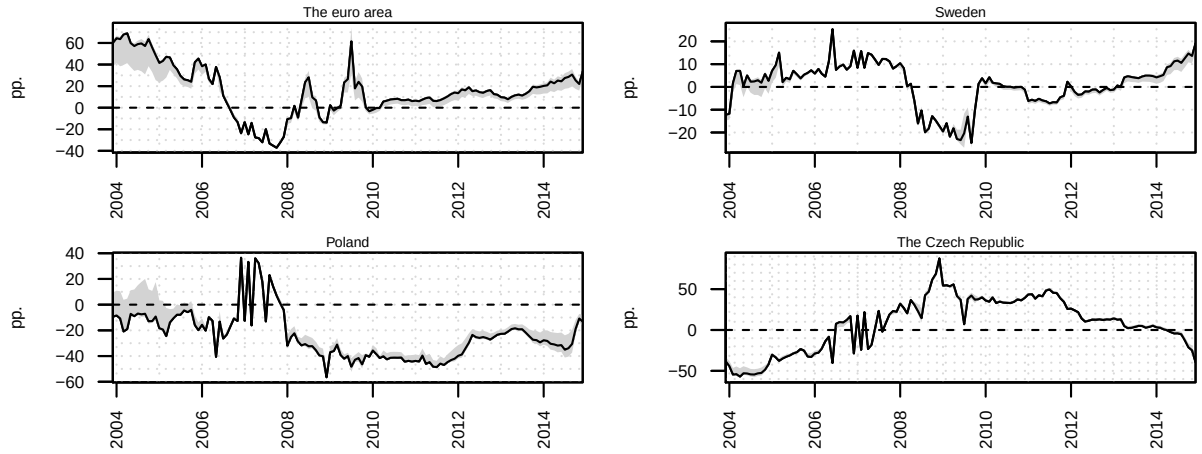
Figure 8: The rolling-window total volatility spillover index for services inflation



After studying the TVSI indicating the amount of volatility coming from spillovers we now focus our attention on the net volatility spillovers, identifying economies that transmit and receive volatility from others in net terms.

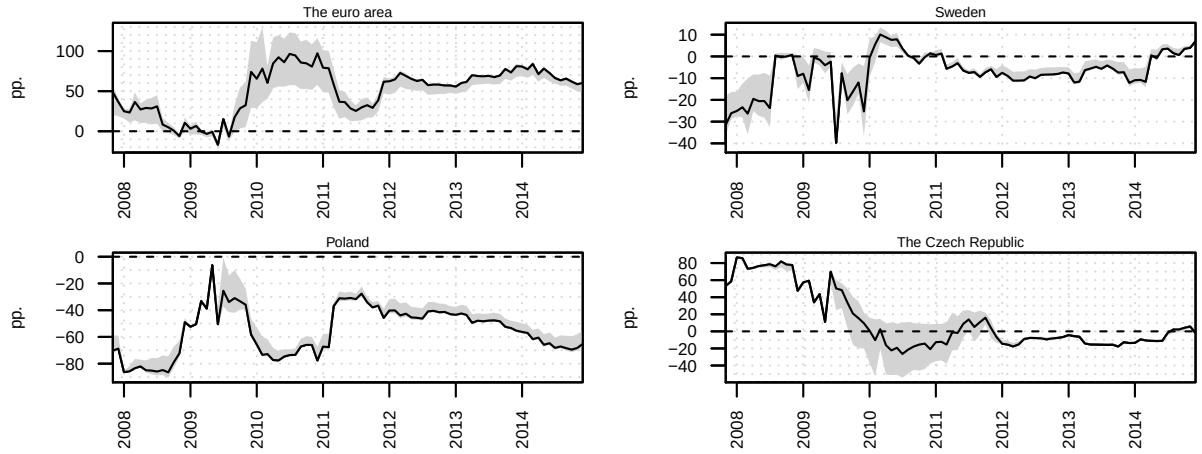
When looking on the Figure 9 of the net volatility spillovers for the HICP we observe that the EA role in transmitting volatility is fading in recent years comparing to the beginning of our sample. Sweden also is a net volatility transmitter excluding the period of the financial crisis outburst when it becomes a receiver in net terms. Not surprisingly, Poland remains the net volatility receiver with insignificant index at the beginning of the sample and negligible spikes to the positive region before the crisis. Quite interesting is the behavior of the Czech Republic, which initially receives heavily volatility from other countries, but during years 2008-2012 it becomes a volatility transmitter, presumably to Poland. Lately, the net volatility spillover index for the Czech Republic has become negative again.

Figure 9: The rolling-window net volatility spillovers for HICP



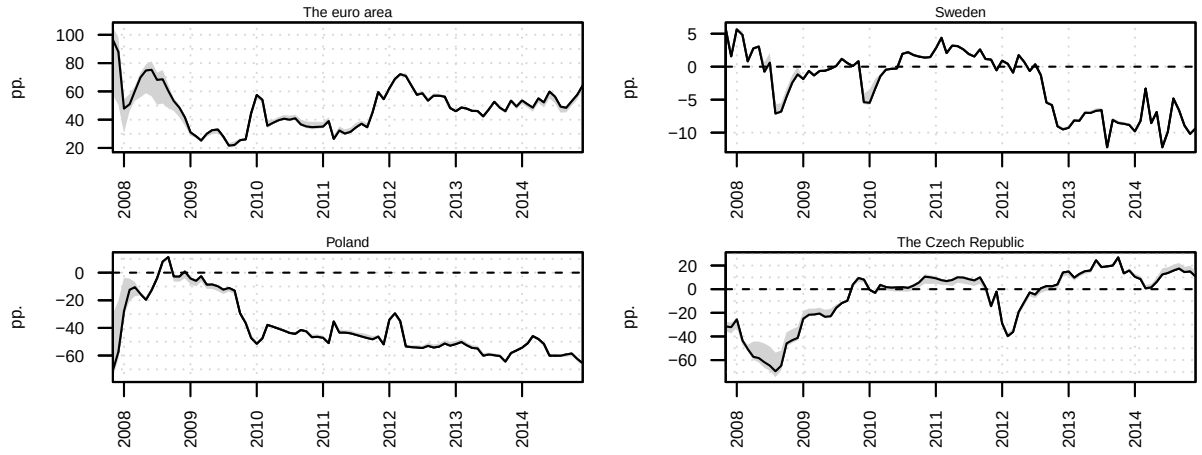
The results of the net volatility spillovers for the core measure are more intuitive (compare Figure 10). The EA again remains the volatility transmitter throughout the whole sample and its impact strengthen over time with Sweden being generally a minor net volatility receiver and Poland being an addict of the volatility transmitted from other countries. Once again the results for the Czech Republic are somewhat puzzling as it transmits volatility at the beginning of the sample, again most probably to Poland, and then becomes a minor volatility receiver with an insignificant period of 2010-2011.

Figure 10: The rolling-window net volatility spillovers for HICP excluding energy and unprocessed food



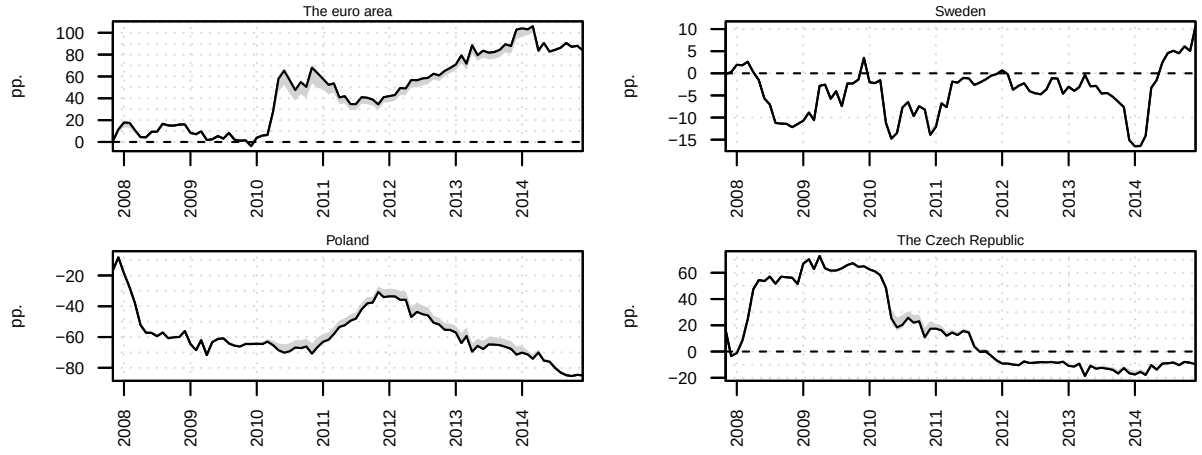
The estimated net volatility spillovers for the non-energy industrial goods are shown on Figure 11. As an influential economy, the EA remains a confident volatility transmitter with the ratio chaotically increasing since the global crisis. The index for Sweden fluctuates around zero until the second half of the 2012 suggesting minor volatility spillovers in net terms and then decreases making Sweden a net volatility receiver. Being dependent on the global industrial goods Poland receives a lot of volatility in net terms, whereas the Czech Republic initially is a receiver but since 2010 the index oscillates changing the Czech's Republic category.

Figure 11: The rolling-window net volatility spillovers for non-energy industrial goods inflation



Finally, on Figure 12 there can be distinguished a rising importance in transmitting volatility of the services inflation from the EA, especially after the 2010 when the index starts to rise considerably from negligible fluctuations indicating the importance of the EA in shaping services inflation dynamics. Sweden receives minor spillovers in net terms throughout the sample whereas Poland is a heavy net receiver with Czech Republic showing again bizarre behavior by beginning as a considerable net transmitter and becoming a minor net volatility receiver.

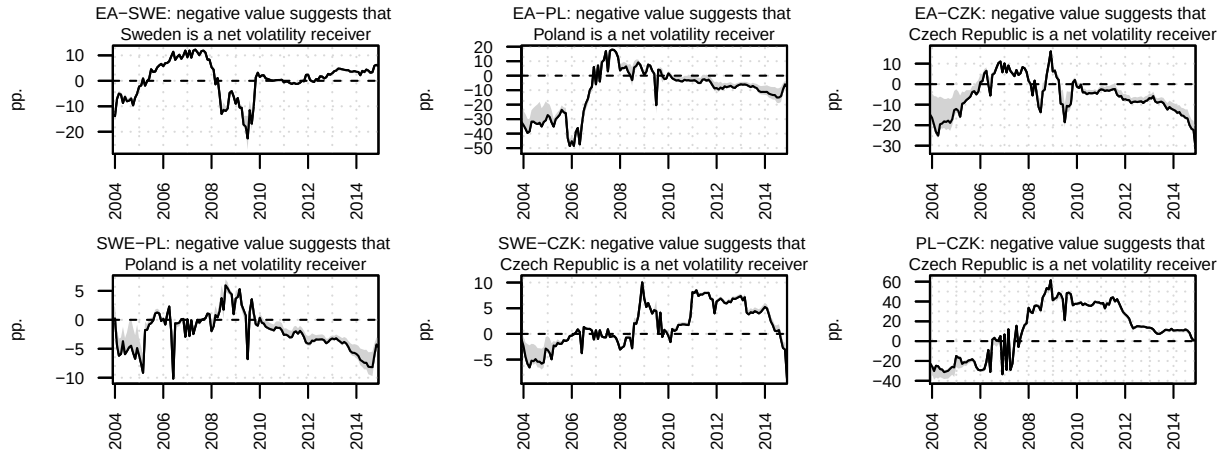
Figure 12: The rolling-window net volatility spillovers for services inflation



Lastly, in order to investigate the economic connection between distinguished countries, we explore the net pairwise volatility spillovers between them. Surprisingly, basing on estimates shown on Figure 13 lately in net terms the EA is a minor net volatility receiver from Sweden, however the estimates remain close to zero signaling that the relationship may be not significant. Apart from short periods around the financial crisis Poland and the Czech Republic are in net pairwise terms receiving volatility from the EA which is consistent with the notion of importing inflation from bigger economies. Poland receives also to a minor extent the

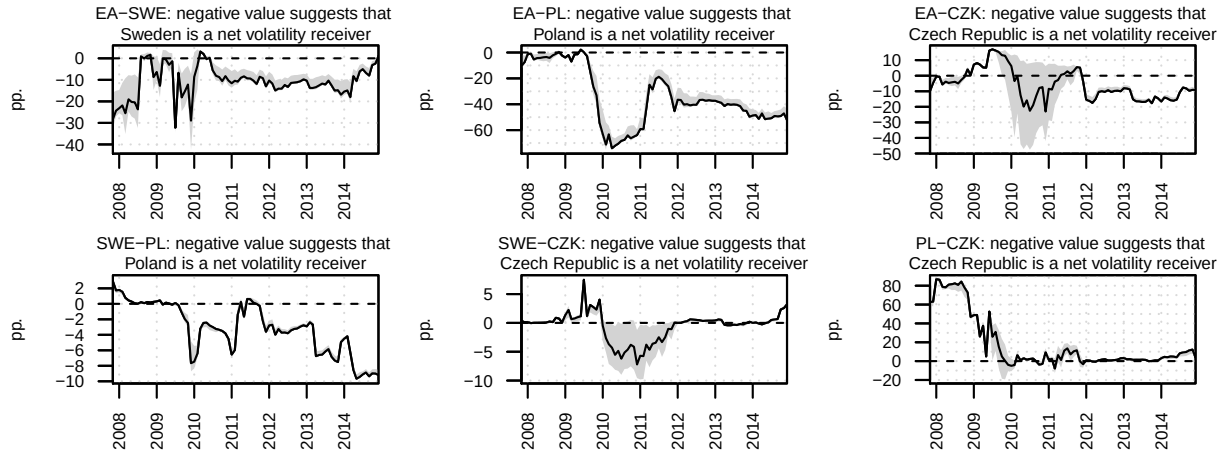
volatility from Sweden whereas the behavior of the Czech Republic is astonishing again. It transmits in net pairwise terms some volatility to Sweden as well as a considerate amount to a bigger, Polish economy.

Figure 13: The rolling-window net pairwise volatility spillovers for HICP



The conclusions are not as striking when investigating the results for the core measure (compare Figure 14). All smaller economies generally receive volatility from the EA with Poland acquiring the most of the it. Poland also imports the volatility from Sweden, however to a minor extent only. The relationships between Sweden and the Czech Republic as well as Poland and the Czech Republic are mostly insignificant – the index oscillates around zero and the quasi confidence bands suggest neutrality when it deviates further. Once again baffling for us is the heavy net spillover transmission from the Czech's core measure to the Polish one up to 2009.

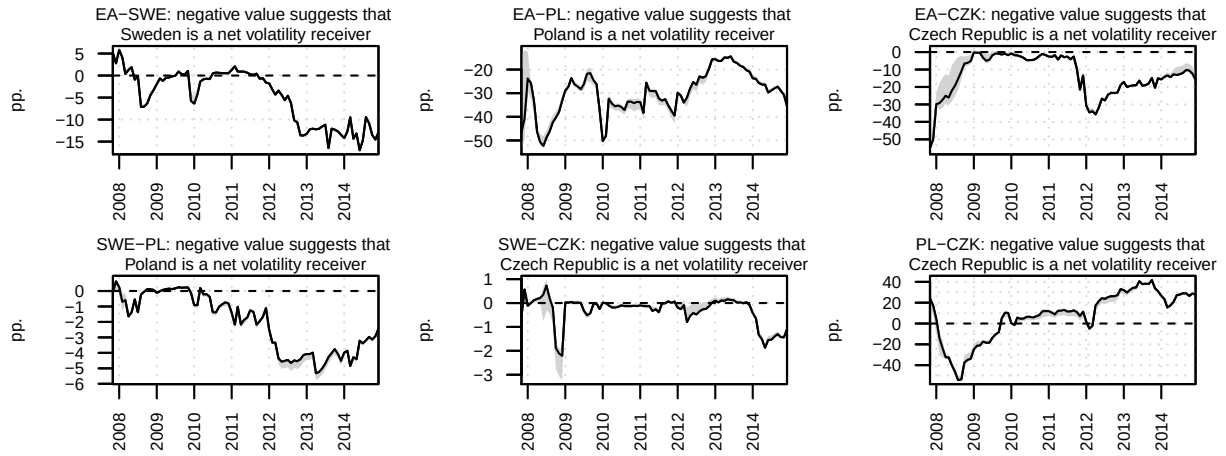
Figure 14: The rolling-window net pairwise volatility spillovers for HICP excluding energy and unprocessed food



Moving further, the analysis of the net pairwise volatility spillovers for the non-energy industrial goods shown on Figure 15 brings to the conclusion, that goods prices in smaller economies are affected by the importing of the inflation from big ones. All countries are in net pairwise terms receivers of the volatility from the EA with Poland and the Czech Republic affected the most. The Polish economy is also affected by the volatility from Sweden, whereas the relationship between Sweden and the Czech Republic is largely insignificant. Once again, quite striking results are observed for the pair Poland – Czech Republic, as the Czech Republic seem to be transmitting volatility in net terms to Poland.

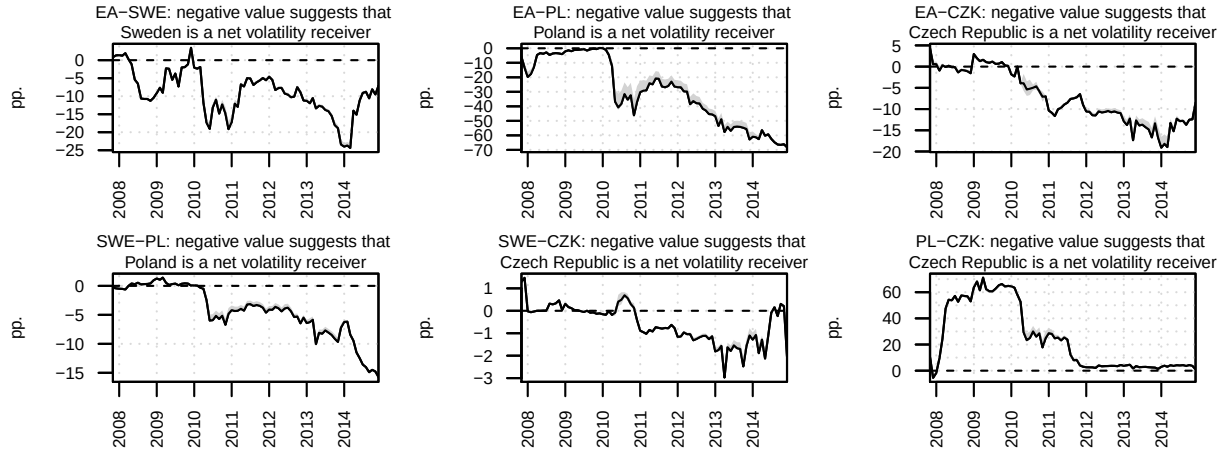
Lastly, we look at the net pairwise spillovers of services inflation among selected countries presented on Figure 16 and conclude that all small economies are more and more strongly receiving volatility from the

Figure 15: The rolling-window net pairwise volatility spillovers for non-energy industrial goods inflation



EA. Again Poland reveals rising dependence on Swedish services inflation whereas the dependence of Czech's inflation on Swedish measure deviates insignificantly from zero. Last years have shown a dampened relationship between the transmission of the volatility between Poland and the Czech Republic.

Figure 16: The rolling-window net pairwise volatility spillovers for services inflation.



The results for the spillovers of the inflation between the EA, Sweden, Poland and the Czech republic are consistent with our expectations; a bigger country is net transmitter of the volatility to the smaller countries. However, the transmission of the volatility between Poland and the Czech Republic the outcomes are puzzling – the smaller country (the Czech Republic) is transferring volatility into the bigger one (Poland), both when comparing net volatility spillovers on the aggregated and disaggregated data. We deliberate over two hypotheses that can explain this ambiguous result, although proving them demands additional studies that are beyond the scope of our analysis. The first one states that there may be a common factor affecting both economies, but the Czech Republic, being the smaller one, reacts faster to this determinant, while prices in Poland need more time to react. The second hypothesis claims that because the Czech Republic is in a tighter relationship with the German and the EA economy as well as it exports more intermediate goods than Poland, its enterprises, having more flexible prices, may react faster to the changes in the external conditions. This hypothesis finds some evidence in conducted researches. According to the outcomes of Murarik (2011) approximately one in every four prices is changed compared to the month before while Macias and Makarski (2013) approximates the ratio for Poland to 19% in Poland.

V. Conclusion

In the recent months a widely spread drop of inflation is observed. Most of the analytics attribute it predominantly to a positive supply shock, namely falling oil and food commodity prices. However according to our results the phenomenon of low inflation is much deeper and broader than it is commonly acknowledged. Not only food and energy prices experience low dynamics, but also goods and services included in the core measure what is proved by historically low fraction of goods with "too high" inflation. In addition we observe very low and falling Discrepancy Index indicating a growing fraction of HICP components that actually face deflation.

Further, we find that there exists strong inflation dependence of the smaller economies (the Czech Republic, Poland and Sweden) on the inflation development from the bigger one (the EA). All small economies are net receivers of the volatility from the EA, with Poland being the biggest one. Furthermore, our research indicates that not only non-energy industrial goods, but also services are influenced by the spillovers from the external environment. This outcome proves that services are under the influence of the globalization process. Additionally, we can spot it also in growing power of the volatility spillovers of the services inflation in recent years, especially from the EA into the Czech Republic and Poland.

We believe that our study may be helpful for the monetary policy authorities in several ways. Firstly, our research indicates that monetary authorities should look carefully not only at the evolution of the domestic conditions but also at the external surrounding. Analysis of the external developments may help to take right actions before the volatility spillovers will show up in the domestic variables and becomes encompassed in the price setting behavior of the companies leading to too low or too high inflation. It may help to prevent policy makers to fall behind the curve and take right actions in the right time.

Secondly, disaggregation of the HICP may help to better understand the inflationary process – the total volatility spillover index is much smaller for the core measure in comparison with the index calculated on the two subcomponents – goods and services.

Finally, if the inflation becomes more global, the policy makers may find it more difficult to control inflation developments and therefore could find themselves in a position when their decisions should be more courageous.

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A. Annual Inflation Rates

Figure 17: The HICP inflation

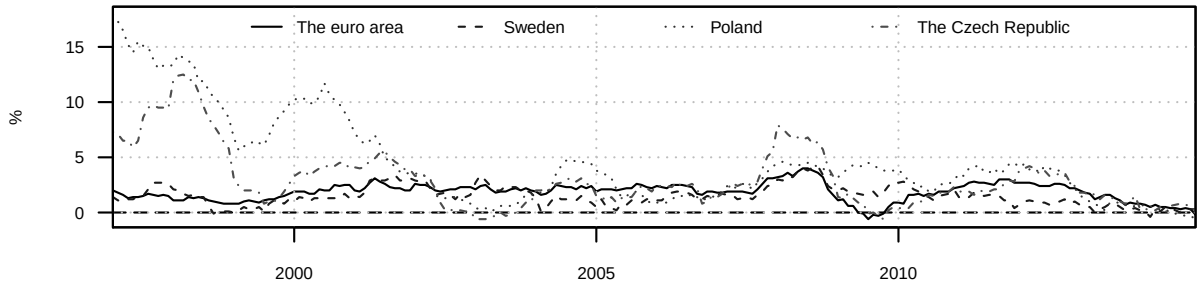

Figure 18: The HICP inflation excluding energy and unprocessed food

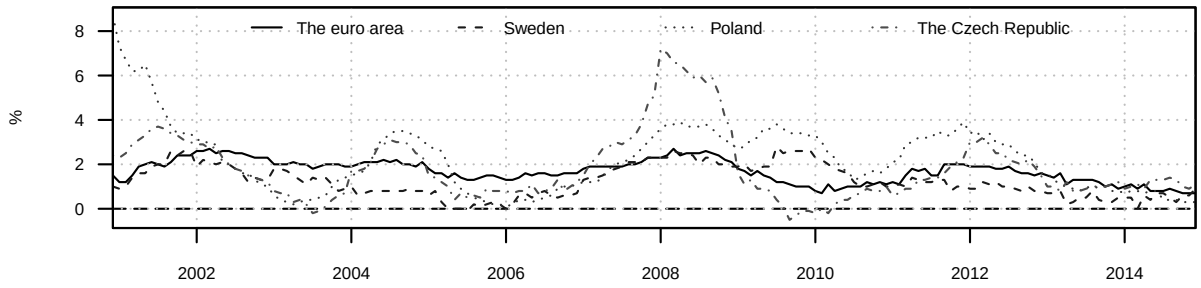

Figure 19: The non-energy industrial goods inflation

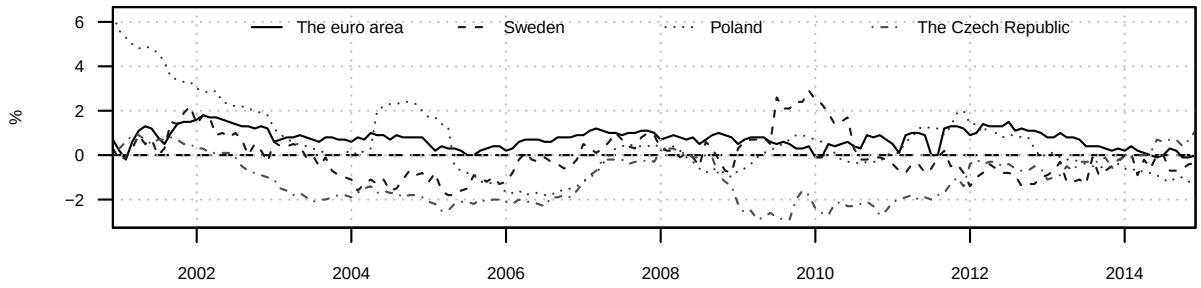

Figure 20: The services inflation