Inflation comovements in advanced economies. Facts and drivers [*]

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Abstract

In this paper, we analyze inflation comovements and their macroeconomic drivers across a wide set of advanced economies. We find a high degree of inflation interdependence, which is highest for euro area countries, which show strong trade links and share a common monetary policy. In contrast, core inflation interdependence is very limited. We also find that inflation interconnectedness is a medium- to long-run phenomenon. Inflation comovements across countries are well explained by an open economy new Keynesian Phillips curve.

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1 Introduction

Recent decades have witnessed an increase in the degree of interconnectedness among global economies associated with the growing economic and financial integration among countries. This globalization process is having an impact not only on real macroeconomic variables, but also on nominal ones, such as inflation. The aim of this paper is twofold. On the one hand, to derive a set of stylized facts on the degree of inflation comovement across countries. On the other hand, to analyze the macroeconomic drivers of inflation interdependence.

The open economy New Keynesian Phillips curve model provides a useful conceptual framework that suggests a variety of channels that potentially link inflation developments across countries. According to this model, inflation in a given country is driven by developments in external prices, including those of commodities, business cycles and inflation expectations, so that comovements in these drivers may lead to interdependence in inflation rates of different countries. For instance, commodity prices are largely determined in global markets, so that consumer price fluctuations can be experienced in many countries at the same time. This is particularly the case for oil prices, given that their transmission to domestic retail prices is typically fairly quick. A second natural explanation for the comovement of national inflation rates is that real activity is also correlated across countries. That is, business cycle comovement could lead to inflation comovement, via a Phillips Curve mechanism, as domestic inflation responds to changes in domestic demand.[1] For instance, the global financial crisis of 2007-2008 was followed by a period of missing disinflation that led to a prolonged period of low inflation worldwide. A third reason to explain inflation synchronization across countries rests on comovements in inflation expectations. These, in turn, may be affected by similar monetary policies and similar reaction functions by central banks or private agents to common shocks.

Open economy models also suggest that increases in the degree of openness, such as those

[1] An alternative theoretical reason behind inflation comovements is that domestic inflation is affected by world output to the extent that it has an impact on real marginal costs (e.g. Gali and Monacelli (2005)). From an empirical standpoint, Borio and Filardo (2007) show that measures of global slack have explanatory power into standard Phillips curve type equations of domestic consumer price inflation, but this finding has not been found to be robust. See e.g. Mikolajun and Lodge (2016).

brought about by globalization, may lead to higher inflation synchronization. In this regard, the growing importance of global value chains -i.e. cross-border trade in intermediate goods and services-, which also increase international competitive pressures on domestic price setting (Auer et al. (2017b)), would reinforce the degree of inflation interconnectedness.

Alternatively, mark-up pricing models suggest a highly relevant role of productivity developments in inflation dynamics. Indeed, in the presence of technological spillovers, productivity growth can generate movements in inflation which are synchronized across countries (Henriksen et al. (2013)) and common sector-specific technology shocks are amplified due to input-output linkages (Auer et al. (2017a)). Finally, inflation synchronization may also be explained by relative purchasing power parity theories (Taylor and Taylor (2004)).

Even though, as discussed above, there are many theoretical channels that explain inflation interdependence, the evidence on the synchronization of inflation dynamics is very limited, in contrast with that on business cycle comovement, the well-known fact that fluctuations in real economic activity tend to coincide across countries.[2] Early attempts at documenting inflation comovements, such as in Wang and Wen (2007) or Henriksen et al. (2013), have relied on Pearson correlation coefficients between country pairs and clearly show that headline inflation rates between any country pairs are positively correlated. A related strand of literature, following the seminal work by Cicarelli and Mojon (2010), estimates common/latent factor models[3] and uses variance decompositions to measure the extent to which world and country-specific components explain the variation in national inflation rates.

Against this background, our contribution to the literature can be summarized as follows. First, we analyze to which extent developments in macroeconomic variables are able to explain inflation interdependence, an aspect not previously addressed in the literature. Second, we consider to which extent inflation interdependence is affected by heterogeneity in price dynamics. i.e. are inflation comovements mostly due to synchronization of sectoral shocks (e.g energy) or are they

[2]See, for instance, Kose et al. (2008) or de Haan et al. (2008).

[3]Other contributions include Neely and Rapach (2011), Mumtaz and Surico (2012) or Forster and Tillmann (2014). Carriero et al. (2018) analyze the global component of inflation volatility.

broad-based? Heterogeneity in price dynamics has been documented along a number of dimensions,[4] such as the degree of price stickiness (Álvarez et al. (2006)), the size of price adjustments (Dhyne et al. (2006)), the degree of inflation persistence (Lünnemann and Mathä (2004)), or demand elasticities, to name but a few, and it is standard in the inflation forecasting literature to consider different consumer price components (e.g. ECB (2016)) to capture heterogeneity in their response for different shocks. Moreover, optimal monetary policy is different when there is heterogeneity in price setting (Aoki (2001) and Carvalho (2006)). Third, we systematically study to which extent the degree of inflation interdependence is different for trends, business cycle fluctuations or short-term movements in inflation.[5] For instance, comovement of trend inflation is likely to be due to similarities in central banks' inflation targets.[6] In contrast, idiosyncratic shocks, such as those related to changes in indirect taxes, or weather conditions, and differences in transmission mechanisms, such as those due to differences in the degree of nominal stickiness, are likely to result in a low degree of inflation synchronization over the short run. Finally, inflation comovement is expected to be strongest at business cycle frequencies, reflecting the interdependence of international business cycles and its impact on national inflation via Phillips curve mechanisms. Fourth, we focus not only on advanced economies, but also on the subset of euro area countries, which have strong trade links and share a common monetary policy, that is a source of common demand shocks. Fifth, we consider summary measures of inflation interdependence which allow us to carry out statistical inference rather than using pair-wise country correlations that are difficult to summarize.[7] These summary measures can also be used to analyze changes in inflation synchronization over time. Indeed, the degree of inflation interdependence is not stable over time, reflecting the time-varying importance of the different types of shocks.[8]

[4]The scant evidence on heterogeneity in inflation synchronization is limited to CPI stripped off energy and food prices. See e.g. Henriksen et al. (2013).

[5]Some papers present results on inflation interdependence over business cycle frequencies, e.g. Henriksen et al. (2013).

[6]Monetarist models of trend inflation (e.g. McCallum and Nelson (2011)) suggest, on average a one-for-one relation between long-run money growth, adjusted for trend output growth, and long-run inflation.

[7]Specifically, we consider the Stock and Watson (2008) modification of the Moran statistic used in the spatial correlation literature.

[8]For instance, evidence in Cicarelli and Mojon (2010) or Mumtaz and Surico (2012) suggest a lower degree of inflation synchronization early this Century than during the latest decades of the 20th Century.

Our main results can be summarized as follows. First, we find that inflation interdependence among advanced economies is quite relevant. Second, inflation synchronization is not broad-based and there is marked heterogeneity in the degree of interdependence across sectors. Unexpectedly, inflation comovement is fairly low for core goods and services. Third, inflation interdependence is a medium to long-run phenomenon. Fourth, the degree of comovement in headline inflation has increased over our sample period, possibly reflecting the role of growing trade integration and the impact of the common euro area monetary policy. Fifth, inflation synchronization among original euro area countries is higher than for all euro area countries, given that some of the newer members could not be characterized as having price stability prior to joining the euro, which in turn is higher than for advanced economies as a whole, partly due to the existence of different central banks with different reaction functions. Sixth, inflation interdependence seems to be particularly explained by comovements in driving variables of open economy new Keynesian Phillips curve models. Specifically, inflation expectations, business cycles and external prices.

After this introduction, the rest of the paper is organized as follows. Section 2 describes the data, whereas section 3 is devoted to presenting results on inflation interdependence along several dimensions, such as country groups, types of products or frequency bands. Section 4 presents some robustness exercises. Section 5 analyses the macroeconomic drivers of inflation interdependence and section 6 concludes.

2 The data

We focus on analyzing inflation developments in a wide set of advanced economies. Specifically, we consider a sample of 24 countries:[9] Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, United Kingdom and United States. In our analysis, we pay particular attention to euro area countries (EA), as they show a high degree of

[9] We have considered all European Union countries with published HICP data starting from January 1996, plus the US, Canada and Japan.

trade linkages and share a common monetary policy that could lead to a high degree of inflation interdependence. Among EA, we distinguish between original euro area countries (OEA) and newer euro area countries (NEA) to take into account that the latter only recently met the criteria needed to join this monetary union,[10] including price convergence, and generally show a lower degree of trade interconnection with the rest of countries. Finally, the rest of advanced economies have country-specific monetary policies and are grouped as other advanced countries (OAC). See Table 1 for details.

To carefully assess the degree of heterogeneity in price setting, we have put together a database harmonizing, to the extent possible, country definitions. Specifically, we consider, besides the headline index, the following breakdown: (i) energy prices, which are typically quite volatile and subject to supply shocks, (ii) food prices, which are also volatile and subject to sizable transitory shocks and (iii) core inflation, defined as the headline index excluding food and energy. We further decompose this core measure into (iv) non-energy industrial goods[11] and (v) services, which are less exposed to external competition than manufactured goods.

We employ consumer price indices for the period from January 1996 to April 2018. The series are seasonally adjusted. Data for the European countries come from Eurostat, US data from the Bureau of Labor Statistics, Canadian data from Statistics Canada and data for Japan from the Statistics Bureau of Japan.

3 Interdependence among advanced economies

A natural way to analyze inflation comovements is to consider the Pearson correlation coefficient for all country pairs. However, in our setting we would have 276 measures of synchronization for each inflation measure. To solve this dimensionality problem, we use the Moran-Stock-Watson index of comovement (Stock and Watson, 2008). This measure, based on the spatial correlation

[10] Specifically, developments in HICP inflation, government budget deficit, government debt-to-GDP ratio, exchange rate stability and long-term interest rates.

[11] We have also considered a further breakdown just for euro area countries in terms of durable, semi-durable and non-durable goods. Results are available upon request.

literature, summarizes in a single number the degree of comovement in inflation across different countries. Furthermore, the distribution of this statistic is known, so that statistical inference can be carried out.

3.1 A first look at the data: Pearson correlation measures

Figure 1 presents correlation matrices for headline and core inflation, which are visualized with schemaballs. The width of the parabola joining two countries represents the absolute value of the bivariate correlation coefficient. Yellow is used for positive correlations and purple for negative correlations. Countries are arranged alphabetically, grouping them as original euro area members, new euro area members and non euro area countries.

For headline inflation, we show that inflation comovements among euro area countries are higher than for advanced economies as a whole, possibly reflecting the fact that these countries show a high degree of trade linkages and share a currency. Among non-euro area countries, the Japanese economy stands out for its very low degree of comovement with the rest of countries. In contrast, the high correlation of Denmark with respect to the rest of countries could be due to the fact that the Danish krone has been linked to the euro since the beginning of our sample. We also observe a higher degree of synchronization among original euro area countries than among those euro area countries of more recent incorporation.

For core inflation, we find that core inflation measures generally show a low degree of comovement, a result also found in Carney (2017). This is particularly so for non-energy industrial goods,[12] which may be affected by some country-specific factors, such as the timing of sales[13] and promotions or the use of different quality adjustment procedures. Comovement is very high for energy prices, reflecting the role of common oil price shocks. Finally, there is a substantial degree of synchronization in food prices, probably reflecting high trade linkages.

[12]Results are available upon request.

[13]Sales periods vary from country to country and even within regions of the same country. Moreover, the size of discounts vary substantially depending on the stock of unsold items during the normal season.

3.2 Moran-Stock-Watson index of comovement

The Moran-Stock-Watson (MSW) index of comovement (Stock and Watson, 2008) summarizes in a single number the degree of synchronization in inflation developments across different countries. Specifically, the modification by Stock and Watson (2008) of Moran's I_t statistic is given by:

$$MSW_t = \frac{\sum_{i=1}^{N}\sum_{j=1}^{i-1} cov(\pi_{it},\pi_{jt})/(N-1)/2}{\sum_{i=1}^{N} var(\pi_{it})} \tag{1}$$

where

$$cov(\pi_{it},\pi_{jt}) = \frac{1}{k}\sum_{s=t-int(k/2)}^{t+int(k/2)}(\pi_{is}-\overline{\pi_{it}})(\pi_{js}-\overline{\pi_{jt}}) \tag{2}$$

$$var(\pi_{it}) = \frac{1}{k}\sum_{s=t-int(k/2)}^{t+int(k/2)}(\pi_{is}-\overline{\pi_{it}})^2 \tag{3}$$

$$\overline{\pi_{it}} = \frac{1}{k}\sum_{s=t-int(k/2)}^{t+int(k/2)}\pi_{is} \tag{4}$$

where π_{it} is the inflation of country i in time t, $k = 61$ is the rolling window, which equals to 5 years working with monthly data, and N, the number of countries equals 24 and *int* refers to the integer part. It would be possible to build a spatial weights matrix $W(w_{ij})$ to weigh the different spatial units. Following Stock and Watson (2008), we have assumed that all countries behave like neighbors and, therefore, $w_{ij} = 1$ if i$\neq j$ and 0 if $i = j$.[14]

This index is bounded between 1 and -1, and the higher (lower) is its absolute value the higher is the degree of comovement. Positive values mean that inflation rates in different countries tend to go up (down) in tandem. An advantage of this index is that its distribution is known, so that we can carry out statistical inference and compute confidence intervals. Indeed, its mean and variance under the null hypothesis of no spatial autocorrelation are given by:

[14] The calculation of the MSW indices using a spatial contiguity matrix does not change the results.

$$E[MSW_t] = -1/(N-1) \tag{5}$$

$$Var_t[MSW_t] = \frac{NS_4 - S_{3t}S_5}{(N-1)(N-2)(N-3)S_0^2} \tag{6}$$

where

$$S_0 = \sum_i \sum_j w_{ij}$$

$$S_1 = \frac{1}{2}\sum_i \sum_j (w_{ij} + w_{ji})^2$$

$$S_2 = \sum_i (\sum_j w_{ij} + \sum_j w_{ji})^2$$

$$S_{3t} = \frac{N^{-1}\sum_i \frac{1}{k}\sum_{s=t-int(k/2)}^{t+int(k/2)} (\pi_{is} - \overline{\pi})^4}{(N^{-1}\sum_i \pi_i - \overline{\pi})^2)^2}$$

$$S_4 = (N^2 - 3N + 3)S_1 - NS_2 + 3S_0^2$$

$$S_5 = (N^2 - N)S_1 - 2NS_1 + 6S_0^2$$

and the z-score for the MSW statistic is computed as:

$$z_t(MSW_t) = \frac{MSW_t - E(MSW_t)}{\sqrt{Var_t(MSW_t)}} \tag{7}$$

Before exploring the time series dimension of the Moran-Stock-Watson index of comovements we have computed a scalar version by considering the whole sample. The results for advanced economies and the euro area ones are presented in Table 2. We observe that inflation comovements are important and significant for all areas. Furthermore, interdependence is higher for original euro area countries than for all euro area countries which, in turn, is higher than for advanced economies as a whole. We interpret these results as reflecting the role of high trade linkages, which are particularly high among original euro area countries, and common monetary policy in the euro area.

We also analyze the role of heterogeneity across goods and services in the degree of synchronization. As expected, we find a high degree of heterogeneity in the degree of comovement of price change measures of the different types of goods and services. First, interdependence of core inflation measures is significantly lower than for headline inflation ones, in line with Carney (2017).[15] This synchronization is particularly low for non-energy industrial goods.[16] This low degree of comovement, which may be somewhat puzzling, is in line with simple average correlation measures and suggests that more permanent fluctuations of inflation are not heavily synchronized across countries. Our explanation is that this low degree of synchronization reflects factors such as differences across countries in sales and promotion practices, which are particularly relevant for some goods, such as clothing, footwear or electrical appliances, and which have sizable impacts on retail prices.[17] Notice also that we use final consumer goods prices, which have a sizable non-tradable component linked to factors, such as retailers' labour costs such as rentals and, whose developments will generally vary across countries. We would expect export prices of these type of goods to display a higher degree of comovement. Second, the highest degree of comovement corresponds to energy prices. This is consistent with the relevance of common oil price shocks and the low degree of stickiness of these prices. Third, we find that food prices are also quite synchronized, probably due to globalization of food commodity markets and the increasing existence of multinational companies. Fourth, regarding the geographical breakdown, the highest degree of comovement for all categories of goods and services corresponds to original euro area countries, which is higher than for the whole set of euro area countries, which, in turn is higher than for

[15]Similarly, Carriero et al. (2018) find that the global component of the volatility of headline inflation is considerably higher than that of core measures.

[16]We have also computed comovement statistics for different non-energy industrial goods types based on their durability for euro area countries. Non-durables present the highest degree of synchronization.

[17]Moreover, it has also to be borne in mind that, some countries make quality adjustments in some articles, while others do not. See Eurostat (2018) for further details on quality adjustment in the HICP.

advanced economies as a whole. As mentioned above, the high degree of trade linkages and the common monetary policy in the euro area may be behind these results.

3.2.1 Interdependence over time

To analyze changes over time in the degree of inflation synchronization we have used two complementary approaches. The first one refers to the examination of interdependence measures for two different subsamples and the second one to the use of rolling windows in the computation of measures. Notice that the subsample analysis considers a higher number of observations, so that inference is more precise than when using rolling windows. This comes at the cost of subsample analysis being less accurate in the timing of changes than the one with rolling windows.

In the subsample analysis, we consider two different subsamples: the first subsample spans the period prior to the global financial crisis (that is, it goes from 1996 to 2007) and the second one covers the period after it (from 2008 to 2018).

Results are presented in Tables 3 and 4. Overall, inflation interdependence has increased after the global financial crisis, with the only exception of core inflation among the original euro area countries. This most likely reflects the fact that different countries increased indirect taxes and administered prices in a non-synchronized fashion after the crisis and, as a result, consumer prices tended to show a lower degree of interdependence.[18]

Some interesting information can also be obtained by analyzing developments over time considering rolling windows (see Figures 2 and 3), as some of the underlying factors, such as globalization are more relevant in the more recent period than in the past. Indeed, computing this statistic for centered rolling windows of 5 years,[19] we find that inflation interdependence has not remained stable, but rather has tended to increase over time among advanced economies and also among euro area countries. This possibly reflects the role of growing trade integration and the role of a

[18]Core measures, non-energy industrial goods and services, also present different patterns across subsamples and geographical areas.

[19]Alternatively, we have considered rolling windows of 8 and 10 years. Qualitative results remain the same but, as expected, the Moran-Stock-Watson measures are smoother. Note that use of a longer window leads to a loss of more observations at the beginning and at the end of the sample.

common euro area monetary policy in the latter group of countries.

Although the subsample analysis shows that inflation comovement is higher in the period after the global financial crisis in comparison with the previous one, evidence of time series developments shows some heterogeneity inside these broad periods of time. For instance, considering the different components for the whole sample of countries the upward trend in comovement that was observed up to 2011 for core inflation seems to be reversing. This reversal probably reflects the fact that different euro area countries passed indirect tax increases in a non-synchronized manner. In contrast, in the case of energy a mild upward trend over time is observed. Patterns for euro area countries as a whole are broadly similar to those of advanced economies.

As the statistical distribution of the Moran-Stock-Watson index of comovement is known, we have calculated confidence intervals for advanced economies (Figure 4) and euro area ones (Figure 5) for each of the six types of products. The blue dotted lines show the confidence intervals for each of the six inflation measures. We find that the increase in synchronization trend is statistically significant for headline inflation and the most volatile components, energy and food. For core inflation, comovement is significant only around the years of the global financial crisis.[20]

Finally, given the well documented comovement in GDP, we compare it with inflation synchronization. We have computed the Moran-Stock-Watson index of comovements using GDP data. We find that inflation interdependence among advanced economies is quite relevant, but it is smaller than GDP interdependence (Table 2), a result that is also found for euro area countries. Moreover, developments over time in the degree of synchronization are different for inflation and activity. For instance, whereas headline inflation interdependence has remained quite high in recent years, GDP synchronization, which peaked at the time of the global financial crisis, decreased after the two latest European recessions.[21]

[20]Considering windows of 10 years, comovement in core is significant.
[21]See Alvarez et al. (2019) for details.

3.3 Interdependence across frequency bands

The analysis above has not considered possible differences in the degree of inflation interdependence regarding developments in trend inflation, business cycle fluctuations in inflation or short-term movements in inflation, despite the fact that there are theoretical reasons for expecting differences in the degree of comovement depending on the more permanent or transitory nature of the forces driving inflation. For instance, country-specific shocks, such as those stemming from changes in indirect taxes or regulated prices, are likely to result in a low degree of inflation synchronization over the short run, since they typically come into force in different countries at different times. In turn, synchronization of trend inflation may be due to similarities in central banks' inflation targets. Finally, inflation interdependence is expected to be strongest at business cycle frequencies, reflecting the synchronization of international business cycles and its impact on national inflation rates via Phillips curve mechanisms.

To decompose inflation into its trend, business cycle and short-term movements we use a band-pass filter.[22] Different band-pass filters can be used to carry out this decomposition. For instance, Christiano and Fitzgerald (2003) or Baxter and King (1999) filters. In this paper, given than the Baxter and King filter involves losing observations at the start and end of the sample, we follow Henriksen et al. (2013) and use the Christiano and Fitzgerald filter. Specifically, we decompose inflation as:

$$\pi_t = \pi_t^T + \pi_t^{BC} + \pi_t^{SR} \tag{8}$$

where π_t^T captures movements in trend inflation, defined as cycles over 5 years, π_t^{BC} captures business cycle fluctuations between 2 and 5 years and π_t^{SR} captures short-run fluctuations, that is cyclical movements below 2 years.

To determine the source of comovements, we compute the Moran-Stock-Watson-based syn-

[22] Band-pass filters are explicit about frequency bands considered, in contrast with unobserved components models. Note that trend, cycle and irregular decompositions in unobserved component models implicitly consider different frequency bands, so some care is needed when comparing across countries or type of products. See Álvarez and Gómez-Loscos (2018).

chronization indices separately for π_t^T, π_t^{BC} and π_t^{SR}. Results of this interdependence measure for advanced economies, euro area countries and original euro area countries are displayed in Table 5 for the six products and the three frequency bands considered.[23]

Regarding headline inflation, we find that the degree of comovement is fairly low for high frequencies, reflecting the relevance of country-specific transitory shocks. In contrast, it is highest for the medium run, when the Phillips curve mechanism is expected to be strongest. In turn, trend inflation also shows a sizable degree of comovement, although it is lower than for long-run GDP fluctuations. Interestingly, for every frequency band, the degree of interdependence is higher for original euro area countries than for all euro area countries than for all advanced economies, suggesting a relevant role of (original) euro area-specific shocks. A similar pattern applies to GDP growth.

Regarding the product breakdown, we find that short-run interdependence of core inflation is close to zero, in sharp contrast with the energy component, which is heavily affected by common oil shocks. Core inflation synchronization for business cycle frequencies is significantly higher that for the short run, but still quite limited. Again, the highest degree of comovement in the medium run is found for the energy component. Finally, synchronization is limited for trend movements in core inflation, in contrast with energy prices. For all frequency bands, food prices comove more than core ones, but less than energy ones.

4 Robustness analysis

4.1 Leading/lagging countries

The analysis above exploits contemporaneous comovement among inflation rates, that is, the interrelationships of inflation across countries at the same moment of time. Here, as a robustness check, we analyze whether some countries could be leading/lagging the rest. To that end, we have computed cross-correlation coefficients of inflation in advanced economies/euro area ones with

[23]We have also computed mean Pearson correlation coefficients and results are broadly the same.

national inflation series for up to 12 leads and up to 12 lags. To save space, in Table 6 we report the highest and lowest correlation coefficient for lags 1 to 12, the contemporaneous one, and the highest and lowest correlation coefficient for leads 1 to 12, both for advanced economies as a whole and for euro area ones. This exercise is useful for determining whether inflation in some of the countries tends to lag or lead inflation in advanced economies or the euro area. Results show no clear evidence that any country is markedly leading or lagging advanced economies/euro area inflation developments. This allows us to discard the possibility that inflation in a particular country (for example, the United States) has been systematically leading that of the rest of the advanced economies. This supports the use of contemporaneous spatial correlation indices.

4.2 Alternative measures of inflation interdependence

An alternative measure of comovement across countries is given by Pesaran's cross dependence test (Pesaran, 2004), which measures interdependence as a function of simple correlation coefficients across variables. Specifically, the measure is given by:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \tag{9}$$

where T is the total number of observations, N refers to the number of countries and ρ_{ij} to Pearson correlation coefficients. This statistic, under the null hypothesis of no cross-sectional dependence, follows a standard Gaussian distribution for $N \to \infty$ and T sufficiently large.

Results on Pesaran's cross-dependance test are displayed in Table 7. We find that results found using the Moran-Stock Watson measure are confirmed by using Pesaran's measure. That is, the lowest degree of synchronization is found for core prices and particularly so for those of non-energy industrial goods. In contrast, energy prices show the highest degree of comovement.[24]

We have also considered the Peña-Rodriguez measure of cross-sectional dependence (Peña and Rodriguez, 2003). Similarly to the previous measures, we find that for all types of products and

[24]Notice that Pesaran's statistic depends on the number of countries considered, so, on the basis of it, no claims can be made on the relative degree of interdependence for groups of countries of different sizes.

groups of countries, we reject the null hypothesis of no cross-sectional dependence.

5 Drivers of inflation interdependence

Although of great interest, none of the papers available in the literature has analysed the macroeconomic drivers of the degree of inflation comovements across countries. In this section, we assess the explanatory power of open economy new Keynesian Phillips curves, using a two-stage approach. First, we estimate panel data models to decompose, for each country, observed inflation into explained and non-explained components. Second, we use two measures to assess to which extent observed inflation interdependence across countries can be accounted for by inflation comovements explained by our models.

We present results both for the full set of advanced countries and for the subset of euro area economies.[25] Furthermore, we analyse separately headline and core inflation measures. We estimate standard open economy New Keynesian Phillips curves (Gali and Gertler, 1999) considering country fixed effects.[26] Specifically, the hybrid version is given by:

$$\pi_{it} = \alpha_i + \beta\pi_{it-1} + \gamma E_t\pi_{it+1} + \delta(y_{it} - y^*_{it}) + \tau p^m_{it} + \varepsilon_{it} \tag{10}$$

where π_{it} refers to inflation at time t in country i, π_{it+1} to expected inflation, $(y_{it} - y^*_{it})$ to the business cycle and p^m_{it} to external prices.[27] Backward and forward looking versions of the Phillips curve are just particular cases of the hybrid Phillips curve. Specifically, the backward looking Phillips curve is obtained when γ equals zero and the forward looking one when β equals zero.

[25] Robust standard errors are computed following Driscoll and Kraay (1998).

[26] New Keynesian Phillips curves have been used extensively in recent years. See e.g. Ball and Mazumder (2019), Bobeica and Jaroncisnksi (2019) or Cicarelli and Osbat (2017).

[27] Inflation expectations have been computed using the methodology of Buchmann (2009) for the European countries (see the Appendix A for details). For Japan, we apply the Carlson and Parkin (1975) methodology to Bank of Japan data. For Canada, data refer to firms and come from the Bank of Canada. For the US, they come from the St. Louis Fed FRED database. The business cycle is proxied by quarter-on-quarter GDP change and external prices are measured by the import deflator. Data for these variables are from Eurostat for the European countries, Statistics Canada for Canada, Cabinet office for Japan and Bureau of Economic Analysis for the US.

Our sample period in this section starts in 2000, since this is the first year for which we have data on inflation expectations for European countries.[28]

Our estimates, presented in Table 8, support the use of open-economy new Keynesian Phillips curves. Inflation shows both backward and forward components (that is both past and expected inflation) are significant, although the former is more relevant. Moreover, the business cycle and external prices also help explain inflation. The role of external prices is more relevant for headline inflation, which is particularly affected by worldwide oil prices, than for core inflation.[29]

These models allow us to obtain the explained inflation component as:

$$\widehat{\pi}_{it} = \widehat{\alpha}_i + \widehat{\beta}\pi_{it-1} + \widehat{\gamma}E_t\pi_{it+1} + \widehat{\delta}(y_{it} - y^*_{it}) + \widehat{\tau}p^m_{it} \tag{11}$$

where a hat above a coefficient denotes its estimated value.

To assess to which extent our Phillips curves are able to explain inflation interdependence across countries, we consider two alternative measures. First, the Moran-Stock-Watson index of comovement. Second, a measure of matrix distance between the correlation matrix of observed inflation and that of explained inflation. We note that Phillips curve estimates aim at tracking observed inflation dynamics, but this does not mean that these models are necessarily able to match observed inflation interdependence, which depends on the variance-covariance matrix of inflation across countries.

Table 9 compares the degree of inflation interdependence in terms of the Moran-Stock-Watson index of comovement of explained inflation interdependence using the full sample for the different specifications:

$$MSW = \frac{\sum_{i=1}^{N}\sum_{j=1}^{i-1} cov(\widehat{\pi}_{it}, \widehat{\pi}_{jt})/(N-1)/2}{\sum_{i=1}^{N} var(\widehat{\pi}_{it})} \tag{12}$$

[28] Furthermore, for some small countries there are missing data in some months for the inflation expectations variable.

[29] Inflation expectation series are only available for headline inflation but, unfortunately, none for core inflation. Therefore, we follow the standard practice in estimating NKPC models for core inflation, which is to use headline inflation expectations (see. e.g. Alvarez and Correa-Lopez (2020), Bobeica and Sokol (2019) or Eser et al. (2020)).

As can be seen, point estimates of the MSW index for inflation explained by the different models are fairly similar to the MSW index for observed inflation. Furthermore, we cannot reject the hypothesis that the value of both indices is the same for all cases considered. All in all, inflation interdependence explained by these Phillips curve models matches that of observed inflation.

As a robustness check, we compute the degree of similarity in the interdependence between observed inflation and explained inflation using a Frobenius norm.[30] This matrix norm is given by:

$$\|P_{\pi} - P_{\widehat{\pi}}\|_F = \sqrt{Tr[(P_{\pi} - P_{\widehat{\pi}})(P_{\pi} - P_{\widehat{\pi}})']} \tag{13}$$

where P_{π} is the correlation matrix of observed inflation across countries, $P_{\widehat{\pi}}$ is the correlation matrix of explained inflation and Tr is the trace operator.

This norm measures the distance between two square matrices as a scalar value. The lower (higher) is the value of this norm, the closer (farther) are the two matrices. In the extreme case in which the two matrices are identical, the Frobenius distance between them is equal to zero.

The statistical distribution of the Frobenius norm between these two matrices is unknown, so we resort to Monte Carlo techniques to estimate it. Specifically, we have designed an exercise in which we compute the empirical distribution with 10,000 replications of two random correlations matrices with a dimension equal to the number of involved countries. To generate random correlation matrices we use the algorithm by Pourahmadi and Wang (2015).[31] Figure 6 shows the kernel density from which the p-values are calculated.

Results of the Frobenius norm, along with the p-values, are presented in Table 10. As can be seen, Phillips curve models are able to account for the observed degree of inflation interdependence across countries. Specifically, we cannot reject the hypothesis that the model-based degree of inflation interdependence is the same as the observed degree of inflation interdependence.[32]

[30]For a discussion on matrix norms, see e. g. Horn and Johnson (2012).

[31]Briefly, the idea is to represent a correlation matrix using Cholesky factorization and hyperspherical coordinates. Coordinates are sampled from a given distribution using the efficient sampling algorithm of Makalic and Schmidt (2018) and then converted to the standard correlation matrix form.

[32]Note that this distance is not invariant to the number of countries considered.

6 Concluding remarks

This paper has documented that inflation tends to move together in advanced economies. This is particularly so for euro area countries, which have substantial trade linkages and share a common monetary policy. Moreover, there is important heterogeneity in the degree of interconnectedness by type of product. Surprisingly, core inflation synchronization is fairly low, in clear contrast with energy prices, which are heavily dependent on oil global markets. Comovement across countries is higher when removing short-run fluctuations, which are typically quite country-specific, so that inflation interdependence is a medium to long run phenomenon. Furthermore, inflation synchronization has increased in recent years, against a background of globalization. However, the recent surge of protectionism points that this process may not necessarily deepen in the future.

Regarding the drivers of inflation interdependence, we find that comovements in driving variables of open economy new Keynesian Phillips curves are able to explain observed inflation interdependence across countries.

On further work, one interesting line of research is the quantitative role of structural factors in explaining comovements in inflation. For instance, we expect that countries with closer trade links will tend to have more tightly correlated inflation rates. Other potential driving variables include the structure of production and consumption or some features of financial sectors. Another element well worth exploring in further research is the study of the implications for monetary policy of the low degree of core inflation interdependence.

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Tables

Geographical breakdown			
	Euro Area countries		
Country aggregates	Original EA countries (OEA)	Newer EA countries (NEA)	Other advanced countries (OAC)
Advanced economies (AE)	Austria	Cyprus	Canada
Euro Area (EA)	Belgium	Greece	Denmark
	Finland	Latvia	Japan
	France	Lithuania	Poland
	Germany	Malta	Sweden
	Ireland	Slovakia	United Kingdom
	Italy		United states
	Luxembourg		
	Netherlands		
	Portugal		
	Spain		
Product breakdown			
Headline inflation			
1. Energy			
2. Food			
3. Core inflation (Headline ex food and energy)			
3.1 Non-energy industrial goods			
3.2 Services			

Table 1: Geographical and product breakdown

Countries	Headline	Energy	Food	Core	Non-energy	Services	GDP
Advanced economies (AE)	0.30	0.60	0.32	0.15	0.09	0.19	0.42
	(0.00)	(0.00)	(0.00)	(0.01)	(0.07)	(0.00)	(0.00)
Euro area (EA)	0.36	0.65	0.36	0.20	0.14	0.22	0.42
	(0.00)	(0.00)	(0.00)	(0.02)	(0.06)	(0.01)	(0.01)
Original EA countries (OEA)	0.59	0.84	0.51	0.29	0.18	0.31	0.55
	(0.00)	(0.00)	(0.00)	(0.04)	(0.14)	(0.03)	(0.00)

Note. p-values in parentheses.

Table 2: Moran-Stock-Watson indices of comovement. Full sample

Countries	HICP	Energy	Food	Core	Non-energy	Services
Advanced economies (AE)	0.05	0.50	0.18	0.07	0.10	0.06
	(0.24)	(0.00)	(0.00)	(0.13)	(0.06)	(0.16)
Euro area (EA)	0.03	0.55	0.22	0.04	0.08	0.02
	(0.39)	(0.00)	(0.01)	(0.34)	(0.20)	(0.43)
Original EA countries (OEA)	0.40	0.81	0.43	0.41	0.32	0.31
	(0.01)	(0.00)	(0.00)	(0.01)	(0.02)	(0.03)

Note. p-values in parentheses.

Table 3: Moran-Stock-Watson indices of comovement. Sample period: 1996M1-2007M12

Countries	HICP	Energy	Food	Core	Non-energy	Services
Advanced economies (AE)	0.50	0.67	0.47	0.19	0.03	0.19
	(0.00)	(0.00)	(0.00)	(0.00)	(0.33)	(0.00)
Euro area (EA)	0.55	0.74	0.51	0.23	0.12	0.25
	(0.00)	(0.00)	(0.00)	(0.01)	(0.10)	(0.00)
Original EA countries (OEA)	0.77	0.86	0.65	0.22	0.11	0.25
	(0.00)	(0.00)	(0.00)	(0.09)	(0.25)	(0.06)

Note. p-values in parentheses.

Table 4: Moran-Stock-Watson indices of comovement. Sample period: 2008M1-2018M4

Countries	Headline	Energy	Food	Core	Non-energy	Services	GDP
Trend inflation							
Advanced economies (AE)	0.26	0.63	0.29	0.15	0.10	0.20	0.40
	(0.00)	(0.00)	(0.00)	(0.01)	(0.06)	(0.00)	(0.00)
Euro area (EA)	0.33	0.69	0.31	0.20	0.15	0.24	0.40
	(0.00)	(0.00)	(0.00)	(0.02)	(0.06)	(0.01)	(0.00)
Original EA countries (OEA)	0.58	0.89	0.47	0.30	0.20	0.34	0.58
	(0.00)	(0.00)	(0.00)	(0.03)	(0.10)	(0.02)	(0.00)
Business cycle fluctuations							
Advanced economies (AE)	0.40	0.61	0.42	0.20	0.07	0.18	0.58
	(0.00)	(0.00)	(0.00)	(0.00)	(0.13)	(0.00)	(0.00)
Euro area (EA)	0.45	0.67	0.48	0.23	0.14	0.22	0.57
	(0.00)	(0.00)	(0.00)	(0.01)	(0.07)	(0.01)	(0.00)
Original EA countries (OEA)	0.65	0.83	0.62	0.33	0.16	0.36	0.65
	(0.00)	(0.00)	(0.00)	(0.02)	(0.16)	(0.01)	(0.00)
Short-run fluctuations							
Advanced economies (AE)	0.28	0.50	0.12	0.03	0.00	0.02	0.15
	(0.00)	(0.00)	(0.03)	(0.34)	(0.55)	(0.38)	(0.01)
Euro area (EA)	0.26	0.51	0.14	0.03	0.01	0.03	0.14
	(0.00)	(0.00)	(0.06)	(0.38)	(0.53)	(0.42)	(0.07)
Original EA countries (OEA)	0.45	0.72	0.20	-0.01	-0.03	0.02	0.14
	(0.00)	(0.00)	(0.11)	(0.61)	(0.71)	(0.52)	(0.19)

Note. p-values in parentheses.

Table 5: Moran-Stock-Watson measures of comovements across frequency bands

Countries	Advanced economies					Euro Area				
	lags min	lags max	comtemp.	leads min	leads max	lags min	lags max	comtemp.	leads min	leads max
Austria	-0.15	0.69	0.73	0.03	0.71	0.09	0.77	0.80	0.12	0.78
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Belgium	-0.05	0.71	0.76	-0.06	0.75	0.16	0.79	0.82	-0.06	0.79
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Finland	-0.25	0.39	0.45	0.29	0.51	0.02	0.60	0.64	0.36	0.66
	(12)	(1)	(0)	(12)	(4)	(12)	(1)	(0)	(12)	(2)
France	-0.01	0.77	0.82	0.09	0.79	0.24	0.92	0.95	0.24	0.91
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Germany	-0.03	0.79	0.83	0.17	0.79	0.17	0.87	0.90	0.24	0.86
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Ireland	0.12	0.53	0.56	0.30	0.57	0.26	0.62	0.64	0.27	0.63
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Italy	0.09	0.66	0.70	0.31	0.72	0.32	0.88	0.92	0.42	0.92
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Luxembourg	0.08	0.83	0.86	0.02	0.81	0.32	0.88	0.89	0.14	0.84
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Netherlands	-0.00	0.34	0.39	0.38	0.50	0.21	0.61	0.64	0.43	0.66
	(12)	(1)	(0)	(12)	(8)	(12)	(1)	(0)	(12)	(4)
Portugal	0.20	0.63	0.65	0.13	0.65	0.44	0.79	0.79	0.15	0.77
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Spain	0.22	0.79	0.80	0.18	0.78	0.40	0.91	0.92	0.26	0.89
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Cyprus	0.09	0.62	0.67	0.12	0.69	0.31	0.75	0.78	0.25	0.77
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Greece	0.29	0.49	0.51	0.10	0.49	0.47	0.62	0.62	0.13	0.59
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Latvia	-0.06	0.53	0.57	0.39	0.61	0.03	0.55	0.58	0.32	0.60
	(12)	(1)	(0)	(12)	(4)	(12)	(1)	(0)	(12)	(2)
Lithuania	-0.19	0.34	0.39	0.29	0.47	-0.14	0.34	0.38	0.20	0.42
	(12)	(1)	(0)	(12)	(5)	(12)	(1)	(0)	(12)	(4)
Malta	-0.16	0.30	0.38	0.29	0.53	-0.09	0.47	0.52	0.22	0.57
	(12)	(1)	(0)	(12)	(7)	(12)	(1)	(0)	(12)	(2)
Slovakia	0.24	0.38	0.40	0.16	0.40	0.31	0.39	0.40	0.13	0.39
	(12)	(1)	(0)	(12)	(1)	(11)	(1)	(0)	(12)	(1)
Canada	0.02	0.68	0.73	-0.19	0.66	0.28	0.59	0.61	-0.08	0.56
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Denmark	-0.03	0.62	0.67	0.18	0.66	0.28	0.78	0.80	0.22	0.78
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Japan	-0.48	0.15	0.20	-0.17	0.22	-0.59	-0.13	-0.10	-0.17	-0.05
	(12)	(1)	(0)	(12)	(2)	(12)	(1)	(0)	(12)	(3)
Poland	0.03	0.23	0.25	0.16	0.24	0.08	0.16	0.17	0.05	0.17
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
Sweden	-0.16	0.31	0.36	0.12	0.35	0.13	0.48	0.49	0.14	0.47
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
United Kingdom	-0.04	0.37	0.42	0.06	0.44	0.09	0.47	0.51	0.22	0.53
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)
United States	0.01	0.94	0.99	-0.07	0.92	0.24	0.77	0.78	0.01	0.73
	(12)	(1)	(0)	(12)	(1)	(12)	(1)	(0)	(12)	(1)

Note. The numbers in brackets refer to the lag/lead with the highest/lowest cross-correlation.

Table 6: Cross-correlations of inflation of each country with the Advanced economies and the Euro Area

Countries	HICP	Energy	Food	Core	Non-energy	Services
Advanced economies (AE)	116.20	176.28	103.94	47.46	17.10	70.40
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Euro area (EA)	98.29	133.35	86.78	44.36	21.98	56.43
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Original EA countries (OEA)	76.71	102.54	66.29	37.07	23.09	37.63
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note. p-values in parentheses.

Table 7: Pesaran's cross-dependence test (CD)

	Advanced economies (AE)			Euro area (EA)		
	Hybrid Phillips curve	Backward Phillips curve	Forward Phillips curve	Hybrid Phillips curve	Backward Phillips curve	Forward Phillips curve
			Headline inflation			
π_{t-1}	0.78 (0.00)	0.88 (0.00)	–	0.73 (0.00)	0.89 (0.00)	–
$E(\pi_t)$	0.16 (0.00)	–	0.74 (0.00)	0.20 (0.00)	–	0.82 (0.00)
$y_t - y_t^*$	0.05 (0.00)	0.06 (0.00)	-0.03 (0.36)	0.03 (0.00)	0.04 (0.01)	-0.03 (0.33)
p_t^m	0.03 (0.00)	0.03 (0.00)	0.05 (0.00)	0.04 (0.00)	0.04 (0.00)	0.07 (0.00)
R^2	0.87	0.87	0.56	0.90	0.88	0.71
n	1638	1748	1640	1115	1237	1115
			Core			
π_{t-1}	0.89 (0.00)	0.93 (0.00)	–	0.88 (0.00)	0.93 (0.00)	–
$E(\pi_t)$	0.07 (0.00)	–	0.43 (0.00)	0.08 (0.00)	–	0.53 (0.00)
$y_t - y_t^*$	0.04 (0.00)	0.04 (0.00)	0.01 (0.77)	0.04 (0.00)	0.04 (0.00)	0.02 (0.36)
p_t^m	0.002 (0.53)	0.01 (0.20)	-0.04 (0.00)	-0.003 (0.14)	0.002 (0.71)	-0.06 (0.00)
R^2	0.88	0.89	0.28	0.91	0.93	0.39
n	1638	1748	1640	1115	1237	1115

Note. Fixed effects and robust standard errors to cross-sectional correlation following Driscoll and Kraay (1998). p-values in parentheses.

Table 8: Panel Phillips curve

	Hybrid Phillips curve		Backward Phillips curve		Forward Phillips curve	
	Observed inflation	Explained inflation	Observed inflation	Explained inflation	Observed inflation	Explained inflation
			Headline inflation			
Advanced economies (AE)	0.43	0.46	0.37	0.39	0.43	0.41
	[0.28, 0.57]	[0.31, 0.60]	[0.22, 0.52]	[0.24, 0.54]	[0.28, 0.57]	[0.26, 0.56]
Euro area (EA)	0.48	0.52	0.42	0.44	0.48	0.50
	[0.26, 0.70]	[0.30, 0.74]	[0.20, 0.63]	[0.23, 0.66]	[0.26, 0.70]	[0.28, 0.71]
			Core inflation			
Advanced economies (AE)	0.17	0.17	0.17	0.16	0.17	0.24
	[0.02, 0.32]	[0.02, 0.31]	[0.02, 0.31]	[0.01, 0.30]	[0.02, 0.32]	[0.10, 0.39]
Euro Area (EA)	0.24	0.25	0.23	0.22	0.24	0.32
	[0.02, 0.45]	[0.03, 0.46]	[0.01, 0.44]	[0.01, 0.44]	[0.02, 0.45]	[0.11, 0.54]

Note. Inflation interdependence measured with the Moran-Stock-Watson comovement index. Explained inflation refers to the interdependence accounted for the estimated Phillips curves. 95% confidence intervals in square brackets.

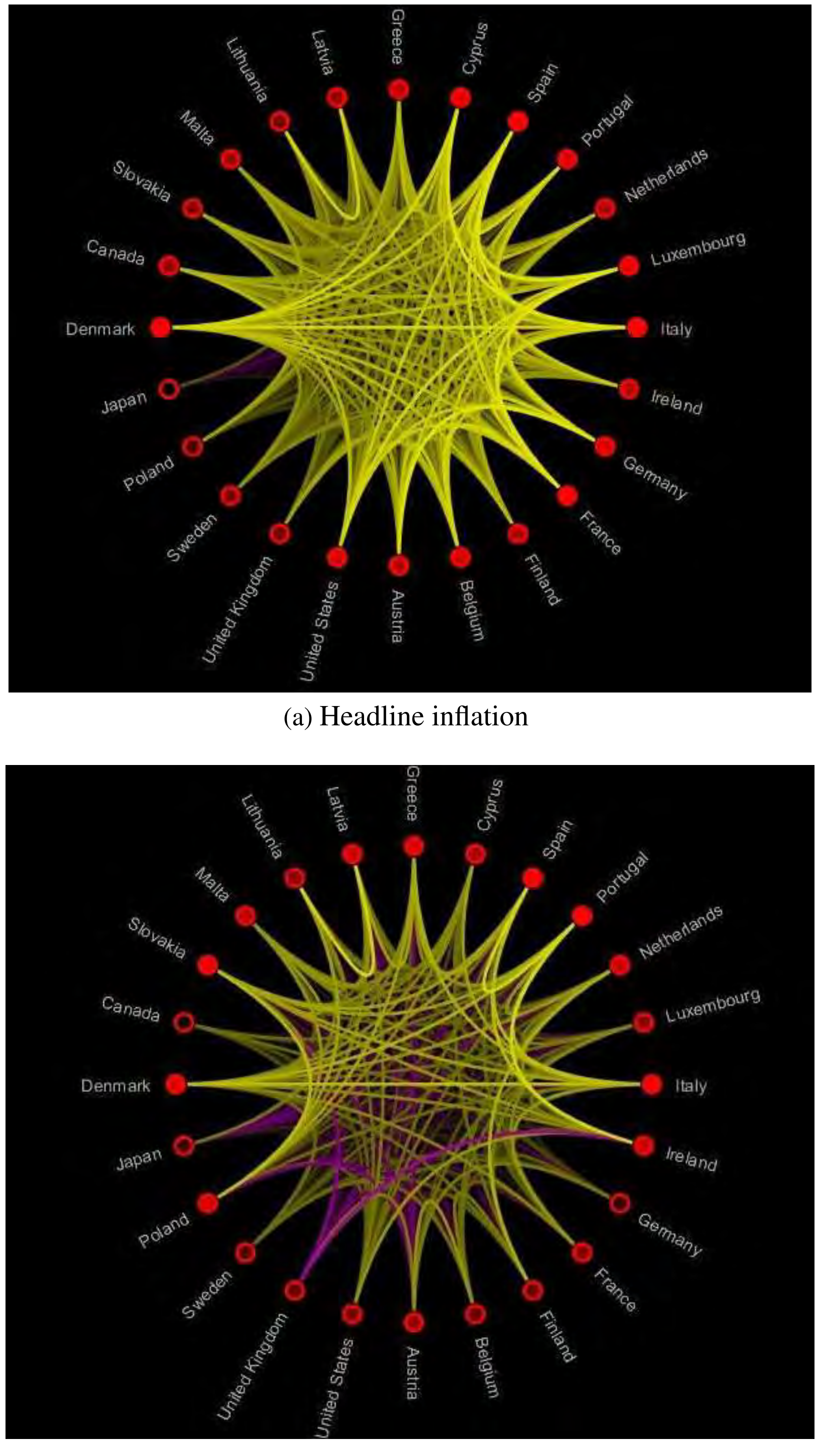
Table 9: Inflation interdependence

	Hybrid Phillips curve	Backward Phillips curve	Forward Phillips curve
		Headline inflation	
Advanced economies (AE)	1.89	1.54	6.99
	(0.00)	(0.00)	(0.90)
Euro area (EA)	1.44	1.00	3.28
	(0.00)	(0.00)	(0.00)
		Core inflation	
Advanced economies (AE)	2.45	1.56	10.10
	(0.00)	(0.000)	(1.00)
Euro area (EA)	1.84	1.09	6.34
	(0.00)	(0.00)	(0.99)

Note. Distance measured in terms of the Frobenius norm of the correlation matrices of cross- country observed and explained inflation. Explained inflation refers to fitted values of Phillips curves. p-values in parentheses.

Table 10: Distance between observed and explained inflation

Figures



(a) Headline inflation

(b) Core inflation

Figure 1: Schemaballs of correlation matrices

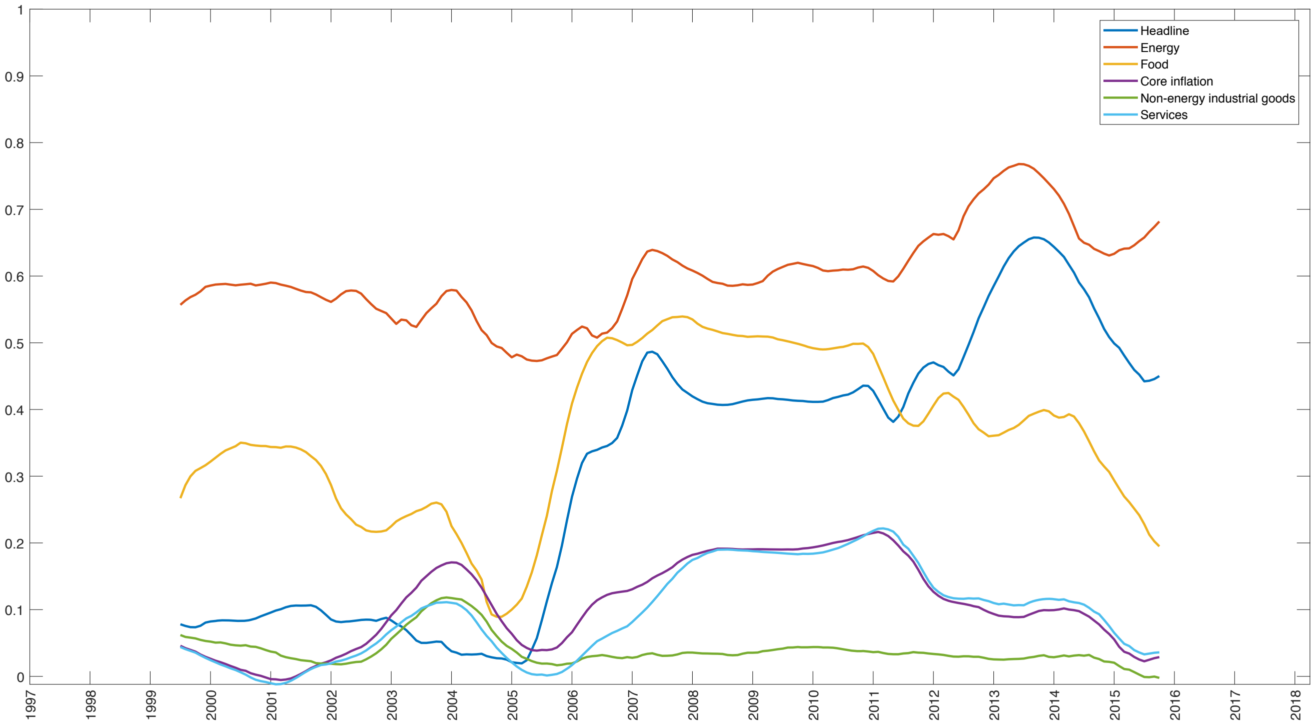


Figure 2: Moran-Stock-Watson indices of comovement. Advanced countries

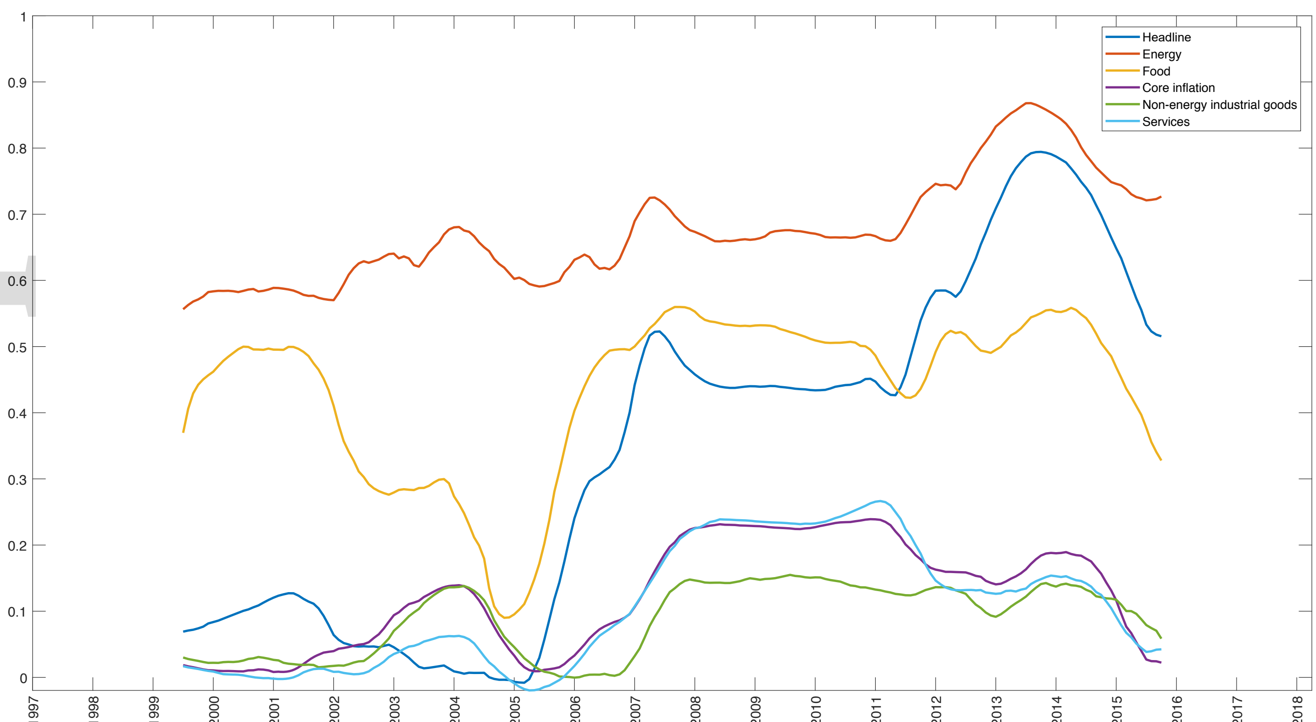


Figure 3: Moran-Stock-Watson indices of comovement. Euro area countries

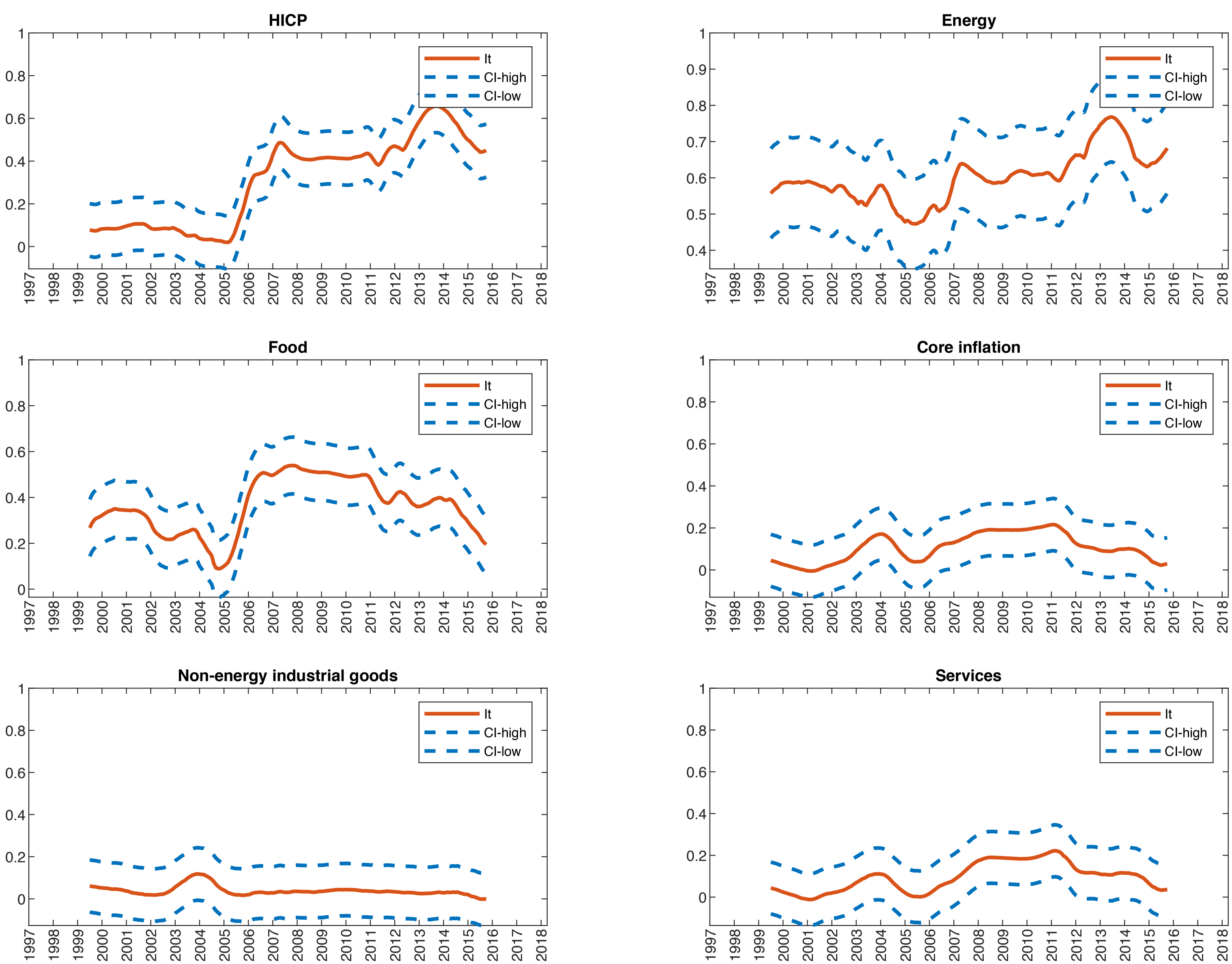


Figure 4: Moran-Stock-Watson measure of comovements. Advanced economies (window=5 years, along with 0.90 confidence intervals)

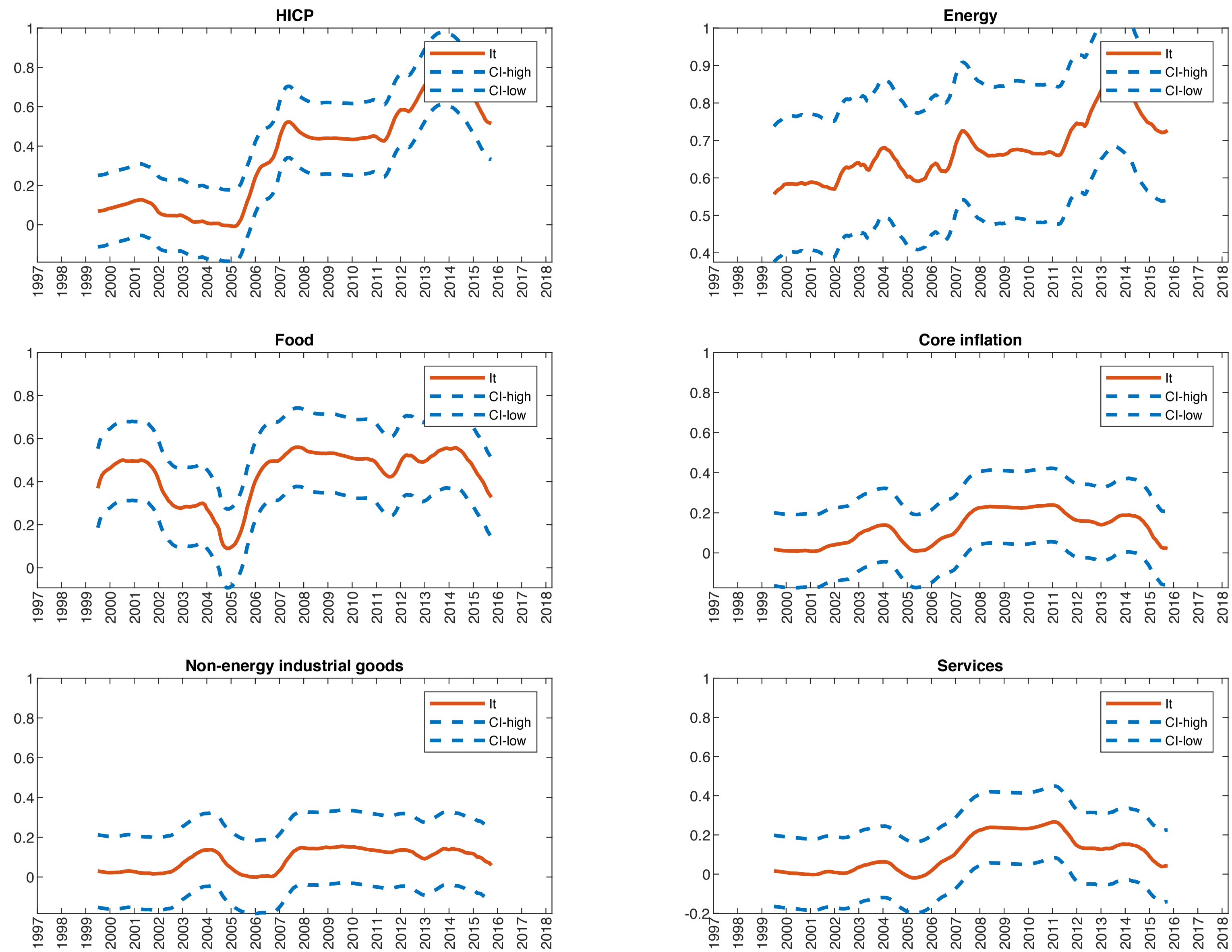


Figure 5: Moran-Stock-Watson measure of comovements. Euro area countries (window=5 years, along with 0.90 confidence intervals)

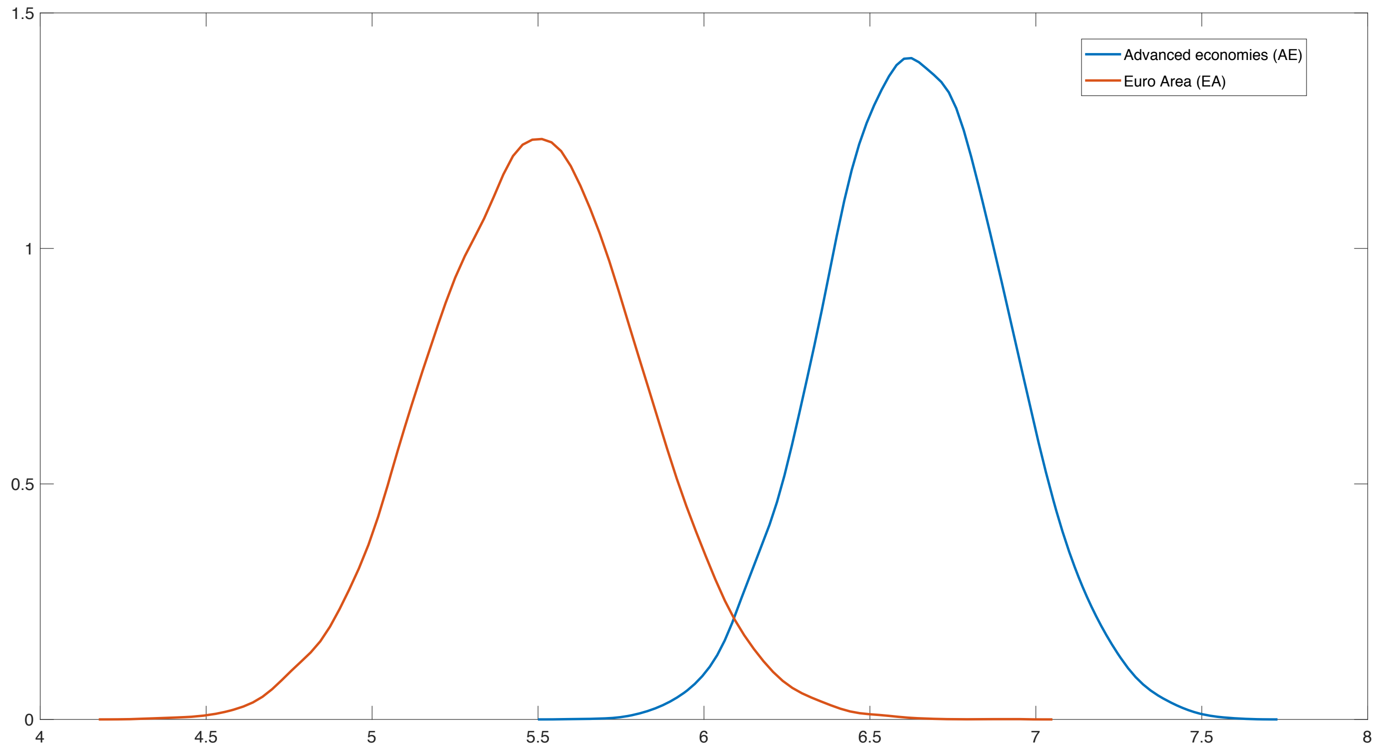


Figure 6: Empirical distribution of the Frobenius norm test

Appendix A. Quantitative measures of inflation expectations

Quantitative measures of inflation expectations for European Union countries are derived on the basis of the European Commission (EC) Consumer Survey. This survey asks consumers quantitative assessments on both past and expected price changes.[33] From their responses, weighted measures[34] are computed that allow one to get qualitative perceived inflation (π_t^p) and expected inflation (π_t^e) measures. In order to derive quantitative estimates of perceived and expected inflation, the modification by Buchmann (2009) of the Carlson and Parkin (1975) method is used.

Specifically, denoting by π_t the observed inflation rate, a linear relationship is assumed between observed inflation and perceived inflation

$$\pi_t = \alpha + \beta\pi_t^p + \varepsilon_t$$

To allow for possible time variation in the relationship between both variables, the equation is estimated using a rolling window of 36 months and fitted values are computed

$$\widehat{\pi}_t^p = \widehat{\alpha}_t + \widehat{\beta}_t\pi_t^p$$

The resulting time series of fitted values gives a quantitative measure of perceived inflation ($\widehat{\pi}_t$).

To obtain a quantitative measure of inflation expectations the conventional Carlson and Parkin (1975) approach is used. Let $\{s_t^{e1}, s_t^{e2}, s_t^{e3}, s_t^{e4}, s_t^{e5}\}$ denote the shares in each of the five response categories in the question on expectations.[35] Then, the conditional expectation of inflation can be computed on the basis of these shares and the measure of perceived inflation

[33] Specifically, the following question is asked: How do you think that consumer prices have developed over the past 12 months? They have... risen a lot (RL), risen moderately (RM), risen slightly (RS), stayed about the same (S), fallen (F) and don't know.

[34] $\pi_t^p = RL + 0.5RM - 0.5S - F$, where all variables are percentages excluding don't know answers.

[35] Specifically, the following question is asked: By comparison with the past 12 months, how do you expect that consumer prices will develop in the next 12 months? They will... increase more rapidly (IM), increase at the same rate (IE), increase at a slower rate (IS), stay about the same (S), fall (F) and don't know. Categories considered correspond to IM, IE, IS, S and F.

$$\pi^e_{t+12|t} = -\widehat{\pi}^p_t \left[\frac{Z^3_t + Z^4_t}{Z^1_t + Z^2_t - Z^3_t - Z^4_t} \right]$$

where

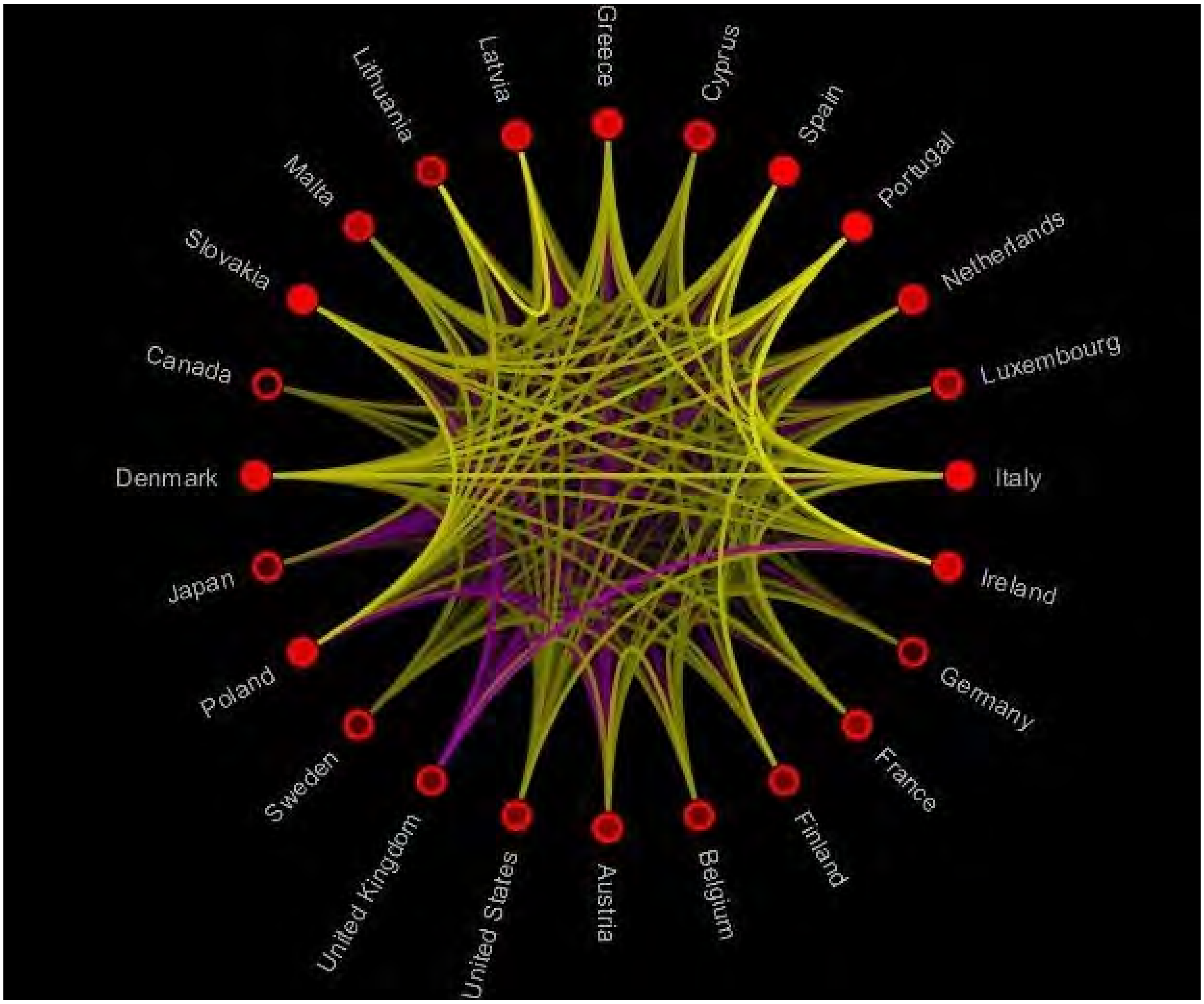
$$Z^1_t = \phi^{-1}(1 - s^{e1}_t)$$

$$Z^2_t = \phi^{-1}(1 - s^{e1}_t - s^{e2}_t)$$

$$Z^3_t = \phi^{-1}(1 - s^{e1}_t - s^{e2}_t - s^{e3}_t)$$

$$Z^3_t = \phi^{-1}(s^{e5}_t)$$

so that expected inflation one year ahead depends on the distribution of the strength of expected inflation and on perceived inflation.



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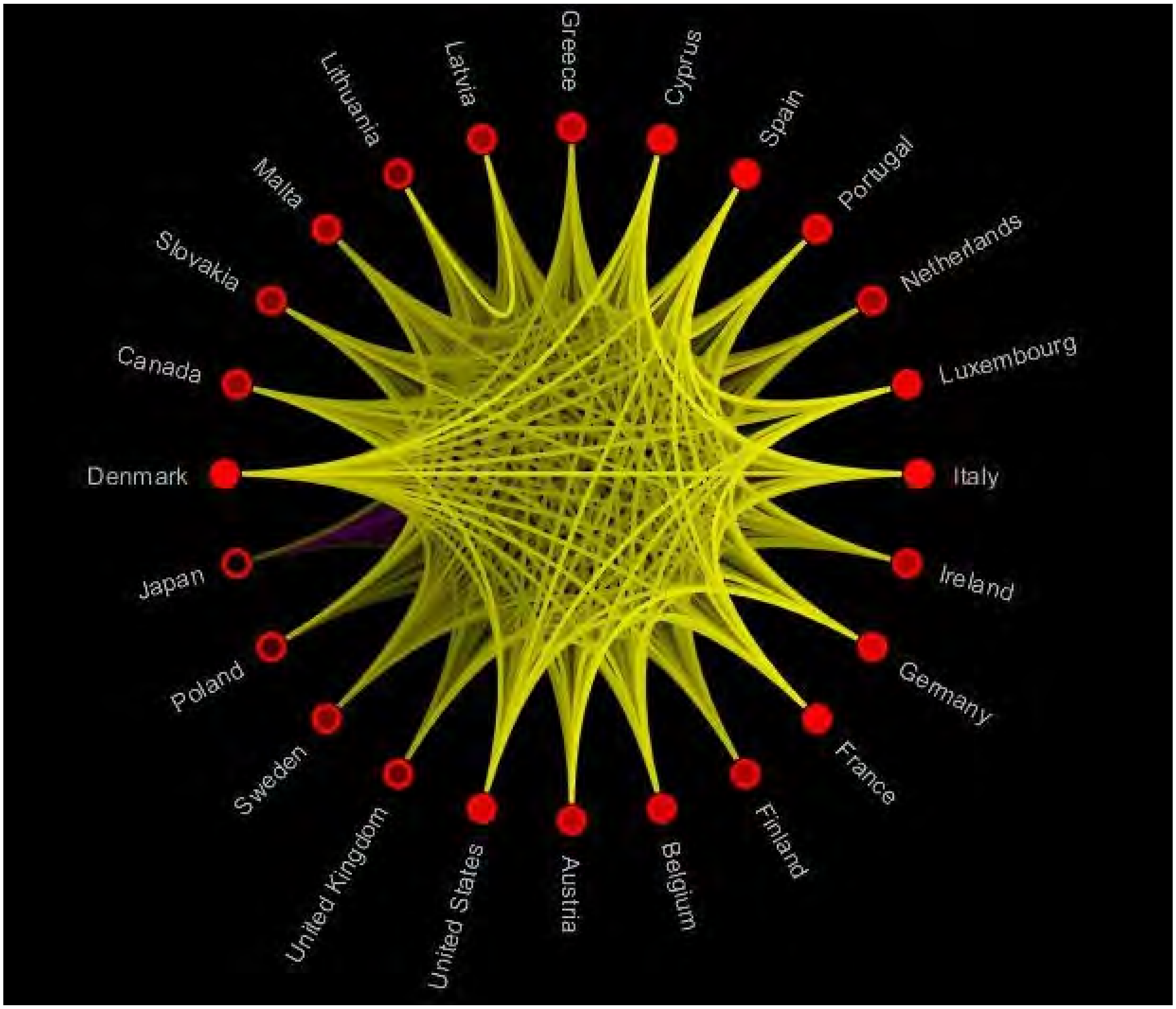

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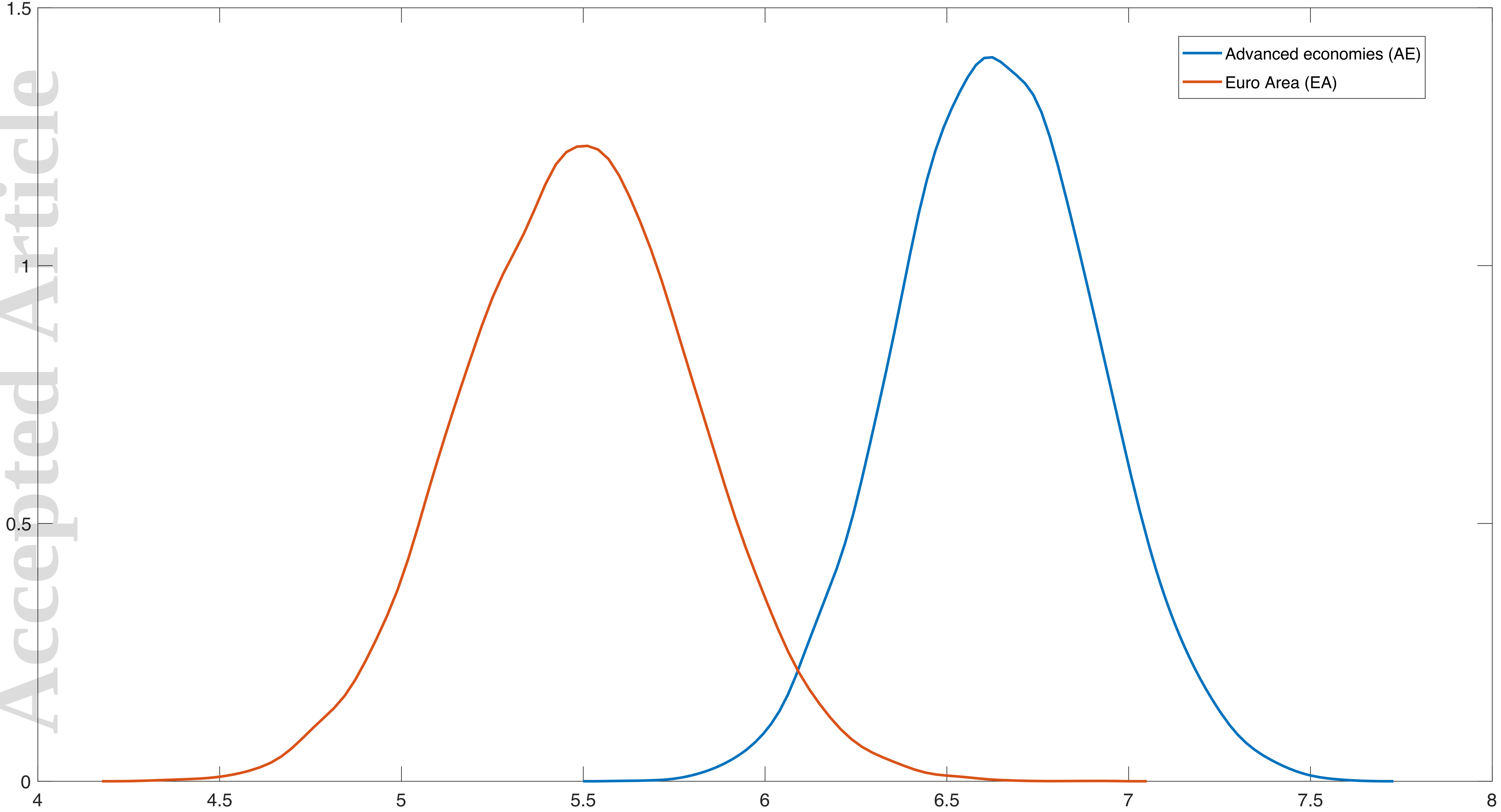
Advanced economies (AE)
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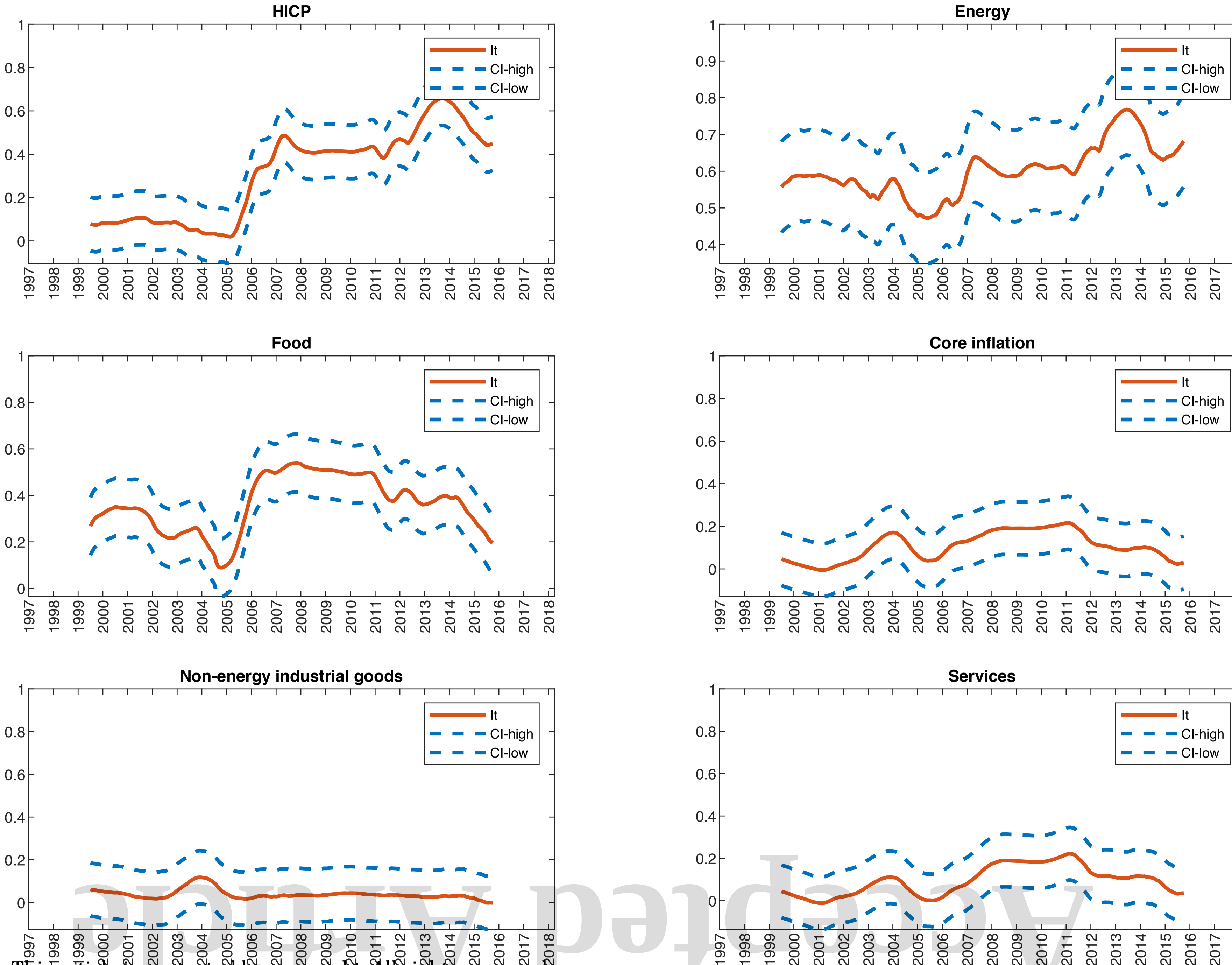
8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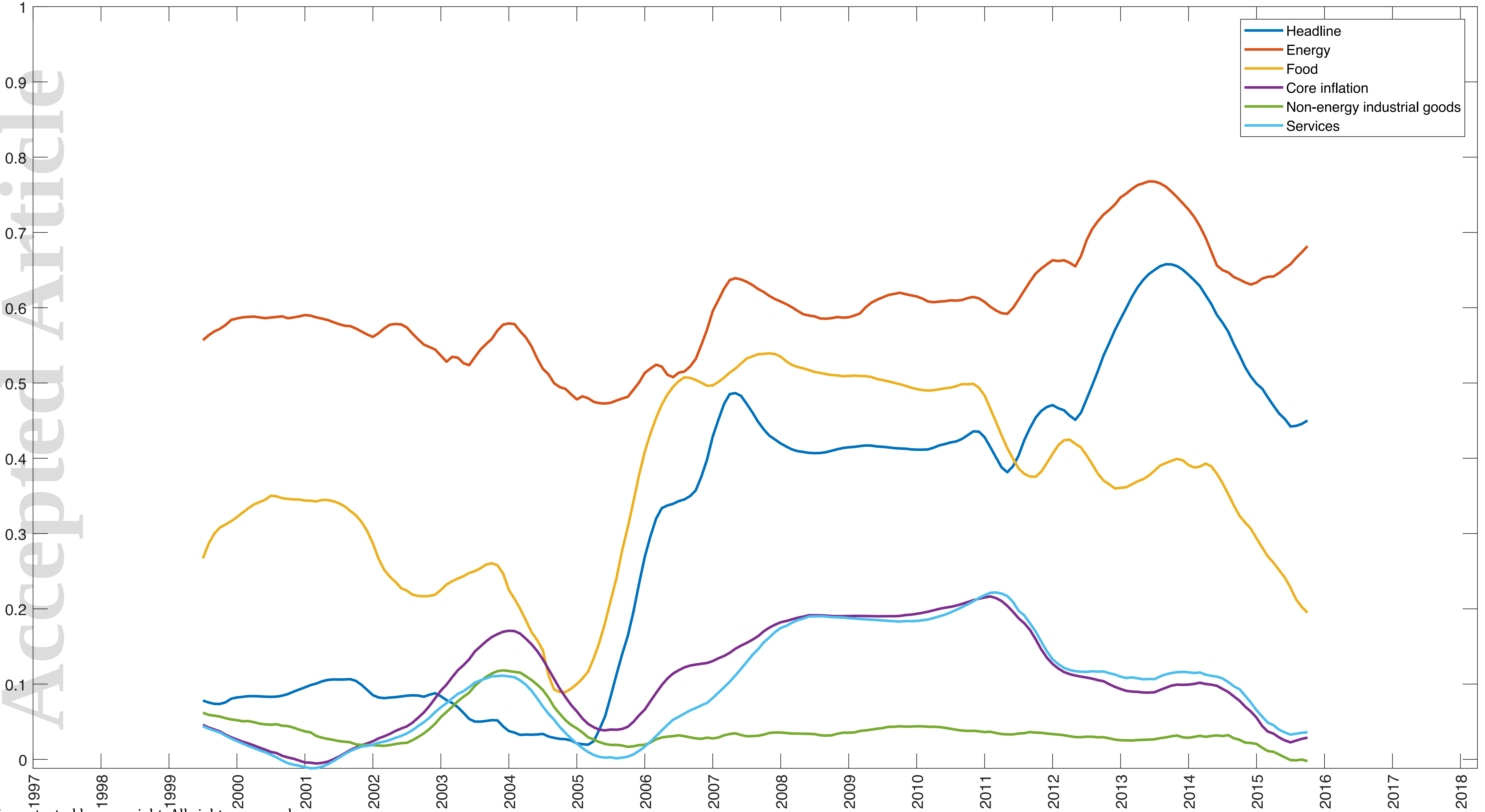
Core inflation
Non-energy industrial goods
Services
It
CI-high
CI-low



Headline
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Non-energy industrial goods
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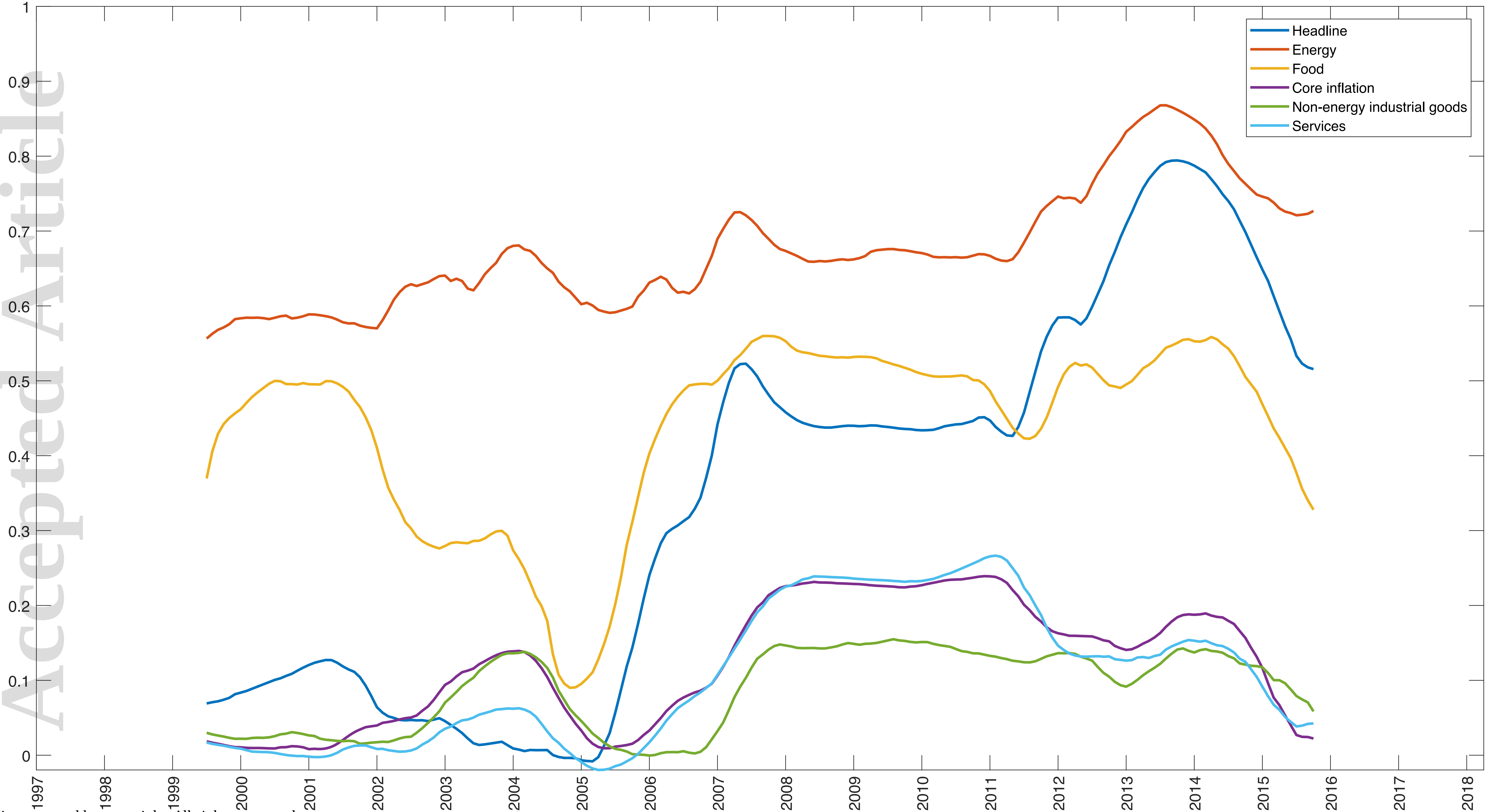
Headline
Energy
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Core inflation
Non-energy industrial goods
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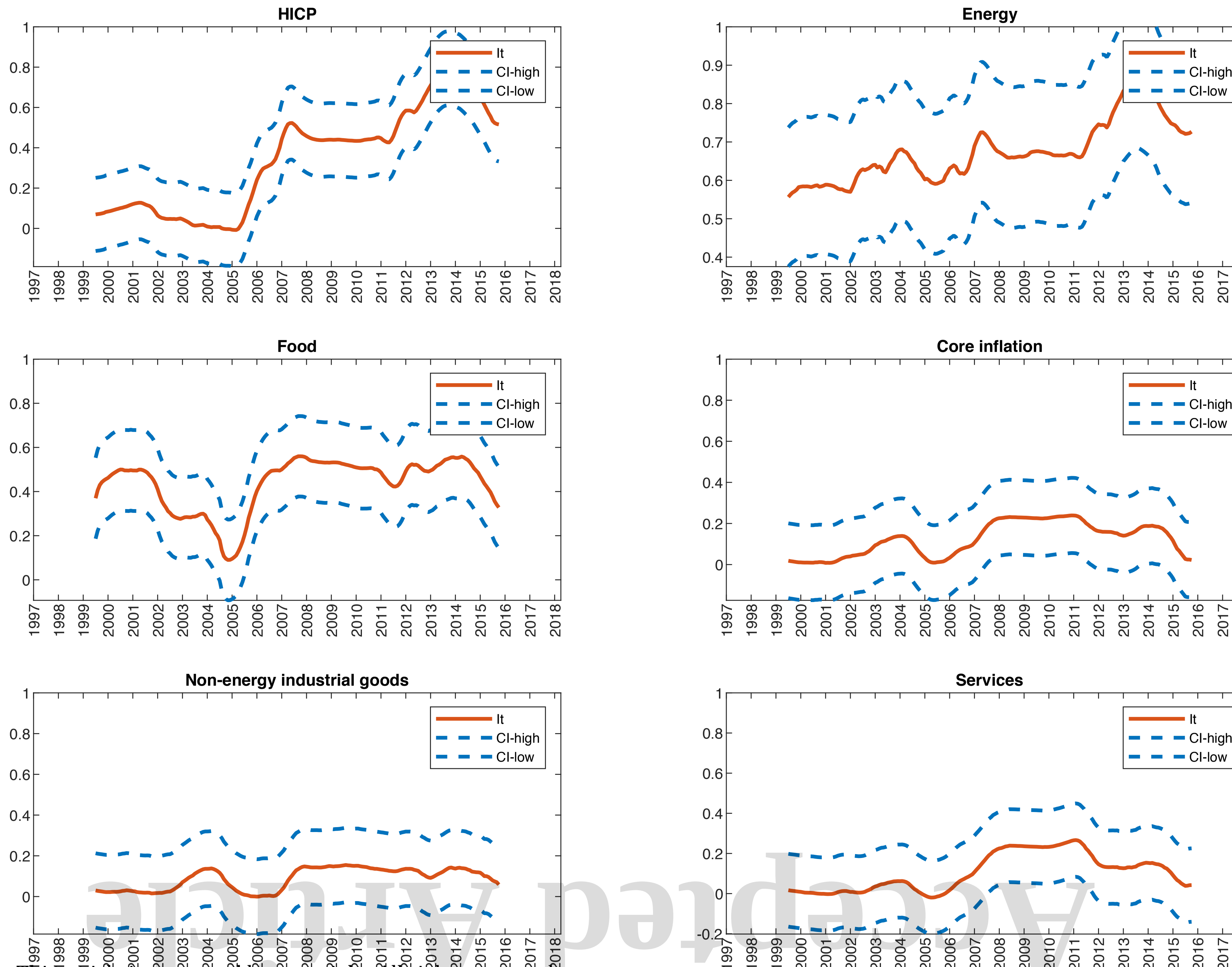
HICP
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