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Inflation and Output Comovement in the Euro Area: Love at Second Sight?

Michal Andrle, Jan Bruha, and Serhat Solmaz

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Prepared by Michal Andrle, Jan Bruha, and Serhat Solmaz

Authorized for distribution by Benjamin Hunt

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Abstract

This paper discusses comovement between inflation and output in the euro area. The strength of the comovement may not be apparent at first sight, but is clear at business cycle frequencies. Our results suggest that at business cycle frequency, the output and core inflation comovement is high and stable, and that inflation lags the cycle in output with roughly half of its variance. The strong relationship of output and inflation hints at the importance of demand shocks for the euro area business cycle.

JEL Classification Numbers:C10, E32, E50

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Author's E-Mail Address:mandrle@imf.org, jan.bruha@cnb.cz, ssolmaz@imf.org

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I. INTRODUCTION

This paper investigates the comovement between inflation and output in the euro area from 1995 up to the first quarter 2013. Our results indicate that the comovement of output and inflation is rather strong at business cycle frequency, when a measure of trimmed mean inflation is considered and a sluggish response of inflation to demand is accounted for. The strong commonality of those two series suggests a dominant role of demand pressures, acting as a single dynamic factor for both nominal and real macro variables. Inflation dynamics are also well aligned with the unemployment rate cycle. Importantly, the positive comovement of output and inflation casts doubts about technology shock driven business cycles as would be suggested by real business cycle theory proponents. Simply put, the *underlying inflation*[1] in the euro area is driven by demand cycles and lags output by roughly one quarter.

Our calculations are clearly motivated by a search for the Phillips correlation[2]. Under the Phillips correlation hypothesis, the business cycle dynamics of output, i.e. excess demand or the output gap, is supposed to be a major driver of business cycle movements of inflation. Presumably, proponents of the real business cycle (RBC) theory would disagree, arguing for technology shocks as the drivers of business cycles. Supply-side driven economic fluctuations are also not likely to induce positive comovement of output and inflation in New-Keynesian dynamic models with price and wage rigidities. In agreement with Summers (1986) or Cooley and Ohanian (1991), we argue that a check for positive and stable comovement between inflation and output may constitute a simple and powerful test of supply-side driven business cycles. Those in favor of demand driven cycles and inflation dynamics may argue that the relationship of output and inflation in the data is not obvious at first sight.

At first sight, the relationship between inflation and output can be easily overlooked, namely when comparing the headline CPI inflation with an arbitrary measure of the ‘output gap’. We argue below that at second sight, using intuitive economic arguments for data transformations, a stable, strong and positive comovement of output and inflation can be found in the

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[1] Henceforth, the trimmed mean inflation proposed in this paper is referred to as the *underlying inflation*. This concept is related to the ‘core inflation’ concept, but the term ‘core inflation’ is sometimes used in official documents. Therefore, not to create unnecessary confusion, this paper rather uses ‘underlying inflation’.

[2] We regard the Phillips correlation as an outcome of a system, i.e. interaction of private agents with policy institutions. The focus is on the business cycle dynamics only, consistent, for example, with a flexible inflation targeting regime. The term ‘Phillips correlation’ is more general than a simple single equation relationship. We use the term Phillip’s curve as used in Samuelson and Solow (1960) – as a summary of the data. A single equation estimation of the Phillips curve equation is not carried out in the paper, since it would not be consistent with the notion of the economy as a simultaneous system.

eurozone. Our closer look involves careful treatment of inflation and frequency-domain analysis.

We determine a cyclical component of output and measure of trimmed mean inflation that feature a high degree of coherence. The inflation 'gap' is defined as trimmed mean underlying inflation, adjusted for the inflation target of the central bank or for longer-term inflation expectations. The optimal frequency of the output cycle and trimming percentiles are identified jointly. The idea is that the measure of underlying inflation should be closely associated with the business cycle. Specifically, we do observe deviation of the underlying inflation from the inflation target and search for frequency band over which it has the closest relationship with the output. We investigate also the comovement of median inflation and output for robustness, showing that the comovement is also strong for median inflation and variety of trimmed mean inflation measures.

Our analysis has an explicit frequency-domain flavor, as we search for an output component featuring high coherence with deviation of the underlying inflation from the target. Our paper is related to investigations of den Haan and Sumner (2004), who also use frequency domain arguments to analyze comovement of output and prices in G7 countries. Our approach differs from theirs in the way we analyze and construct the underlying inflation measure and we use the invariance property of the coherence, a spectral analogue to correlation, to deal with nonstationary data. In contrast to den Haan and Sumner (2004), we acknowledge the inflation targeting nature of modern monetary policy in the euro area, and therefore we focus on the dynamics of inflation, not price level.

The distinction between the price level and inflation is crucial, see Ball and Mankiw (1994) or Chadha and Prasad (1994) for classical arguments why de-trended price level may appear counter-cyclical. Simply put, the de-trended price level becomes countercyclical exactly in the case if inflation follows the cycle in output positively and with a lag. Since both output and price level are non-stationary, researchers who detrend both series fall into a trap and must recover their negative comovement, as in Cooley and Ohanian (1991) for instance.[3] Further, the data starting in the 1990's are influenced by the inflation targeting regimes, which have starkly different implications than a price level targeting with a drift. Under inflation targeting, the changes in the price level are permanent, bygones are bygones. Inflation targeting central bank cares about deviation of inflation from its target.

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[3] Recently, Haslag and Hsu (2012) re-invent this well-known stylised fact, being unaware of Ball and Mankiw (1994) or Chadha and Prasad (1994).

A careful treatment of inflation is crucial for our exploration of its comovement with output. The inflation dynamics in our case are considered along three dimensions – long-run, cycle and short-term variations. The long-run dynamics of the inflation should–ideally, if the regime is credible–be given by the inflation target of the central bank which anchors long-term inflation expectations.[4] In the case of the ECB, the target is constant and, explicit since 1999, which simplifies the analysis. Cyclical dynamics of inflation are presumably greatly affected by persistent demand, productivity and various forms of cost-push shocks. The subject of our analysis comovement of output and cyclical component of inflation. Measures of consumer-price inflation, annualized quarterly growth rates, also feature a very large portion of high-frequency variation. These are sometimes straightforward to interpret, but often they are viewed as noise arising from mis-measurements, quasi-seasonal effects and complex patterns of relative price changes etc. In general, one does not always expect the high-frequency variation of prices to be fully explained by economic theory.

We choose a flexible trimmed mean as our measure of underlying inflation. Trimmed-mean inflation removes extreme movements in prices compared to the general tendency, thus mitigating effects of a cross-sectional price growth distribution with thick tails. The percentiles of the cross-section distribution of price changes to be eliminated are determined by the coherence of the resulting underlying inflation measure with the output cycle. With the exception of Vega and Wynne (2001), analysis using the trimmed mean inflation measure for the euro area is scarce.

There has been more research on the output-inflation comovement for the US economy than for the euro area. The Phillips correlation has been doubted, see e.g. Cooley and Ohanian (1991), but also argued for numerous times, see e.g. King and Watson (1994), Sargent (2001) or Stock and Watson (2010) whose sample cover the Great Recession. Recently Andrle (2012) demonstrates a strong, stable and positive comovement between the cyclical component of output and deviation of core inflation from long-term inflation expectations in the U.S. starting from the 1960's through the Great Recession. This paper documents strong comovement of output and inflation using a set of nonrestrictive assumptions, rather than constructing a formal semi-structural model of the Phillips curve, with many restrictive assumptions as in Basistha and Nelson (2007) for instance.[5] Recently, Basturk and others (2013) proposed

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[4] Analysis by ECB (2012a) documents that longer-term inflation expectations in the euro area in the sample period considered below are well anchored at 2%. The situation is arguably more complex in the case of the longer sample, including 1980s for instance, both in Europe and the United States. The analysis in Andrle (2012), using the U.S. data from 1960 to 2012, confirms a strong comovement of output and deviation of inflation from long-term inflation expectations.

[5] Surprisingly, the literature employing state-space models to analyze the relationship between the inflation and the natural rate of unemployment, or the output gap, has usually not presented the filter weights or how the

a complex nonparametric model of the semi-structural New-Keynesian Phillips curve for the U.S. estimated by computational intensive Bayesian methods. Our approach avoids the restrictive parametric assumptions of previous studies and by being formulated in frequency domain it requires only straightforward and transparent calculations. We do not formulate a structural model of output and inflation, but the relationship between output and inflation that we find would be consistent with response of New Keynesian models to demand shocks, not technology shocks.

The structure of the paper is the following: First, we motivate and describe the approach to our underlying inflation measure. Second, the cyclical comovement of the underlying inflation measure with output from 1996 to 2012 is analyzed. Sensitivity analysis, extension to a longer sample and further properties of underlying inflation follow before we conclude.

II. Underlying inflation for the Euro Area

This section introduces our simple measure of core inflation for the euro area. We evaluate three measures of underlying inflation: a trimmed mean (CPI-T), weighted median inflation (CPI-MED) and a consumer price index excluding food and energy (CPI-X). Trimmed mean inflation is computed by excluding a predetermined percentile from the left and right tails of the cross-section distribution of prices, see Bryan and Cecchetti (1993) or Appendix A for details. The percentiles excluded from the left and right tail of the distribution can be different, asymmetric.

The trimmed mean measure is our preferred estimate of core inflation. It is chosen since it is flexible, allows us to optimize its composition, and it does not exclude a priori a pre-specified commodity, thus potentially introducing a systematic bias.[6] Crucially, it turns out that it displays greater comovement with the cyclical component of output for a wide range of trimming percentiles than exclusion based measure. CPI-X measure of inflation does not give us the flexibility to explore the cross-section distribution of prices and, as we show below, it is a biased measure of underlying inflation. CPI-X measure displays downward trend, thus underestimating the link between output and inflation, resulting in dramatic divergence of

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inflation series actually contributes to the estimation of unobserved components. In our view, this is a crucial information for a parametric model.

[6] Excluding a specific commodity from the CPI has little support in economic or statistical theory. Trimmed means are, however, well established measures in the field robust statistics.

price level implied by CPI and CPI-X measures. Median inflation is a special case of trimmed mean inflation and displays a great degree of coherence with output cycle.[7]

A. Data and computation

We use EA Harmonized Index of Consumer prices (HICP) data at level three of disaggregation. This totals to 94 subcomponents of the aggregate HICP. The data are available for 72 periods, 1995:1–2013:1. After the year 2000, all data on prices and weights are available. Prior to that some small subcomponents are unavailable. See the Appendix for data details and treatment of missing observations. We can replicate the HICP aggregate to a very high degree of precision.

The trimmed inflation measure is derived by trimming left and right percentiles. These left and right trims can be symmetric or asymmetric, but a criterion is needed to indicate what percentiles are to be removed. In the literature, see e.g. Bryan and Cecchetti (1993) or Roger (1995), a smoothed measure of headline inflation is often used as a benchmark. That is rather ad-hoc, but it usually works well as high-frequencies are attenuated. We choose the cross-correlation of trimmed mean inflation with output at cyclical frequencies as our criterion for setting the optimal percentiles to trim.

Why is the comovement with real activity a criterion for underlying inflation estimation? It is an attempt to find evidence in favor of a Phillips correlation. The cyclical component of output consistent with inflation neutrality should be such that the implied cycle has a stable relationship with a well-defined measure of inflation. As expected, inflation lags the output cycle, according to our results. The mean lag is one quarter. Our computations match spectral properties of inflation and output cycle. Our underlying inflation is chosen to be well predicted by the output can thus be an indicator of demand-pull inflation. To avoid circular reasoning, it is important that we look at cyclical frequencies as determined by a rectangular band pass filter, not creating the optimal filter, weighting various frequencies of output into a new composite measure.

Often, the basis for choosing percentiles trimmed is a distance from a smoothed inflation measure. The filter could be a centered n-quarter moving average measure of inflation, an ‘underlying inflation,’ see Bryan and Cecchetti (1993). Alternatively analysts use a q period

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[7] We also investigated a low-pass filter of the price level, which offers the flexibility of choosing the bandwidth to exclude high-frequency variations. Yet it implies a real-time filtering issues associated with two-sided filters and fails to use information on the price distribution.

forecast errors of headline CPI, essentially a pure phase-shift filter, or filtered headline CPI, hoping that the underlying inflation should be a predictor of headline inflation in the medium term. Such criteria are arbitrary and do not use explicitly economic theory as a guide. Inflation dynamics, presumably, depend on the real economy dynamics and policy reactions. Further, in the case of an inflation targeting country, an unbiased forecast two years ahead or above should be the inflation target. Benchmarking to filtered inflation, $\tilde{\pi}_t = S(L)\pi_t$ using a linear filter $S(L) = \sum_{i=-K}^{K} w_i L^i$, where $x_{t-j} \equiv L^j x_t$, amounts to matching spectral density of the underlying inflation $S_{\pi_t^\star}(\omega)$ with the smoothed indicator's spectral density, $S_{\tilde{\pi}}(\omega)$.

Instead of matching a spectral density of underlying inflation to a filtered headline inflation, it is matched to the output cycle. Our procedure is easy to understand as a restricted spectral density matching exercise, i.e.

$$[\alpha_l, \alpha_r, \omega_u] = \text{argmin } ||\tilde{S}_{\pi^\star}(\omega) - \tilde{S}_{\hat{y}}(\omega)||, \tag{1}$$

where α_l, α_r are lower and upper quantiles of the trimmed mean and ω_u is the upper frequency of the band-pass, precisely a high-pass filter. $\tilde{S}(.)$ is a normalized spectral density, whereas $\pi^\star$ and $\hat{y}$ denote a underlying inflation measure and output cycle, respectively. The measure accounts for a lead/lag relationship between the variables.

The baseline percentiles trimmed are determined jointly with the frequency of the output cycle. For each measure of underlying inflation, 31 output cycles were evaluated at frequencies from 0 up to 20 or 60 quarters. The percentiles were varied in steps of size one and we evaluated 2341 core inflation measures. After roughly the 9th percentile, loss function ((1)) continues to fall in a smooth and monotonic way.[8] The optimal trimming percentage, given the whole sample for output and inflation, is [48; 28]. For a reduced sample running only up to 2007:1, the optimal trim is [37; 21]. If the optimization is carried out using symmetric trims, the optimum is reached at 38. However, the gains after the 10th percentile are very modest. It also seems that the median inflation is a relatively robust measure of inflation, given the data and aggregation structure used. Further sensitivity analysis is carried out below.

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[8] See Fig. 10 depicting the countours of the criterian function for different degrees of trimmed percentiles and optimal ω_u in the Appendix

Figure 1. Headline (thin) vs. underlying inflation (thick), %, ann.

B. Properties of inflation and underlying inflation

The cross-section distribution of prices in the euro area is highly non-Gaussian. This is in line with other countries, see e.g. Roger (1995) for the case of New Zealand, or Dolmans (2005) for the United States, among others. The distribution features very thick tails, due to presence of several outlier observations every period. The balance between positive and negative price changes outliers is very fragile.[9] The kurtosis in excess of Gaussian distribution is very large, averaging around 15. Thus, the mean is not a robust measure of the price changes mass, nor of the underlying inflation process. The skewness of the weighted price distribution is very volatile and positive on average.

The components frequently excluded from the trimmed mean measure of inflation feature energy related products, fresh food and transportation. This is not surprising and is in line with the motivation for a CPI-X measure of inflation. The results for median inflation are close to CPI-X inflation, although the median features somewhat less high-frequency variation in the final measure, as expected. In 2008 the CPI-T inflation increased above CPI-X, which hints at stronger demand pressures than what excluding food and energy from infla-

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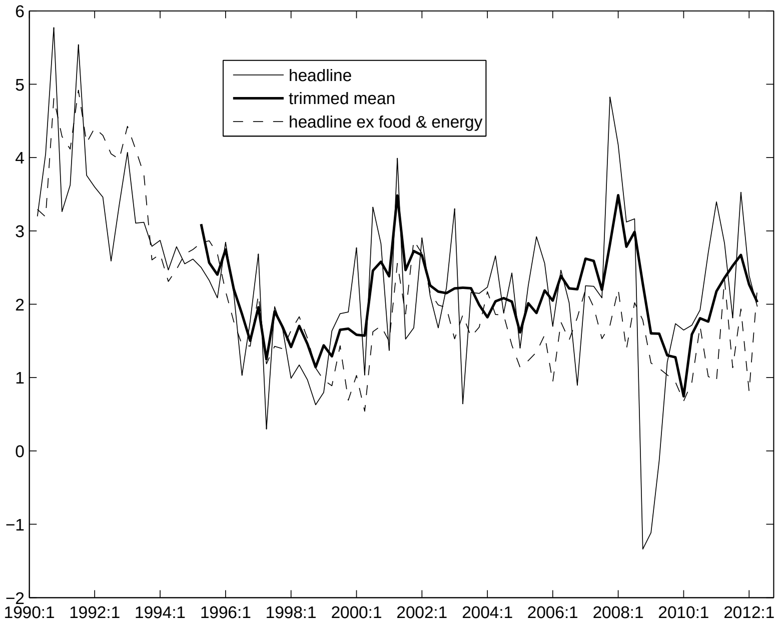
[9] Fig. 8 and 9 in the Appendix depict skewness, kurtosis and several examples of cross-section price distribution

Figure 2. Trimmed mean vs. CPI-X, % ann.



tion would suggest.[10] It also increases faster than the CPI-X measure in 2011-2012, again related to rising energy prices. A big discrepancy between CPI-X and CPI-T arises in 2012 at monthly frequency, where CPI-X is affected by extraordinary volatility.

Our trimmed mean inflation measure seems superior to the strategy of excluding food and energy prices. The CPI-T measure features stronger correlation with the output cycle, for trimming percentiles larger than 10. The CPI-X measure of inflation, based on exclusion of fresh food and energy prices results in a significant bias of the resulting inflation measure on average, see Fig. 2. From 2000Q1–2012Q the annualized quarter-on-quarter CPI-X measure has an average bias of -0.54 with respect to headline CPI, which reflect divergence of implied price level. The bias is -0.37 for the median and 0.14 for the baseline trimmed mean inflation. As can be seen from Fig. 2 the CPI-X is persistently lower than the headline inflation, as the remaining price categories compensate for the increase in food and energy prices in the last decade, allowing the central bank to let the headline measure of inflation to fluctuate around the target. Such desired change in relative prices, however, renders the CPI-X measure less informative, as it may seriously understate demand effects in the economy, namely when the oil prices are higher due to a booming economy.

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[10] This pattern is also visible in our cursory analysis of individual country data, for instance in Spain the CPI-X measure is very volatile after 2008.

III. INFLATION-OUTPUT COMOVEMENT

A. Measuring Comovement

Inflation-output comovement in the euro area seems to be surprisingly strong. Our baseline results suggest a very tight link between the underlying inflation and the output cycle in the euro area during 1995–2012. For a better visualisation, the output cycle is computed using the band-pass filter designed by Christiano and Fitzgerald (1999), see Fig. 3. The underlying inflation is scaled to output variance and phase-shifted by one quarter to align the average phase of both series. The positive correlation is suggestive of the prominence of demand driven business cycles, with supply shocks operating mostly at low or very high frequencies. The results hold for in-sample calculations, to which the optimal trimmed mean measure of underlying inflation and the measure of output cycle were calibrated, as well as for the median inflation.

The comovement is robust with respect to deviations from the optimal trimming percentage. As is shown below, the comovement is strong also for the median inflation. Further, it has been demonstrated that the 'optimal' trimmed mean measure does not differ significantly from other trimmed means as long as the trimming percentage reaches beyond 10%.

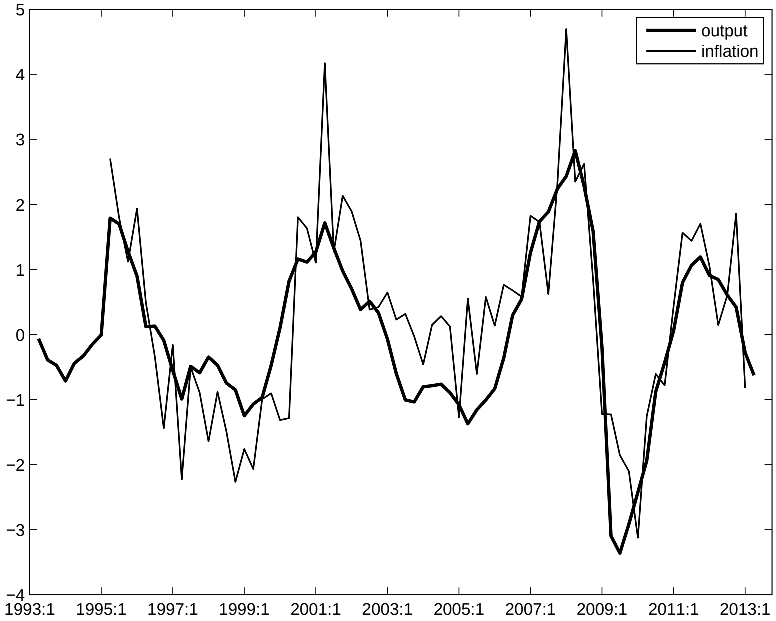
The close alignment of inflation and output cycles is clearly visible when spectral properties are considered. We use the *coherence* as the key measure of comovement. The coherence is defined as

$$\rho^2_{x,y}(\lambda) = \frac{|S_{x,y}(\lambda)|^2}{S_x(\lambda) S_y(\lambda)} \in [0,1] \qquad \text{for } 0 < \lambda \leq \pi, \tag{2}$$

where $S_{x,y}$ denotes the cross-spectrum of x and y. Intuitively, it is a cross-correlation of two series at particular frequencies (bands). Below, the cross-spectrum $S_{x,y}$ is always computed parametrically using a vector autoregressive (VAR) model of order p, from which the cross-spectrum is easily computed, see Koopman (1974) for instance. Since the output is a non-stationary variable, its cross-spectrum with inflation cannot be obtained directly, but there are two approaches one can take.

In the fist approach, the coherence is calculated directly using band-pass-filtered output series and inflation. This approach, however, may suffer from inaccuracies at the end of the sample due to two-sided nature of the time-domain implementation of the filter, but is consistent with the graphs we use to highlight the intuition. In the second approach, first the cross-spectral

Figure 3. Output and inflation cycles



Note: Normalized to output variance. Phase aligned.

density of output growth and inflation is calculated. The integration filter (inverse of the first difference) is applied then on the output component of the cross-spectrum in order to obtain the cross-spectrum of the level of output and inflation, that is:

$$\mathbf{S}_{x,y}(\lambda) = \mathbf{T}(\lambda)\mathbf{S}_{\Delta x,y}(\lambda)\mathbf{T}(\lambda)^H, \qquad \mathbf{T}(\lambda) = \begin{bmatrix} \frac{1}{1-\exp(-i\lambda)} & 0 \\ 0 & 1 \end{bmatrix} \tag{3}$$

for $0 < \lambda \leq \pi$, where the super-script H denotes a conjugate transpose. At this stage, the exact band-pass filter can be applied to the spectrum, which basically amounts to zeroing out frequencies out of interest. Since complex convolutions in the time domain are just simple multiplications in the frequency domain, the filtering is exact.

Crucially, the coherence between two series remains unchanged if both series are pre-processed by linear, time-invariant and invertible filters.[11] This can be shown in general[12], and for the case of the integration filter in particular. Hence, the coherence of GDP growth and infla-

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[11] See (Koopman, 1974, pp. 149). The invariance property holds for all λ for which the transfer function of the filter is not zero, as the application in this paper.

[12] This can be not only shown analytically, but it is also intuitive: the coherence is invariant to linear filters. The filter effects in the denominator is cancelled with the filter effect in the nominator.

tion is identical to the coherence of the level of GDP and inflation due to the coherence filter-invariance property ($\rho^2_{x,y} = \rho^2_{\Delta x,y}$). The invariance does not hold for other statistics, however.

We have considered two approaches to estimate the bivariate spectrum $\mathbf{S}_{\Delta x,y}$ of the GDP growth and underlying inflation. The first one is the parametric approach based on the estimation of a VAR(p) model, where the bivariate spectrum is derived from the estimated auto-covariance function[13], the second one is 'non-parametric' Bartlett lag-window estimator, see Hamilton (1994). Both approaches yield very similar results and hence all results reported in the paper are based on the parametric approach.[14] The spectral characteristics obtained using a VAR(2) model with filtered output series and inflation are displayed in Fig. 4.[15] Spectral densities of the output and underlying-inflation cycles are similar, with the variance of the output cycle being roughly three times larger. Output has more power at business cycle frequencies (the shaded area) even when a normalized spectrum is considered. The sample estimate of coherence –a frequency analogue of correlation– peaks at a value of 0.9. The phase in Fig. 4 is expressed in periods, suggesting that at business cycle frequency with greatest power, inflation lags output roughly by one quarter.

To provide further evidence on output inflation comovement, the coherence of median inflation and output calculated using the approach relying on the coherence filter invariance property is presented in Fig. 5, together with associated confidence intervals obtained using a wild bootstrap. Confidence intervals are somehow larger, nevertheless the strength of the coherence at business cycle periodicity is again clearly visible despite the weighted median inflation measure of underlying inflation has not been optimized to comove with the output cycle.

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[13] Note, the VAR model is used only as a parametric estimate of auto-covariance generating function, hence no structural identification or interpretation of shocks is required.

[14] Bootstrapped confidence intervals for other measures than coherence are available upon request, as well as results from VAR(1), VAR(3) models, and the Bartlett estimator.

[15] A method of 'wild' bootstrap was chosen to reflect the small sample considerations, see Wu (1986). The reader may be interested in whether the available data alow us to precisely estimate the bivariate spectrum. We have conducted a Monte Carlo experiment where we sampled a large sets of datasets (with the same number of observations as we have) from a set of VARMA models and applied our estimation procedures to compare 'true' and estimated coherence peaks. If the assumed data generating process was close to the VAR(2) model, the parametric approach seemed to yield *the unbiased results*, while if the data generating process used in simulation was more complicated, the parametric approach *underestimated* the maximal coherence. The Bartlett non-parametric estimator seems on average to slightly *underestimate* the peak in coherence of interest for both types of data generating processes. Hence, we conclude that our approaches to estimation of the bivariate spectrum are *not biased upward*.

Figure 4. Spectral properties – output and inflation cycle

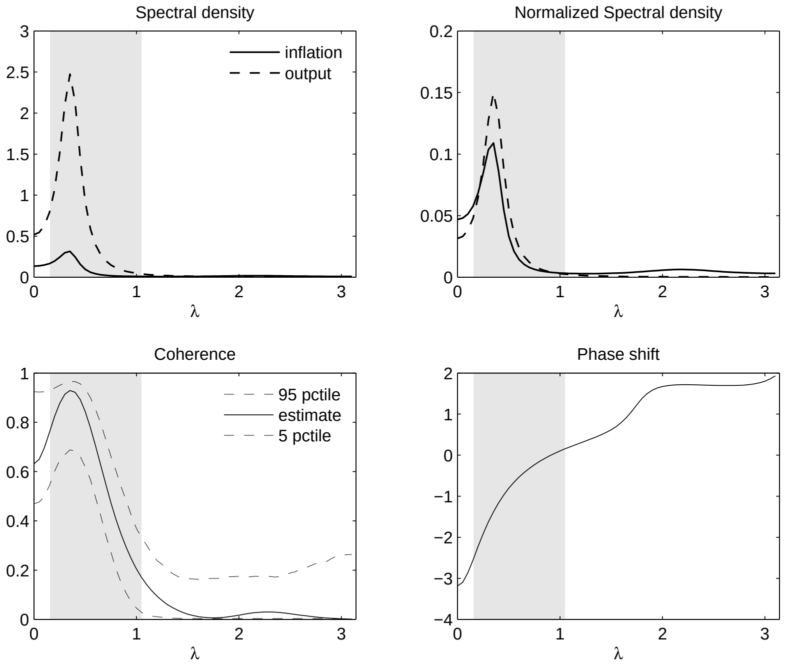
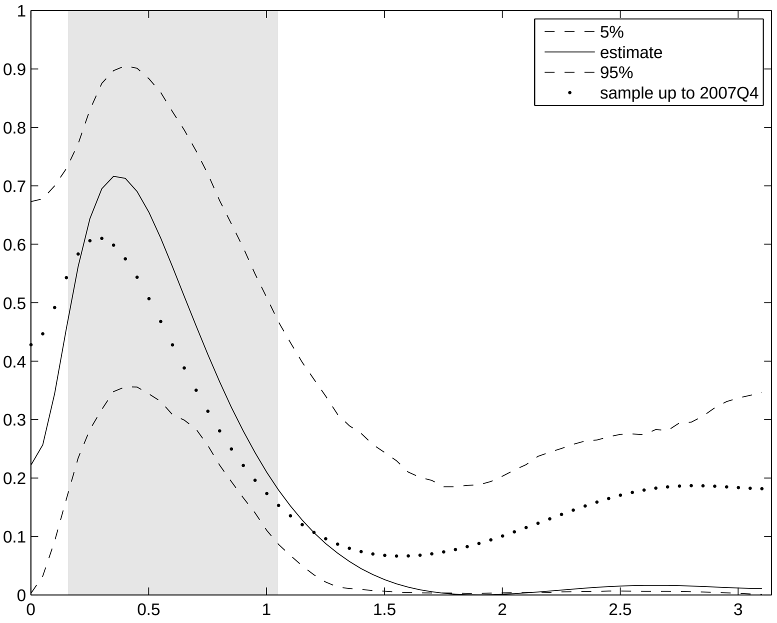


Figure 5. GDP level and median inflation coherence



B. Implications of Output-Inflation Comovement

Despite–or, perhaps, due to– its simplicity, our estimation approach to demand-pull inflation is revealing a stable and positive co-movement between underlying inflation and output. The comovement of real macroeconomic aggregates is consistent with both demand-driven and supply-driven business cycles. Following a tradition of real business cycle (RBC) theory, either in its pure form or embedded into New Keynesian dynamic stochastic general equilibrium (DSGE) models, students of business cycles rely on total factor productivity shocks as a powerful driver of business cycles, see e.g. Galí (2008). Yet, the role of prices has been already stressed by Summers (1986) when discussing the 'price free' economic analysis of the RBC hypothesis. Our results on the comovement of inflation and output at cyclical frequency in the euro area clearly suggest that models centered around technology shocks cannot reasonably explain developments of output, unemployment and inflation in the euro area along the business cycle. The failure of such models would be accompanied by a conclusion that real variables are driven by technology shocks, whereas inflation is explained by variations of markups, i.e. cost-push shocks. Such a conclusion is at odds with a tight positive comovement of output and inflation at cyclical frequencies.[16]

Further, investigating the Okun's law in the euro area suggests that employment is also driven by a strong common demand factor that comoves with inflation. Okun's law, see Okun (1962), posits a relationship between output and unemployment. In our case, output and unemployment are only considered at cyclical frequencies, using the same bandwidth and specification of the band-pass filter. Fig. 6 depicts the close comovement of underlying inflation deviation from the target with output and unemployment cycle (with a reversed sign to enhance readability). The strength of the comovement of key macroeconomic variables has important implications for business cycle interpretation in terms of demand versus supply shocks. Demand shocks, or shocks originating from the supply side and leading to increase in prices, are the likely explanations for euro area business cycles.[17]

One may ask why a larger drop of inflation has not been observed in the euro area during the latest deep recession. One reason could be that the inflation-relevant output cycle might have been depressed far less than the actual output. Stock and Watson (2010) show, for instance,

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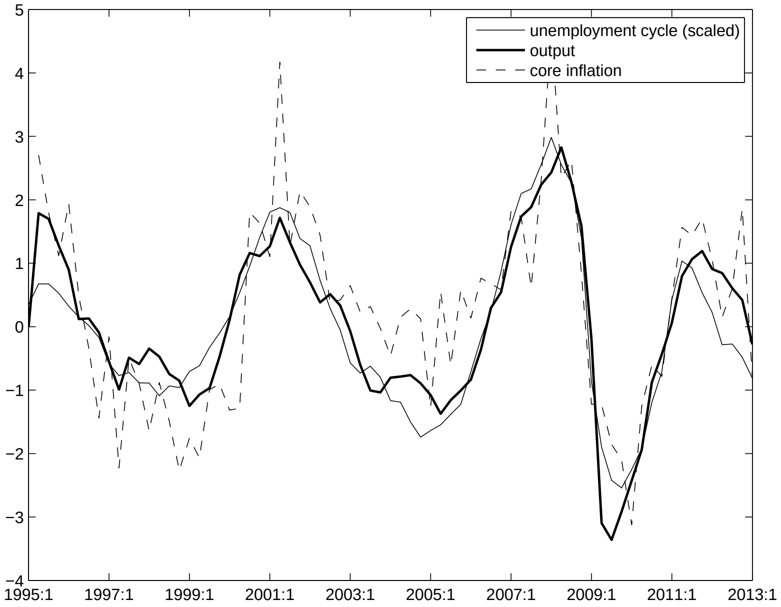
[16] This does not mean there are no supply-side or shocks. Our finding simply suggest that demand shocks are the dominant ones at business cycle frequency, explaining large portion of the data dynamics.

[17] Similar conclusion hold for the U.S. economy, see Andrle (2012). Our ongoing research on some other countries, notably Japan, the U.K., or Canada point in the same direction, despite, or perhaps due to, the longer sample size.

Figure 6. Underlying inflation – output and unemployment cycles



Note: Scaled to output variance, phase shifted. Unemployment cycle depicted with the opposite sign.

that for the U.S. economy a decline in output longer than eleven quarters ceases to affect inflation. A similar logic seems to hold for the euro area, as there is a limit to firms squeezing their margins in the downturn. This would imply that potential output and the structural rate of unemployment have declined, or increased, respectively, during the recession rather sharply, consistently with other evidence, see e.g. ECB (2012b).

One possible interpretation of our new results is that the developments of inflation are reasonably in line with output, once larger flexibility in the trend component of output is allowed for. We emphasise that the evolution of inflation should be an important guiding principle in designing a well-performing measure of excess capacity in the economy, which is not directly observable. Our framework is very flexible, transparent, and agnostic. It is an indirect measurement exercise – proceeding from observable quantity (inflation gap) to an unobservable one, to an inflation-relevant output. Crucially, the frequency-domain nature of our analysis enables us to find out at what frequency output and inflation comove. Other approaches commonly determine a measure of an ‘output gap’ with little or without reference to inflation and relate the headline CPI inflation to such an arbitrary measure using simple, but very restrictive, regression analysis.

IV. ROBUSTNESS

The presence of output-inflation comovement is robust to many changes in our calculations. This section addresses potential concerns associated with our analysis, namely the length of the sample, and construction of the core inflation measure.

The sample available for the computation of trimmed means is relatively short, so the question whether our results hold also for the longer historical sample is a relevant one. The answer is: yes, the strength of demand-pull inflation is also significant in the period from 1970 to 2005. Using the synthetic data for the euro area compiled for the Area Wide Model (AWM) database, see Fagan, Henry, and Mestre (2001), updated until 2005Q4, we can find a strong and positive comovement of output and the consumption deflator at business cycle frequencies.[18] The coherence of the inflation deviation from its trend with the output cycle peaks around 0.6–0.8, depending on a lag length specification of the VAR used for the spectrum estimation. Of course, there are periods clearly marked by supply shocks in the 1970s. Overall, however, the results are suggestive of the importance of demand cycles for inflation determination in Europe, see Fig. 12. We consider the results from an extended sample as an indirect robustness check of the demand-driven inflation hypothesis, while acknowledging the fact that the euro area time series prior to its official establishment may be not be always reliable.

Changing the benchmark period for the estimation of trimming percentiles affects the results modestly. Changing the period to the range 2000:1–2007:1, in order to lower the importance of the ensuing financial crisis, the optimal trimming percentage changes to [37; 21] from our baseline of [48; 28]. This means that in the shorter sample less extreme price decreases are being removed from the headline inflation measure, due to the absence of the year 2009 and a dramatic drop in energy and food related prices. However, the similarity of both measures is very large, so the scope for error is limited. Once the 10th percentile is removed from both sides of the distribution, the additional gains from further trimming are small. That can be inferred from the profile of the loss function in dependence on trimming, in Fig. 10 in the Appendix. The results favour asymmetric trimmed means, even for a shorter benchmark range.

Median inflation and a variety of trimmed mean inflation measures also display cyclical comovements with output. Our underlying inflation measure is constructed to maximize the comove-

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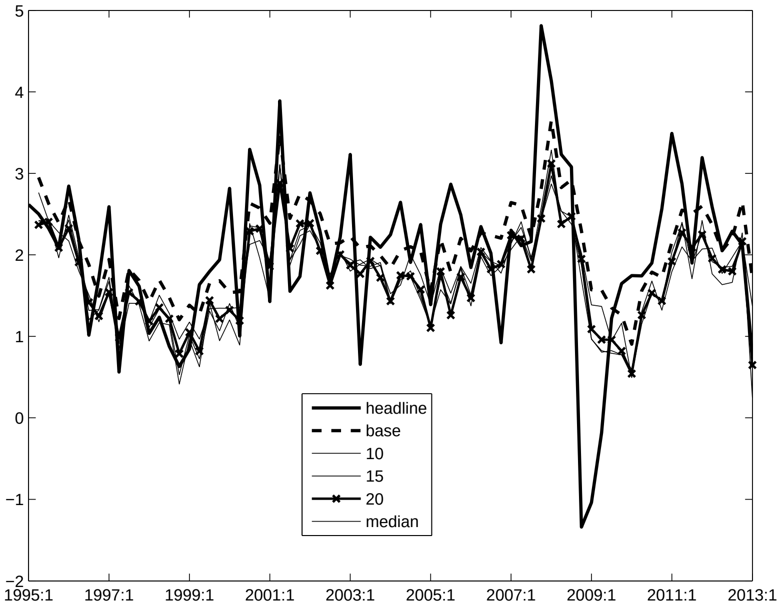
[18] Due to unavailability of an explicit inflation target, or long-term inflation expectations, the trend component is approximated by removal of low-frequency component of inflation.

Figure 7. Headline inflation and variety of trimmed means



ment with output. To guard ourselves against data mining and overfitting we test a variety of trimmed mean measures common in the literature and perform a ‘placebo’ sampling test. Fig. 7 depicts the headline inflation with the 10, 15, 20 and 50th percentile symmetric trimmed mean to indicate similarity and robustness of the measure once the threshold of the 10th percentile is reached. The dynamics of all measures are similar, with the asymmetric baseline case being higher roughly by 30 basis points, annualized. The ‘placebo test’ checks if the matching estimator could generate the comovement by weighting random draws from processes having univariate characteristics of individual price categories. The results reject this possibility, with the median peak coherence in the Monte Carlo study being just 0.1 – see the Appendix for details.

V. CONCLUSIONS

This paper illustrates a strong degree of comovement between inflation and output in the euro area. Underlying inflation, defined as an asymmetric trimmed mean, lags the output at business cycle frequencies on average by one quarter, being roughly twice less volatile than output. The coherence of output and underlying inflation at business cycle frequencies lies in the range 0.6–0.9.

The close comovement of output and inflation is highly suggestive of the dominance of demand factors in the euro area business cycle. Structural models that do not capture the comovement between output and inflation at business cycle frequencies will have a hard time interpreting euro area developments. Various flavors of technology shocks in recent general equilibrium models just will not do, since they imply a negative comovement of output and inflation. That being said, we do not deny that numerous supply-side and policy factors shape the dynamics of the economy at low and high frequencies.

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APPENDIX A. TRIMMED MEAN METHODOLOGY AND COMPUTATIONS

The trimmed mean constitutes a robust measure of location. We follow Bryan and Cecchetti (1993), among others. Having the price changes $\pi_{i,t}$ and associated weights $w_{i,t}$ a trimmed mean is a normalized average, leaving out α_l percents of weights from the left and α_r percents of the weight from the right. Let $W_{i,t}$ be defined as $W_{i,t} = \sum_{j=1}^{i} \tilde{w}_{j,t}$, where $\tilde{w}_{j,t}$ are the weights corresponding to sorted price changes $\pi_{i,t}$, in ascending order. Let the index set be defined as $\mathcal{I} = \{i : \alpha_l < W_{i,t} < (1-\alpha_r)\}$. The asymmetric trimmed mean is defined as

$$\pi_t^{tm}(\alpha_l, \alpha_r) = \frac{1}{1-\alpha_l-\alpha_r} \sum_{i\in\mathcal{I}} w_{i,t}\pi_{i,t}. \tag{4}$$

The asymmetric measure, of course, does not exclude a symmetric trimmed mean as a result.

(A.0.0.1) Data The price and weights data are at the level 3 of disaggregation as provided by the Eurostat. Our immediate source is Haver Analytics database, with codes (ticks) of all series used available upon request. Using 94 items, we replicate the headline CPI growth with negligible loss in accuracy when testing for correctness of our data and procedures. Data for real output are seasonally adjusted, as provided by the Eurostat.

(A.0.0.2) Treatment of missing data We use a data sample for which most of the current euro area members were already using one currency. There are some missing data on weights and prices in our dataset. We treat missing data as any data with zero weight in the aggregate. Since the missing data are mostly pharmaceutical prices in 1995–1996, the aggregate is affected in a negligible way.

(A.0.0.3) Seasonal adjustment The baseline computations are using seasonally adjusted data, as provided by Haver analytics database. In principle, a univariate seasonal adjustment is fraught with hazard, as it breaks the general equilibrium links between relative prices in the economy that, by and large, cancel out given relative demands across seasons.

APPENDIX B. PLACEBO TEST FOR THE MATCHING ESTIMATOR

A simple ‘placebo’ test was performed to guard the analysis against data mining and spurious results. The robustness of the exercise, however, can be also judged by the strength of the coherence of the median inflation and output.

The placebo test replaces individual 94 price components with a random sample drawn from an autoregressive model corresponding to each series. These artificial series are then used for the matching exercise. For each artificial set of HICP components, the matching exercise determines the optimal percentiles to trim and the coherence of the resulting series with output is computed. A distribution of coherence is constructed based on 500 draws.

The results of the ‘placebo’ exercise clearly indicate that one cannot replicate the strength of the output and underlying inflation coherence by ‘accident’ or by manipulating the series. The median peak coherence is 0.15, with the highest outliers attaining value of 0.35.

APPENDIX C. ADDITIONAL GRAPHS & TABLES

Figure 8. Skewness and excess kurtosis

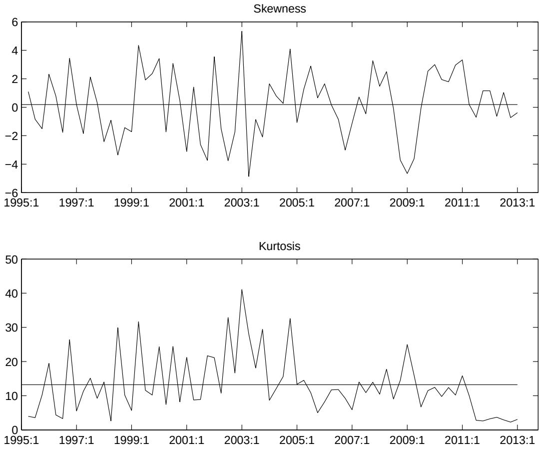

Figure 9. Sample distribution of price changes

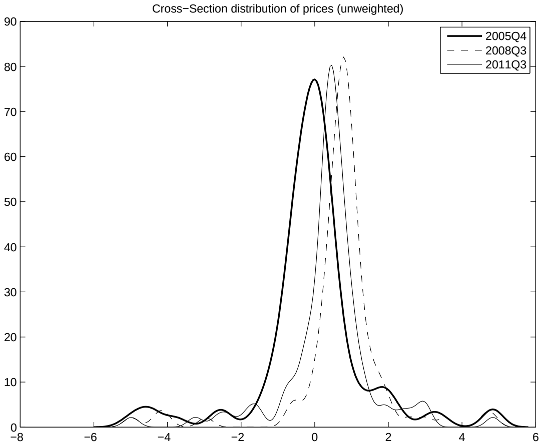

Figure 10. Effect of asymmetric trimmed percentage on the loss

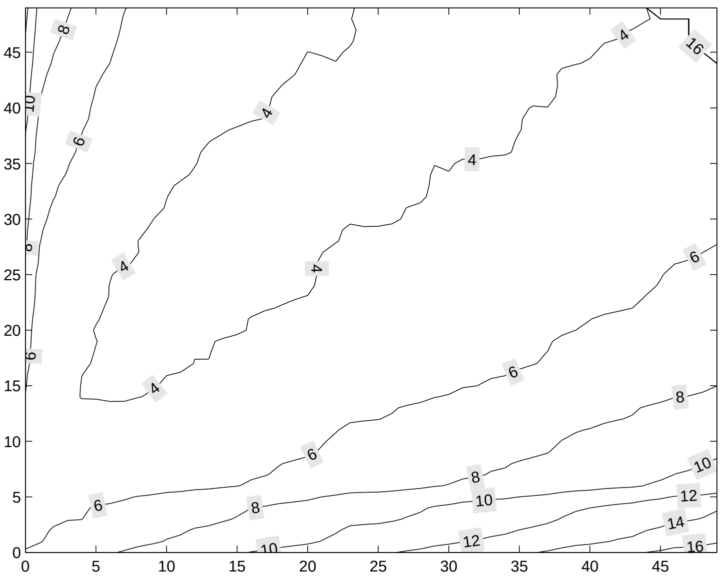

Figure 11. Baseline trimmed mean vs weighted median

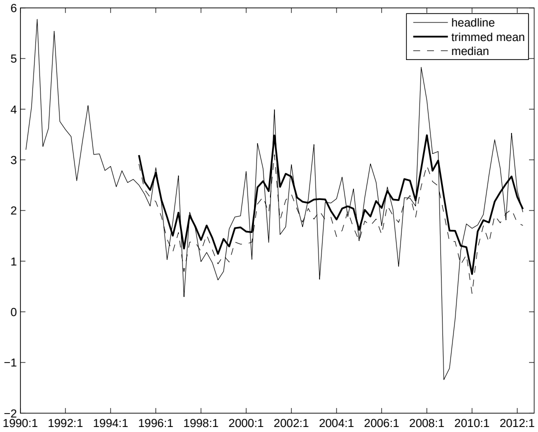

Figure 12. Cons. deflator inflation and output cycle

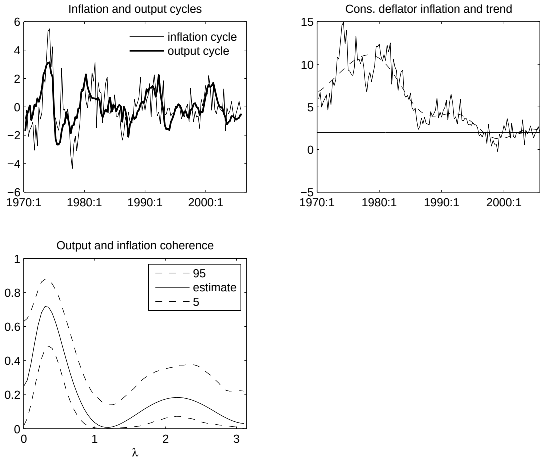

Figure 13. Price level implications of underlying inflation measures

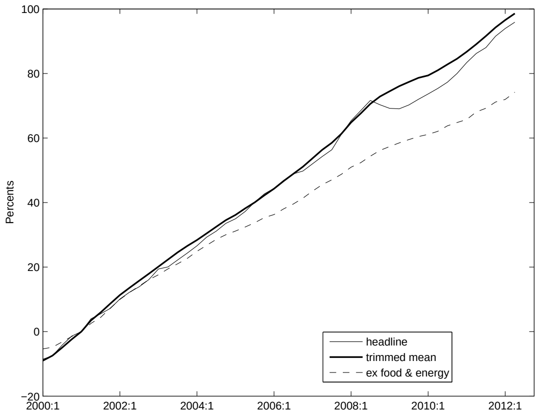

Figure 14. Frequency of exclusions – CPI-T(10,10)

Order	Commodity	Left	Right	Total
1	Recreation: Info Processing Equip	0.944	0.000	0.944
2	Recreation: Eqpt for Sound & Pictures	0.903	0.000	0.903
3	Liquid Fuels	0.319	0.556	0.875
4	Telephone/Telefax Equipment	0.847	0.000	0.847
5	Photographic & Cinematographic Eqpt	0.833	0.000	0.833
6	Transport: Fuels and Lubricants	0.222	0.556	0.778
7	Hot Water, Steam and Ice	0.264	0.444	0.708
8	Vegetables incl Potatoes & Tubers	0.347	0.347	0.694
9	Fruit	0.319	0.347	0.667
10	Gas	0.194	0.458	0.653
11	Passenger Transport by Air	0.292	0.306	0.597
12	Passenger Trans by Sea/Inland Waterway	0.222	0.333	0.556
13	Telephone/Telefax Eqpt and Svcs	0.528	0.014	0.542
14	Oils and Fats	0.236	0.292	0.528
15	Tobacco	0.000	0.486	0.486