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

Michal Andrle, Jan Brůha, and Serhat Solmaz [*]

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. We propose a new estimation approach to trimmed mean inflation, determining jointly the upper and lower quantiles to be trimmed, as well as the frequency bandwidth of real output that best aligns inflation with the output cycle. Our results suggest that at business cycle frequency, the comovement of output and core inflation is high and stable, and that inflation lags behind the output cycle with roughly half of its variance. The strong relationship between output and inflation hints at the importance of demand shocks for the euro area business cycle.

JEL Codes: C10, E32, E50.
Keywords: Business cycle, core inflation, demand shocks, trimmed mean.

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Nontechnical Summary

In this paper, we investigate the comovement between inflation and output in the euro area. The motivation is to investigate the relative importance of supply and demand shocks, which can be loosely interpreted as shocks that induce a negative correlation (supply shocks) or positive correlation (demand shocks) between output and inflation.

We argue that careful treatment of inflation is crucial for the exploration of the comovement of inflation with output. Inflation dynamics are considered along three dimensions – long-run, cyclical, and short-term variations. The long-run dynamics of inflation are given by the central bank's inflation target, which anchors long-term inflation expectations. The cyclical dynamics of inflation are presumably greatly affected by persistent demand, productivity, and various forms of medium-term cost-push shocks. The cyclical dynamics are the component of interest in our analysis of the comovement with output.

We determine the cyclical component of output and the measure of trimmed mean inflation, which share a high degree of common dynamics. The inflation 'gap' is defined as trimmed mean inflation adjusted for the inflation target of the central bank. Trimmed mean inflation removes extreme movements in prices. To avoid the restrictive assumptions of parametric models, we rely on frequency domain techniques based on the estimation of spectral density, and the main measure of interest is coherence – the frequency analog of correlation. The estimated spectral densities of the cycles of output and our measure of trimmed inflation are similar, with the variance of the output cycle being roughly three times larger. The sample estimate of coherence peaks at a value of 0.9.

Our results thus show that the comovement of output and inflation is strong at business cycle frequency. The strength of the comovement of key macroeconomic variables has important implications for business cycle interpretation in terms of demand versus supply shocks. 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.

The paper concludes with a number of sensitivity checks that confirm the results.

1. Introduction

This paper investigates the comovement between inflation and output in the euro area from 1995 up to the first quarter of 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 the 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 doubt on technology shock-driven business cycles as would be suggested by real business cycle theory proponents. Simply put, *underlying inflation*[1] in the euro area is driven by demand cycles and lags behind 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, are 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) and 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. We argue below that at second sight, using intuitive economic arguments for data transformations, stable, strong, and positive comovement of output and inflation can be found in the eurozone.

We determine the cyclical component of output and the measure of trimmed mean inflation, which 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 any deviation of underlying inflation from the inflation target and we search for the frequency band over which it has the closest relationship with output. We also investigate the comovement of median inflation and output for robustness.

Our analysis has an explicit frequency-domain flavor, as we search for an output component featuring high coherence with the deviation of underlying inflation from the target. Our paper is related to the 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. We use the invariance property of coherence, the spectral analog of correlation, to deal with nonstationary

[1] Henceforth, the trimmed mean inflation proposed in this paper is referred to as *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 instead uses 'underlying inflation.'

[2] We regard the Phillips correlation as an outcome of a system, i.e., the interaction of private agents with policy institutions. The focus is on 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 Phillips curve as 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.

data. In contrast to den Haan and Sumner (2004), we acknowledge the inflation targeting nature of modern monetary policy in the euro area, and we therefore focus on the dynamics of inflation, not the 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 for why the de-trended price level may appear countercyclical. Simply put, the de-trended price level becomes countercyclical exactly in the case where inflation follows the cycle in output positively and with a lag. Since both output and the 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] Furthermore, the data starting in the 1990s are influenced by inflation targeting regimes, which have starkly different implications than price level targeting with a drift. Under inflation targeting, changes in the price level are permanent, bygones are bygones. An inflation targeting central bank cares about deviations of inflation from its target.

Careful treatment of inflation is crucial for our exploration of its comovement with output. In our case, inflation dynamics are considered along three dimensions – long-run, cyclical, and short-term variations. The long-run dynamics of inflation should – ideally, if the regime is credible – be given by the central bank's inflation target, which anchors long-term inflation expectations.[4] In the case of the ECB, the target has been constant and explicit since 1999, which simplifies the analysis. The cyclical dynamics of inflation are presumably greatly affected by persistent demand, productivity, and various forms of cost-push shocks. The subject of our analysis is the comovement of output and the 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 the 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 output-inflation comovement for the U.S. economy than for the euro area. The Phillips correlation has been doubted – see e.g. Cooley and Ohanian (1991) – but has also been argued for numerous times – see e.g. King and Watson (1994), Sargent (2001), or Stock and Watson (2010), whose sample covers the Great Recession. Recently, Andrle (2012) demonstrates strong, stable, and positive comovement between the cyclical component of output and the deviation of core inflation from long-term inflation expectations in the U.S. starting from the 1960s through the Great Recession. This paper documents strong comovement of

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

[4] An 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 a longer sample, including the 1980s for instance, in both Europe and the United States. The analysis in Andrle (2012), using U.S. data from 1960 to 2012, confirms strong comovement of output and deviation of inflation from long-term inflation expectations.

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 about the data-generating process, as in Basistha and Nelson (2007), for instance.[5] Recently, to avoid these restrictive assumptions, Basturk et al. (2013) formulated a complex semi-nonparametric model of the New-Keynesian Phillips curve for the U.S. and proposed a computationally intensive Bayesian method to estimate it. Our approach also avoids the restrictive parametric assumptions of previous studies and, by being formulated in the frequency domain, 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 the 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. A sensitivity analysis, an extension to a longer sample, and further properties of underlying inflation follow before we conclude.

2. 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 Appendix A for details. The percentiles excluded from the left and right tail of the distribution can be different, i.e., 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 does not exclude a priori a pre-specified commodity, which would potentially introduce 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 the exclusion-based measure. The 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. The CPI-X measure displays a downward trend, thus underestimating the link between output and inflation, resulting in dramatic divergence of the price level implied by the CPI and CPI-X measures. Median inflation is a special case of trimmed mean inflation and displays a great degree of coherence with the output cycle.[7]

2.1 Data and Computation

We use EA Harmonized Index of Consumer Prices (HICP) data at the level three of disaggregation. This adds up to 94 subcomponents of the aggregate HICP. The data are available for

[5] Surprisingly, the literature employing state-space models to analyze the relationship between inflation and the natural rate of unemployment, or the output gap, has usually not presented the filter weights or how the inflation series actually contributes to the estimation of unobserved components. In our view, this is 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 of robust statistics.

[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. However, it implies real-time filtering issues associated with two-sided filters and fails to use information on the price distribution.

73 periods, 1995:1–2013:2. 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 the 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. This 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 comovement with real activity a criterion for the estimation of underlying inflation? 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 behind the output cycle according to our results. The mean lag is one quarter. Our computations match the spectral properties of inflation and the output cycle. Our underlying inflation is chosen to be well predicted by output and 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, and not create the optimal filter and weight the various frequencies of output into a new composite measure.

Often, the basis for choosing the percentiles trimmed is the distance from a smoothed inflation measure. The filter could be a centered n-quarter moving average measure of inflation – ‘underlying inflation’ (see Bryan and Cecchetti, 1993). Alternatively, analysts use the q-period forecast errors of headline CPI, essentially a pure phase-shift filter, or filtered headline CPI, hoping that underlying inflation is a predictor of headline inflation in the medium term. Such criteria are arbitrary and do not explicitly use economic theory as a guide. Inflation dynamics, presumably, depend on real economy dynamics and policy reactions. Furthermore, in the case of an inflation targeting country, an unbiased forecast two or more years ahead 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 the spectral density of underlying inflation $S_{\pi_t^\star}(\omega)$ with the smoothed indicator's spectral density, $S_{\tilde{\pi}}(\omega)$.

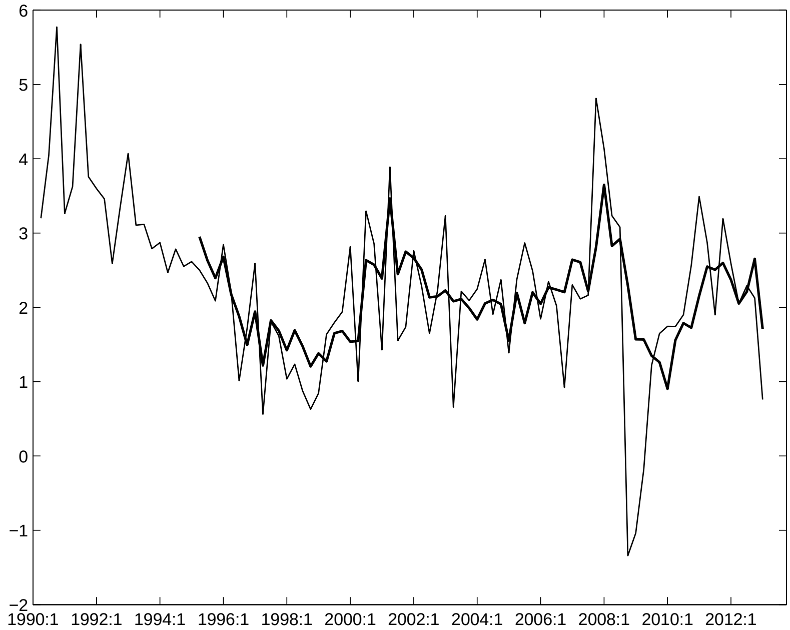
Instead of matching the spectral density of underlying inflation to filtered headline inflation, we match it to the output cycle. Our procedure is easy to understand as a restricted spectral density matching exercise, i.e.,

$$[\alpha_l, \alpha_r, \omega_u] = \text{argmin } ||\tilde{S}_{\pi^\star}(\omega) - \tilde{S}_{\hat{y}}(\omega)||, \tag{2.1}$$

where α_l, α_r are the lower and upper quantiles of the trimmed mean and ω_u is the upper frequency of the band pass – a high-pass filter to be precise. $\tilde{S}(.)$ is the normalized spectral density, whereas $\pi^\star$ and $\hat{y}$ denote the underlying inflation measure and the output cycle, respectively. The measure accounts for the 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 ranging from 0 through to 20 or 60 quarters. The percentiles were varied in steps of size one and we

Figure 2.1: Headline Inflation (Thin) versus Underlying Inflation (Thick), %, ann.



evaluated 2,341 core inflation measures. After roughly the 9th percentile, the loss function (2.1) 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 median inflation is a relatively robust measure of inflation given the data and aggregation structure used. Further sensitivity analysis is carried out below.

2.2 Properties of Inflation and Underlying Inflation

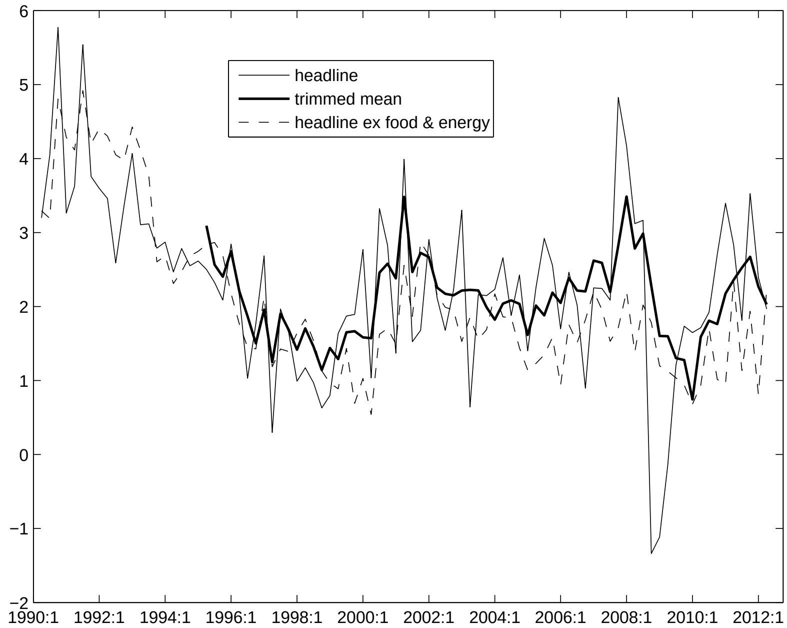
The cross-section distribution of prices in the euro area is highly non-Gaussian. This is in line with other countries – see e.g. Roger (1995) for the case of New Zealand, or Dolmans (2005) for the United States, among others. The distribution features very thick tails due to the presence of several outlier observations every period. The balance between positive and negative price change outliers is very fragile.[9] The kurtosis in excess of the Gaussian distribution is very large, averaging around 15. Thus, the mean is not a robust measure of the price change mass, or 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, CPI-T inflation increased above CPI-X inflation, which

[8] See Fig. C1 in the Appendix depicting the contours of the criterion function for different degrees of trimmed percentiles and optimal ω_u

[9] Fig. C2 and C3 in the Appendix depict skewness, kurtosis, and several examples of cross-section price distribution

Figure 2.2: Trimmed Mean versus CPI-X, %, ann.



hints at stronger demand pressures than what excluding food and energy from inflation would suggest.[10] It also increases faster than the CPI-X measure in 2011–2012, again due to rising energy prices. A big discrepancy between the CPI-X and the CPI-T arises in 2012 at monthly frequency, where the 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 the exclusion of fresh food and energy prices, results in a significant bias of the resulting inflation measure on average (see Fig. 2.2). For the period 2000Q1–2012Q the annualized quarter-on-quarter CPI-X measure has an average bias of -0.54 with respect to headline CPI, which reflects divergence of the 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. 2.2, the CPI-X is persistently lower than 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 fluctuate around the target. This desired change in relative prices, however, renders the CPI-X measure less informative, as it may seriously understate demand effects in the economy, specifically when oil prices are higher due to a booming economy.

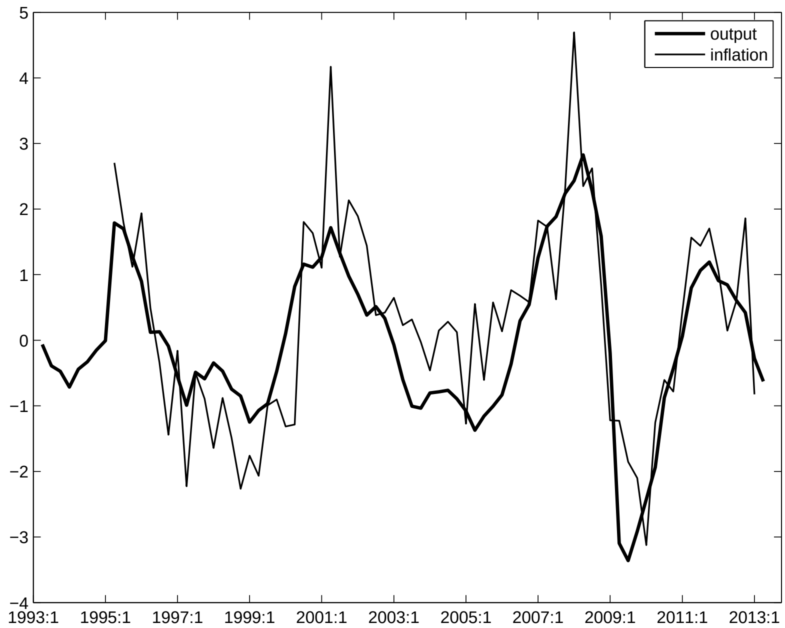
3. Inflation-Output Comovement

3.1 Measuring Comovement

Inflation-output comovement in the euro area seems to be surprisingly strong. Our baseline results suggest a very tight link between underlying inflation and the output cycle in the euro

[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.

Figure 3.1: Output and Inflation Cycles



Note: Normalized to output variance. Phase aligned.

area during 1995–2012. For better visualization, the output cycle is computed using the band-pass filter designed by Christiano and Fitzgerald (1999) – see Fig. 3.1. Underlying inflation is scaled to the output variance and phase-shifted by one quarter to align the average phase of the two 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 the in-sample calculations, to which the optimal trimmed mean measure of underlying inflation and the measure of the output cycle were calibrated, as well as for the median inflation. The comovement is robust with respect to deviations from the optimal trimming percentage.

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

$$\rho^2_{x,y}(\lambda) = \frac{|S_{x,y}(\lambda)|^2}{S_x(\lambda)S_y(\lambda)} \in [0,1] \qquad \text{for } 0 < \lambda \leq \pi, \tag{3.2}$$

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 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 first approach, the coherence is calculated directly using the band-pass-filtered output series and inflation. This approach, however, may suffer from inaccuracies at the end of the sample due to the 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 density of output growth and inflation is calculated. The integration filter (the inverse of the first difference) is then applied to the output component of the cross-spectrum in order to obtain the cross-spectrum of the level of output and inflation, that is:

$$\mathbf{S}_{x,y}(\lambda) = \mathbf{T}(\lambda)\mathbf{S}_{\Delta x,y}(\lambda)\mathbf{T}(\lambda)^H, \qquad \mathbf{T}(\lambda) = \begin{bmatrix} \frac{1}{1-\exp(-i\lambda)} & 0 \\ 0 & 1 \end{bmatrix} \tag{3.3}$$

for $0 < \lambda \leq \pi$, where the superscript 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 that are not of interest. Since complex convolutions in the time domain are just simple multiplications in the frequency domain, the filtering is exact.

Crucially, if the coherence is calculated between two series, it 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 inflation is identical to the coherence of the level of GDP and inflation due to the coherence filter-invariance property ($\rho^2_{x,y}(\lambda) = \rho^2_{\Delta x,y}(\lambda)$) for $0 < \lambda \leq \pi$. The invariance does not hold for other statistics, however.

We consider two approaches to estimating the bivariate spectrum $\mathbf{S}_{\Delta x,y}$ of GDP growth and underlying inflation. The first one is a parametric approach based on the estimation of a VAR(p) model, where the bivariate spectrum is derived from the estimated autocovariance function,[13], while the second one is the 'non-parametric' Bartlett lag-window estimator (Hamilton, 1994). The two approaches yield very similar results and hence all the results reported in the paper are based on the parametric approach.[14] The spectral characteristics obtained using the VAR(2) model with the filtered output series and inflation are displayed in Fig. 3.2.[15] The 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 – the frequency analog of correlation – peaks at a value of 0.9. The phase in Fig. 3.2 is expressed in periods, suggesting that at the business cycle frequency with the greatest power, inflation lags behind output by roughly 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

[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 is the case for the application in this paper.

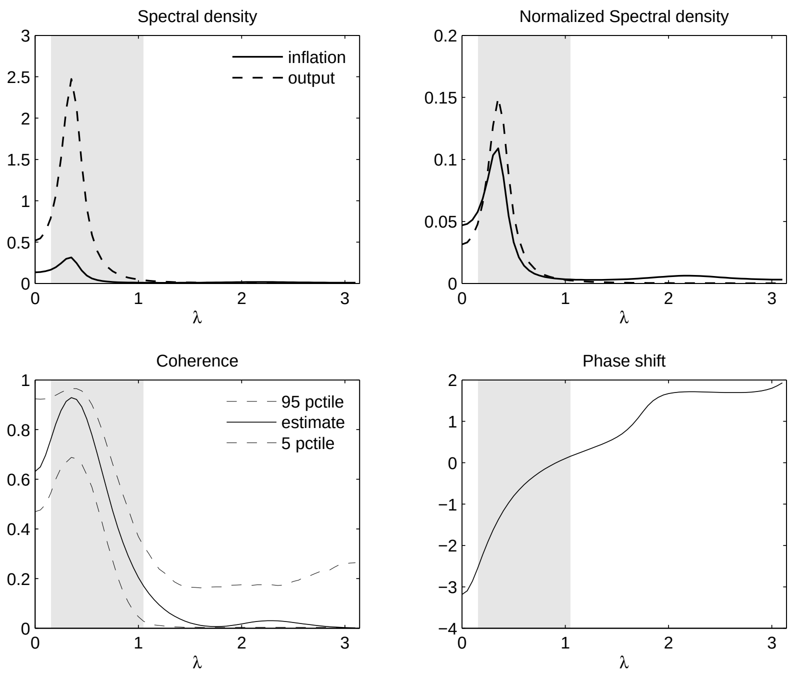
[12] Not only can this be shown analytically, but it is also intuitive: the coherence is invariant to linear filters. The filter effect in the denominator is cancelled out by the filter effect in the nominator.

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

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

[15] The 'wild' bootstrap method was chosen to reflect small-sample considerations – see Wu (1986). The reader may be interested in whether the available data allow us to precisely estimate the bivariate spectrum. We 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 the 'true' and estimated coherence peaks. If the assumed data-generating process was close to the VAR(2) model, the parametric approach seemed to yield *unbiased results*, while if the data-generating process used in simulation was more complicated, the parametric approach *underestimated* the maximum coherence. The Bartlett non-parametric estimator seems on average to slightly *underestimate* the peak in the coherence of interest for both types of data-generating processes. Hence, we conclude that our approaches to estimating the bivariate spectrum are *not biased upward*.

Figure 3.2: Spectral Properties – Output and Inflation Cycle



presented in Fig. 3.3 together with the associated confidence intervals obtained using a wild bootstrap. The confidence intervals are somewhat larger, but the strength of the coherence at business cycle periodicity is again clearly visible despite the fact that the weighted median measure of underlying inflation has not been optimized to comove with the output cycle.

3.2 Implications of Output-Inflation Comovement

Despite its simplicity, we believe that our estimation approach to demand-pull inflation reveals stable and positive comovement between underlying inflation and output. The comovement of real macroeconomic aggregates is consistent with both demand-driven and supply-driven business cycles. Following the tradition of the 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 was 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 on technology shocks cannot reasonably explain the evolution 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 tight positive comovement of the output and inflation cycles.

Investigating Okun's law in the euro area suggests that employment is also driven by a strong common demand factor that fuels 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.

Figure 3.3: GDP Level and Median Inflation Coherence

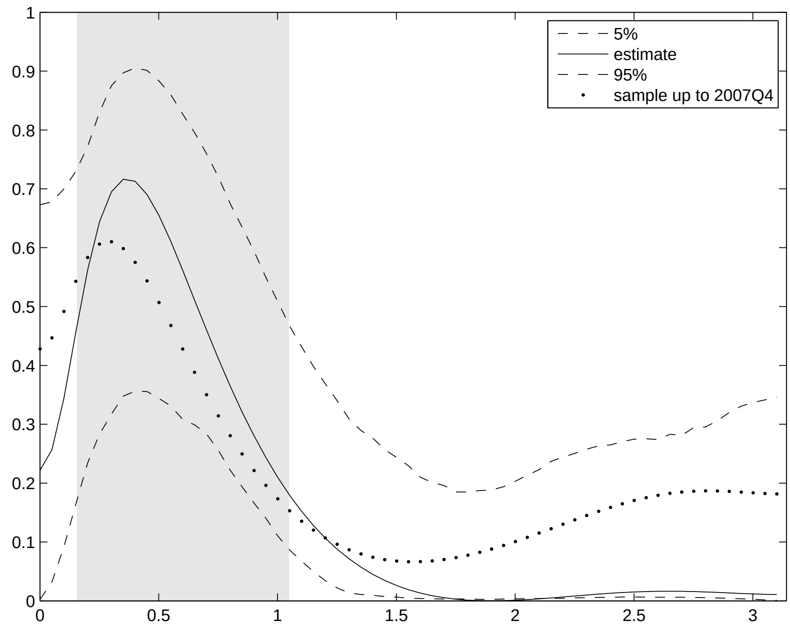


Fig. 3.4 depicts the close comovement of the deviation of underlying inflation from the target with the output and unemployment cycles (with a reversed sign to enhance readability). The strength of the comovement of key macroeconomic variables has important implications for business cycle interpretation in terms of demand versus supply shocks. Demand shocks, or shocks originating from the supply side and leading to an increase in prices, are the likely explanation for euro area business cycles.[16]

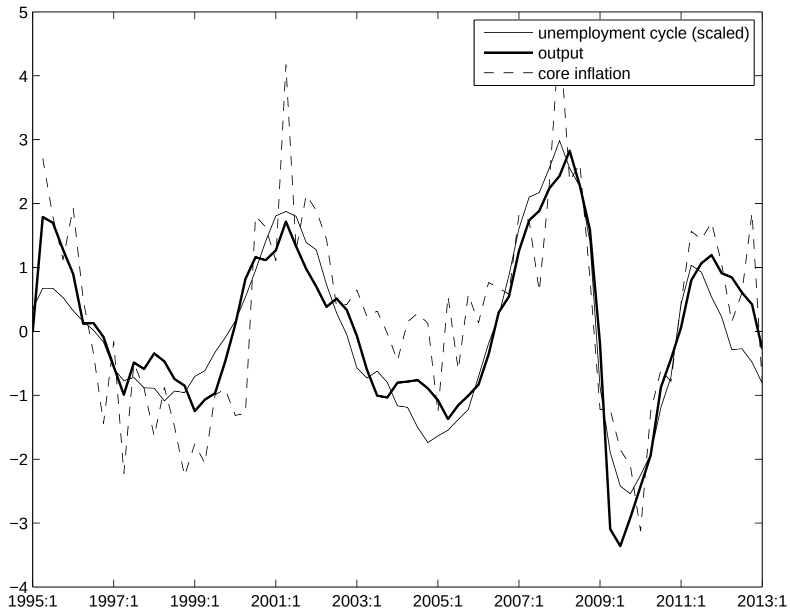
One may ask why a larger drop of inflation has not been observed in the euro area during the latest deep recession. One reason is that the inflation-relevant output cycle might have been depressed less than actual output. Stock and Watson (2010) show, for instance, that for the U.S. economy a decline 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 how much firms can squeeze their margins in a downturn. This would imply that potential output and the structural rate of unemployment have declined and increased, respectively, rather sharply during the recession, consistently with other evidence – see e.g. ECB (2012b). A possible interpretation of our new results is that inflation is reasonably in line with output once more volatility in the trend component of output is allowed for. We emphasize 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.

4. Robustness and Real-Time Properties

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

[16] A similar conclusion holds for the U.S. economy (see Andrle, 2012). Our ongoing research on some other countries, notably Japan, the UK, and Canada, points in the same direction, despite, or perhaps due to, a longer sample size.

Figure 3.4: Underlying Inflation – Output and Unemployment Cycles



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

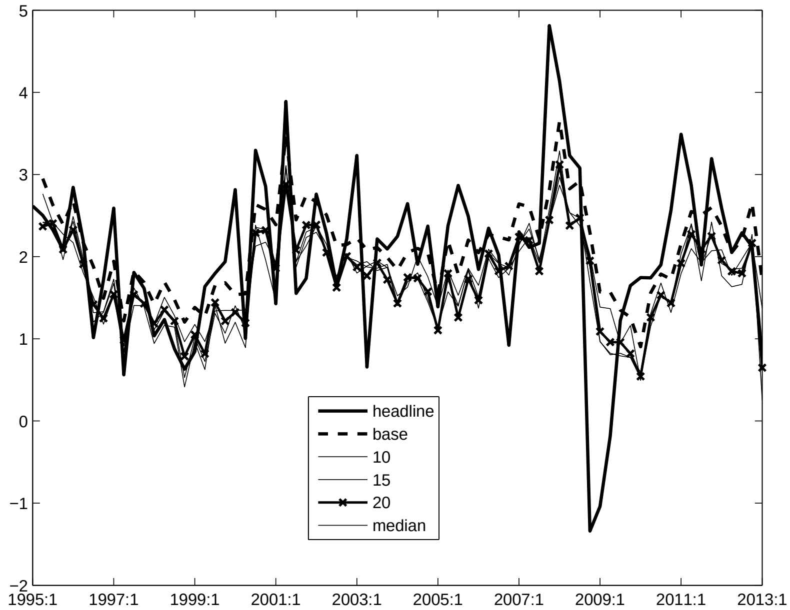
the sample, the construction of the core inflation measure, and the role of the end-point bias of the band-pass filter.

The sample available for the computation of the trimmed means is relatively short, so the question of whether our results also apply to a 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 synthetic data for the euro area compiled for the Area Wide Model (AWM) database (see Fagan et al., 2001), updated until 2005Q4, we find strong and positive comovement of output and the consumption deflator at business cycle frequencies.[17] The coherence of the deviation of inflation from its trend with the output cycle peaks at around 0.6–0.8 depending on the 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. C5). We consider the results from the extended sample to be an indirect robustness check of the demand-driven inflation hypothesis, while acknowledging that the time series for the euro area prior to its official establishment may not always be 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 the two measures is

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

Figure 4.1: Headline Inflation and Variety of Trimmed Means



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. This can be inferred from the profile of the loss function in relation to trimming in Fig. C1 in the Appendix. The results favor asymmetric trimmed means even for a shorter benchmark range.

Median inflation and a variety of trimmed mean inflation measures also display cyclical co-movements with output. Our underlying inflation measure is constructed to maximize the co-movement 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. 4.1 depicts headline inflation with the 10th, 15th, 20th, and 50th percentile symmetric trimmed mean to indicate the similarity and robustness of the measure once the threshold of the 10th percentile is reached. The dynamics of all the measures are similar, with the asymmetric base-line case being roughly 30 basis points higher in annualized terms. The 'placebo test' checks if the matching estimator could have generated 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.

5. 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 behind output at business cycle frequencies by one quarter on average, being roughly half as volatile as 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. The various flavors of technology shocks in recent general equilibrium models will not do, since they imply negative comovement of output and inflation. That 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 $w_{i,t}$, the trimmed mean is a normalized average leaving out α_l percent of the weights from the left and α_r percent of the weights 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

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

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

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

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 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.

Seasonal adjustment The baseline computations use seasonally adjusted data as provided by the Haver Analytics database. In principle, univariate seasonal adjustment is fraught with hazard, as it breaks the general equilibrium links between relative prices in the economy, which, by and large, cancel out the 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 also be judged by the strength of the coherence of median inflation and output.

The placebo test replaces the 94 individual 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 a value of 0.35.

Appendix C. Additional Graphs & Tables

Figure C1: Effect of Asymmetric Trimmed Percentage on Loss

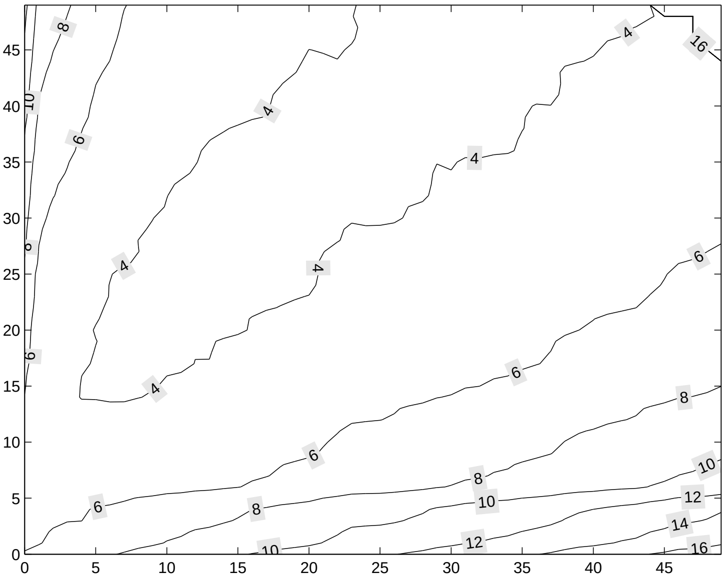

Figure C2: Skewness and Excess Kurtosis

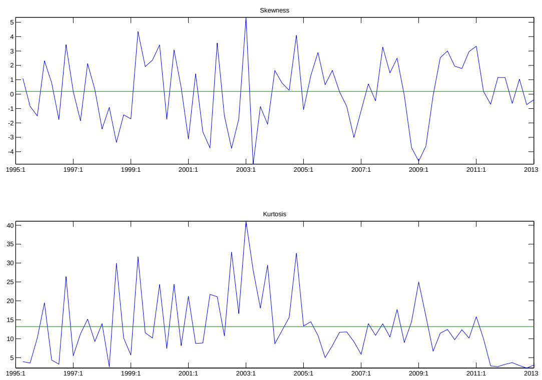

Figure C3: Sample Distribution of Price Changes

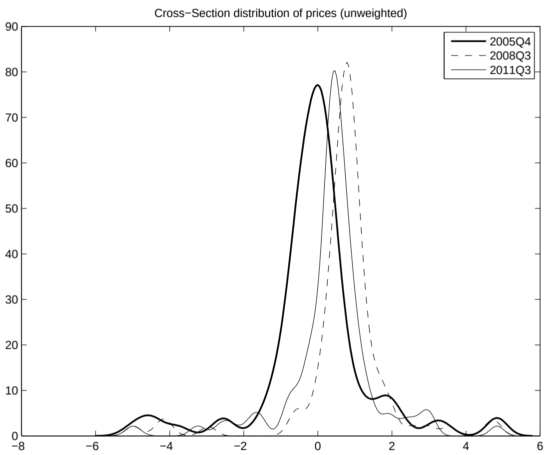

Figure C4: Baseline Trimmed Mean vs Weighted Median

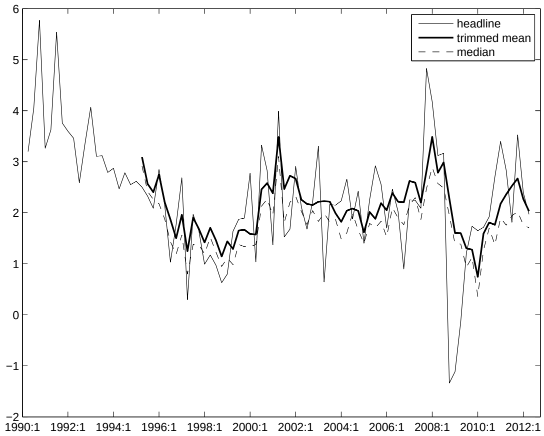

Figure C5: Cons. Deflator Inflation and Output Cycle

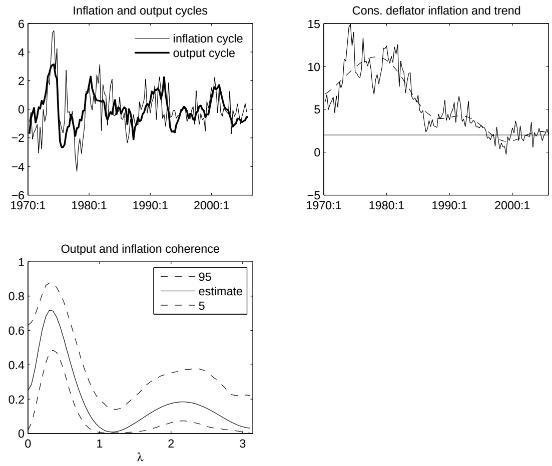

Figure C6: Price Level Implications of Underlying Inflation Measures

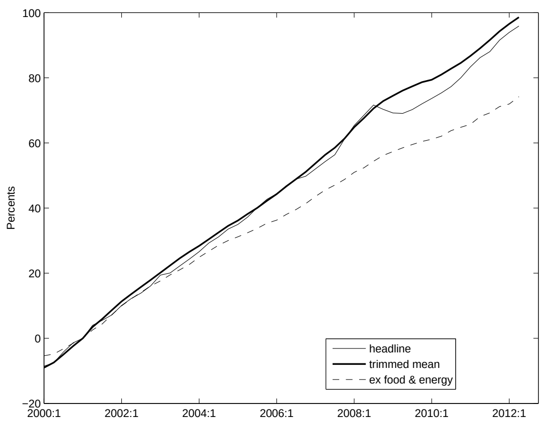

Figure C7: Frequency of Exclusions – CPI-T(10,10)

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

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