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Abstract

This paper explores the behaviour of inflation expectations across countries that share their monetary policy, in particular those of the European Monetary Union. We investigate the possible common features at the various horizons, as well as differentials across euro area countries. A multi-country dynamic factor model based on Diebold *et al.* (2008), where we also add a liquidity risk component, is proposed and estimated using daily data from inflation swaps for Spain, Italy, France, Germany and the euro area as a whole, and for a wide range of horizons. It allows us to calculate the proportion of common vs country-specific components in the term structure of inflation expectations. We find sizable differences in inflation expectations across the main euro area countries only at short maturities, while in general a common component predominates throughout the years, especially at long horizons. The common long-run level of inflation expectations is estimated to have fallen since late 2014, while an increased persistence of lower expected inflation and for longer horizons is estimated from 2012. There has been no reversal in either of these characteristics following the announcement and implementation of the ECB's unconventional monetary policy measures.

Keywords: inflation expectations; monetary union; inflation-linked swaps; multicountry dynamic factor model; liquidity risk premium.

JEL classification: E31, C32, G13.

Resumen

Este trabajo explora el comportamiento de las expectativas de inflación en países que comparten su política monetaria, en particular los de la UEM. Se investigan las posibles características comunes a varios horizontes, así como los diferenciales entre países. Se propone un modelo multipaís de factores dinámicos basado en Diebold *et al.* (2008), aumentado con un componente de riesgo de liquidez. El modelo se estima con datos diarios de *swaps* de inflación para España, Italia, Francia, Alemania y el área del euro en su conjunto, y para un amplio rango de horizontes. Con él se calcula la proporción de los componentes comunes y específicos de cada país que explican la estructura temporal de las expectativas de inflación. Diferencias notables entre las expectativas de inflación de los países del euro aparecen solamente en los plazos cortos, mientras que en general domina el componente común a lo largo de los años, y especialmente a horizontes largos. El componente común estimado para el nivel de inflación esperado a muy largo plazo ha caído desde finales de 2014, mientras que desde 2012 se estima un aumento en la persistencia de la baja inflación esperada, que se propaga a plazos cada vez más largos. Ninguna de estas dos características ha revertido tras el anuncio y la implementación de las medidas de política monetaria no convencional del BCE.

Palabras clave: expectativas de inflación; unión monetaria; *swaps* de inflación; modelo de factores dinámico multipaís; prima de riesgo de liquidez.

Códigos JEL: E31, C32, G13.

1 Introduction

How are inflation expectations formed across countries that share their monetary policy? The question is not trivial. In the long run, and under full credibility of the common monetary authority, agents in all countries belonging to a monetary union should expect the same inflation rate: the monetary policy target. However, at shorter horizons, individual countries' expected inflation could reflect country-specific factors due to different fundamentals affecting short-to-medium run inflation dynamics.[1]

What is the behavior of inflation expectations across countries in the European Monetary Union (EMU)? Do they share common features at the various horizons or do expected inflation differentials across Euro area countries emerge at different horizons, say, more at shorter than longer horizons? Has the degree of common behavior changed over time? And, in terms of direct monetary policy implications, has the long-run expected inflation remained well anchored across these countries at the European Central Bank (ECB) target of below, but close to 2%?

This paper provides an empirical approximation to answer these questions. The challenge starts with the very issue of constructing a good measure of inflation expectations at different horizons and for different countries. We use financial market-based daily data from inflation swaps, which exist for the four biggest EMU countries and for the Euro area aggregate, and provide a very valuable high-frequency source of information. To the best of our knowledge, this paper is the first one to use these data. In particular, bid and ask rates for Zero-Coupon Inflation-Linked Swaps (ILS) are available for Spain, Italy, France, Germany and the Euro area, and for a wide set of maturities ranging from 1 to 30 years. From these quotes, we obtain not only mid-prices, but also bid-ask spreads that approximate the liquidity of each contract. We compare the market-based ILS information to the other usual source of inflation expectations: survey-based data, which is available for the same countries on a monthly and half-yearly basis from Consensus Forecasts (CF). CF covers expectations for longer horizons than other surveys that refer also to inflation expectations, such as the Business and Consumer Survey of the European Commission.

[1] Among these could be, for instance, different oil-dependencies across countries which can cause the same change in world oil prices to have different impacts in the short run, or fiscal measures in one country causing its VAT taxes or regulated prices to rise.

Section 2 explains the data sources and provides some graphical evidence and summary statistics about inflation forecasting performance. Contrary to survey data, swaps data is available at a much higher frequency and for a complete set of forecasting horizons, which makes them more suitable for empirical analysis. However, the information on inflation expectations contained in inflation swap contracts may be affected by the possibly limited liquidity of the market as well as by the presence of term premia. We explore these issues in this section, too. Section 3 presents the model used to evaluate commonalities and differences among inflation expectations across the EMU, which is estimated using the ILS daily data. It is a multi-country model based on Diebold et al. (2008), which allows to compute the proportion of common vs country-specific components in the term structure of inflation expectations. The model proposed here extends Diebold et al. (2008) in several dimensions. The more important one is to include a model-based measure of time-varying liquidity risk premium. The main findings of the model estimation are discussed in Section 4. Finally, Section 5 concludes.

2 The data

Measuring inflation expectations is usually done through two different types of information. One is market-based, where information for inflation expectations is obtained from the prices in markets for inflation protection. In the case of EMU countries, we have daily quotes of Inflation Linked Swaps (ILS) at a wide range of maturities (from 1 to 30 years) since June 2004 for the inflation rate of the Euro area aggregate as well as for French, Italian and Spanish inflation, and since April 2006 for German inflation. This paper uses data up to August 15th, 2016. Zero-Coupon inflation swap contracts exchange the increase in a price index (P_t) over an agreed period (the contract horizon), that is, the realized inflation rate, against a fixed rate, which is an inflation compensation (π_t) that approximates markets' inflation expectations over the swap contract duration:

$$\begin{array}{ccc} \text{Fixed leg} & & \text{Floating leg} \\ (1+\pi_t(m))^m & \text{vs.} & \frac{P_{t+m}}{P_t} \end{array} \tag{1}$$

In quoted inflation swap contracts there is an indexation lag of three months, meaning that the reference inflation rate for a swap contract of 2 years maturity today is the inflation rate[2] for the 24-month period covering the last 3 months and the next 21 months. This is done in order to ensure that at maturity the inflation index that must be used to settle the contract is known.

An alternative source for inflation expectations to inflation swaps would be inflation-linked bonds (equivalent to American TIPS). However, this market is not as developed in Euro area countries as it is in the US: most inflation linked bonds provide protection against Euro area inflation, and not national inflation.[3] In addition to the scarcity of bonds and the different level of market development, extracting a valid inflation compensation in those bonds is not simple. First, the number of bonds available to obtain a reliable daily curve is limited, but more importantly, inflation compensation is obtained by comparing this curve to the one derived from the nominal yield curve with different levels of liquidity distorting inflation compensation signals. Moreover, after monetary interventions like the Federal Reserve's or the ECB's Quantitative Easing programs, different amounts purchased for inflation-linked and nominal bonds may produce additional distortions on these measures of inflation compensation.

Apart from financial markets, the other main source of information for inflation expectations is surveys. In the case of the main Euro area countries, *Consensus Economics* surveys every month a panel of 10 to 30 private sector financial and economic forecasters per country for their estimates of a range of variables, including future GDP growth, inflation, interest rates and exchange rates. In particular, every month they provide their expectation for the average inflation rate for current and next calendar years. These Consensus Forecasts (CF) are published in the second week of each month, based on a survey performed in the previous two weeks.[4] Twice

[2] In the case of the swap rates used in this paper, the reference inflation rate is the national total CPI inflation rate for the ILS for Spain and Germany, and the national CPI inflation excluding tobacco for those for France and Italy. Swap markets for aggregate Euro area inflation use as reference the HICP inflation rate excluding tobacco.

[3] For example, as of Sept 26^{th}, 2015, all six iBund issued by the Deutsche Finanzagentur were linked to Euro area inflation, and none to German inflation. That was also the case for the three Spanish inflation linked bonds. Only France and Italy issued both Euro area inflation and domestic inflation linked bonds. In the case of France, the Agence France Trésor issued both OATi, linked to French inflation, and OAT€i, linked to Euro area inflation (6 and 9 bonds, respectively). Similarly, Italian BTP€i (issued by Italian Dipartimento del Tesoro) were linked to eurozone inflation, while BTPi were linked to Italian inflation (10 and 8 bonds, respectively).

[4] Hence, one can safely assume that the information contained in the survey corresponds to the last day of the previous month, when comparing these monthly series to daily financial market-based data.

a year, the April and October CF surveys also provide longer-term forecasts which include expected annual inflation for the current and next five years, as well as the average annual inflation expected for the following five years, that is, from 6 to 10 years ahead.

Figure 1 and 2 compare the swap rates with the CF forecasts for the horizons for which there is survey-based information. Figure 1 displays for the four EMU countries and the Euro area aggregate the daily Zero-Coupon Inflation Swap of one year maturity (swap1y, in blue) together with the monthly series of current calendar year inflation forecast from Consensus Forecasts (CF(y), in green) and the actual annual HICP inflation rate observed 8 months ahead (in red).[5] Figure 2 plots the inflation expectations of CF for next year and the following four (CF($y+1/+2/+3/+4/+5$), in green) together with the 1-year forward swaps referring to the annual inflation one to five-years ahead (swaps 1y1y/1y2y/1y3y/1y4y/1y5y, in blue) and the corresponding HICP inflation (in red); and the CF for the average 5-year inflation 6 to 10-years ahead (CF($y+6, y+10$)) with the corresponding 5-year forward inflation swap rate 5-years ahead (swap 5y5y).

Swap rates react quicker and may reflect better real-time changes in inflation expectations than survey-based measures: not only the data is available at higher frequency (daily vs monthly or semi-annually) but also the reference inflation moves gradually as time goes by, as opposed to the CF case where the reference inflation changes abruptly at year end.[6] But despite the differences in the exact period of the reference inflation in the CF survey and the swap rates,[7] they track each other quite closely.

[5] We use HICP instead of CPI for cross-country comparability reasons. The three month indexation lag in swap contracts means that the reference inflation rate for swap1y spans from the previous 3 months to the current and next 8 months.

[6] The fact that the survey asks for the same current and next year every month of the calendar year is reflected in some jumps in the CF series: forecasters seem to change less their perceptions of the same year as months go by than what they predict will be the change in inflation from one year to the next one.

[7] From the January CF survey to the December one of the same year, current year inflation expectations, CF(y), refers to the same annual inflation rate at year end. However, the swap rate for one-year maturity, swap1y, refers to the inflation rate for a 12-month period which moves with time. From January to December of year y it moves from covering the 12-month period of October($y-1$)-September(y) to covering that of September(y)-August($y+1$), respectively. Hence, the overlap between CF survey and ILS markets annual inflation references changes throughout the year, reaching a total overlap of 12 months only in April each year, and decaying with the time distance with respect to the previous or the next April.

Figure 1. Annual Inflation expectations from financial markets (1year-ILSwaps, in blue) and survey (Consensus Forecast for the current calendar year, in green). In red, the realized reference annual HICP inflation for swaps contracts, with the appropriate lag (current month+8months).

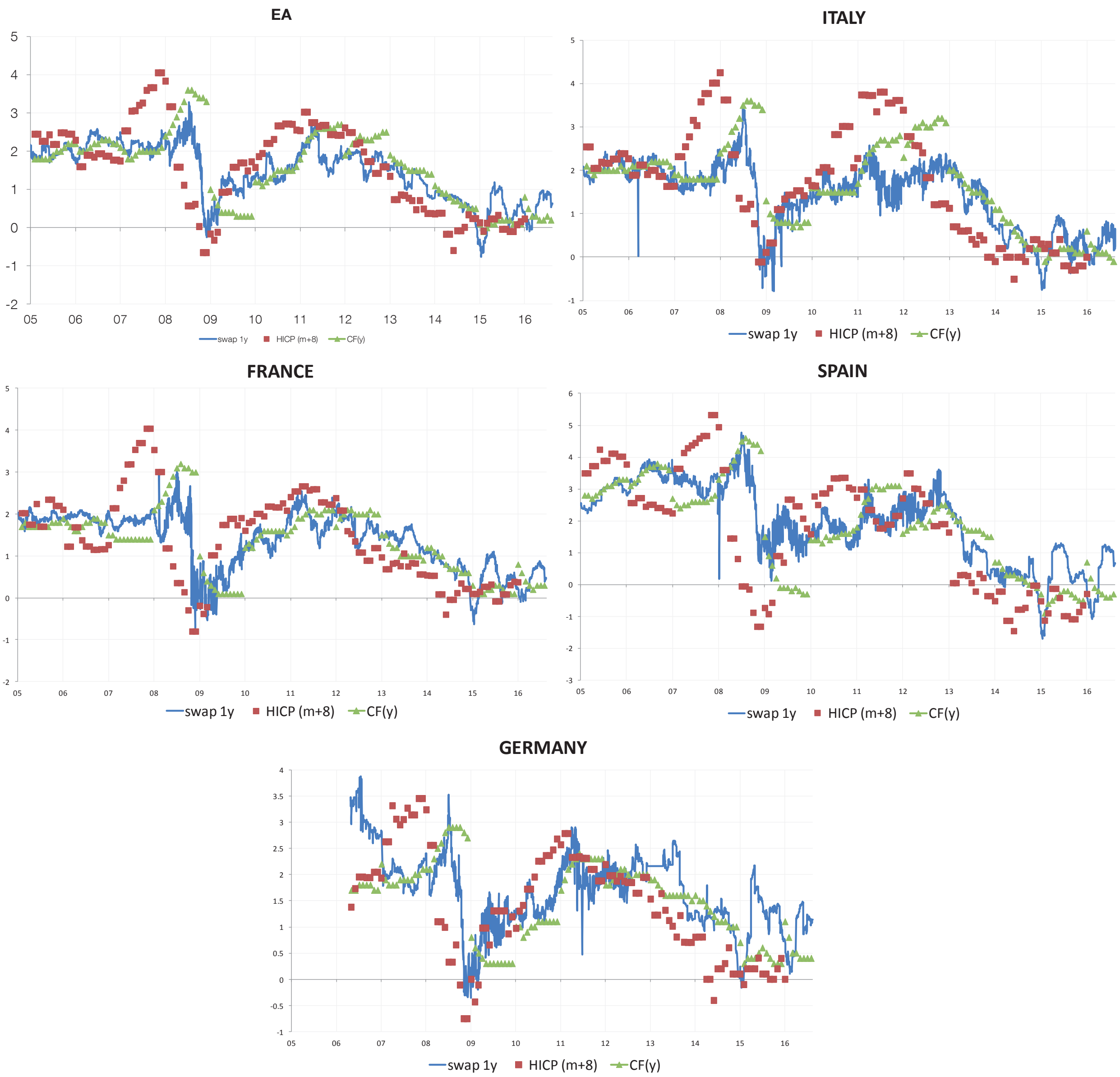


Figure 2a: Annual Inflation expectations at various horizons from financial markets (ILSwaps 1y1y, 1y2y, and 1y3y, in blue) and survey (Consensus Forecast for y+1, y+2, and y+3, in green). In red, the realized annual HICP inflation for the corresponding swap contract, with the appropriate lag.

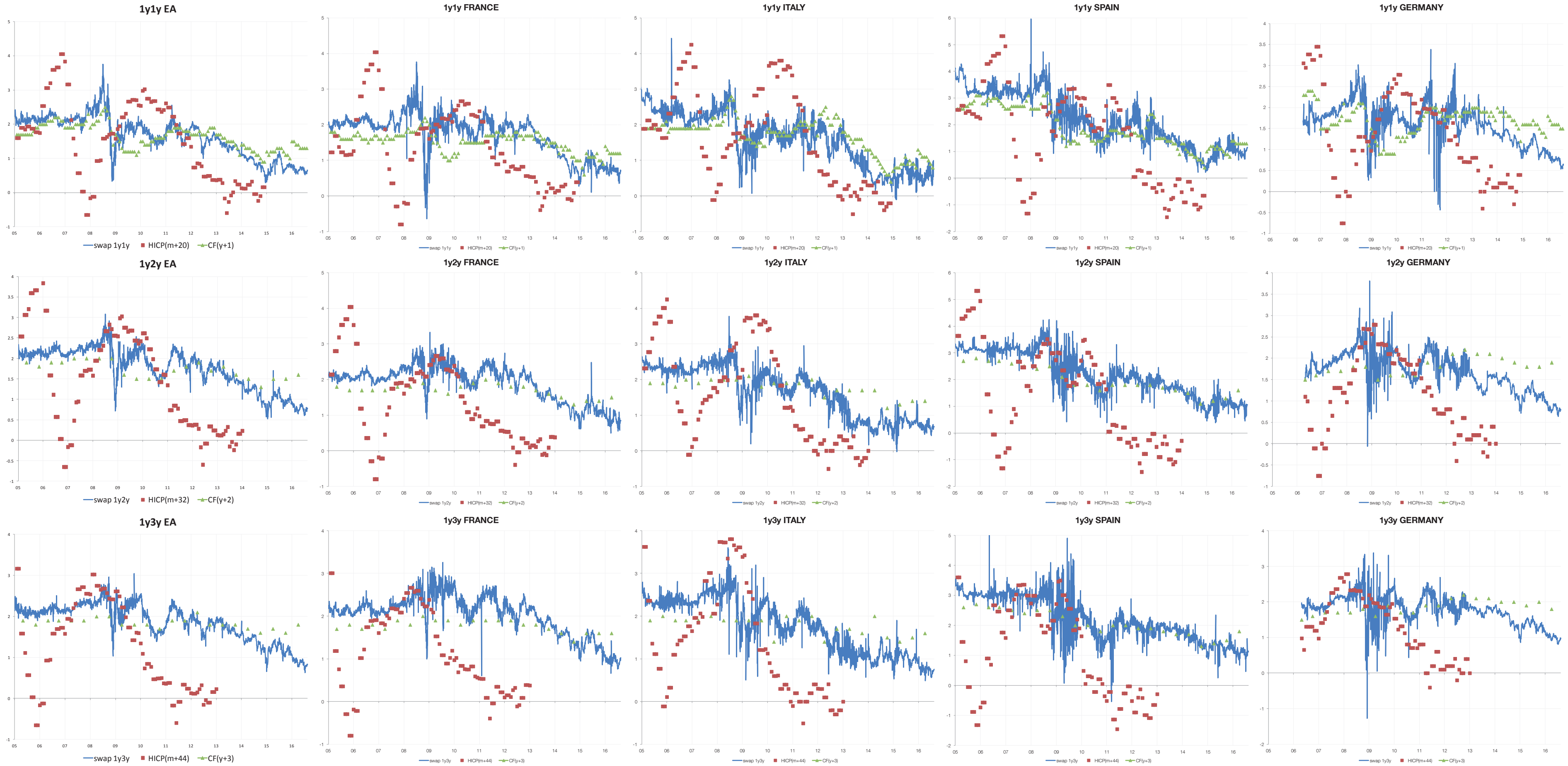


Figure 2b: Annual Inflation expectations at various horizons from financial markets (ILSwaps 1y4y, 1y5y, and 5y5y, in blue) and survey (Consensus Forecast for y+4, y+5, and avg(y+6 to y+10), in green). In red, the realized annual HICP inflation for the corresponding swap contract, with the appropriate lag.

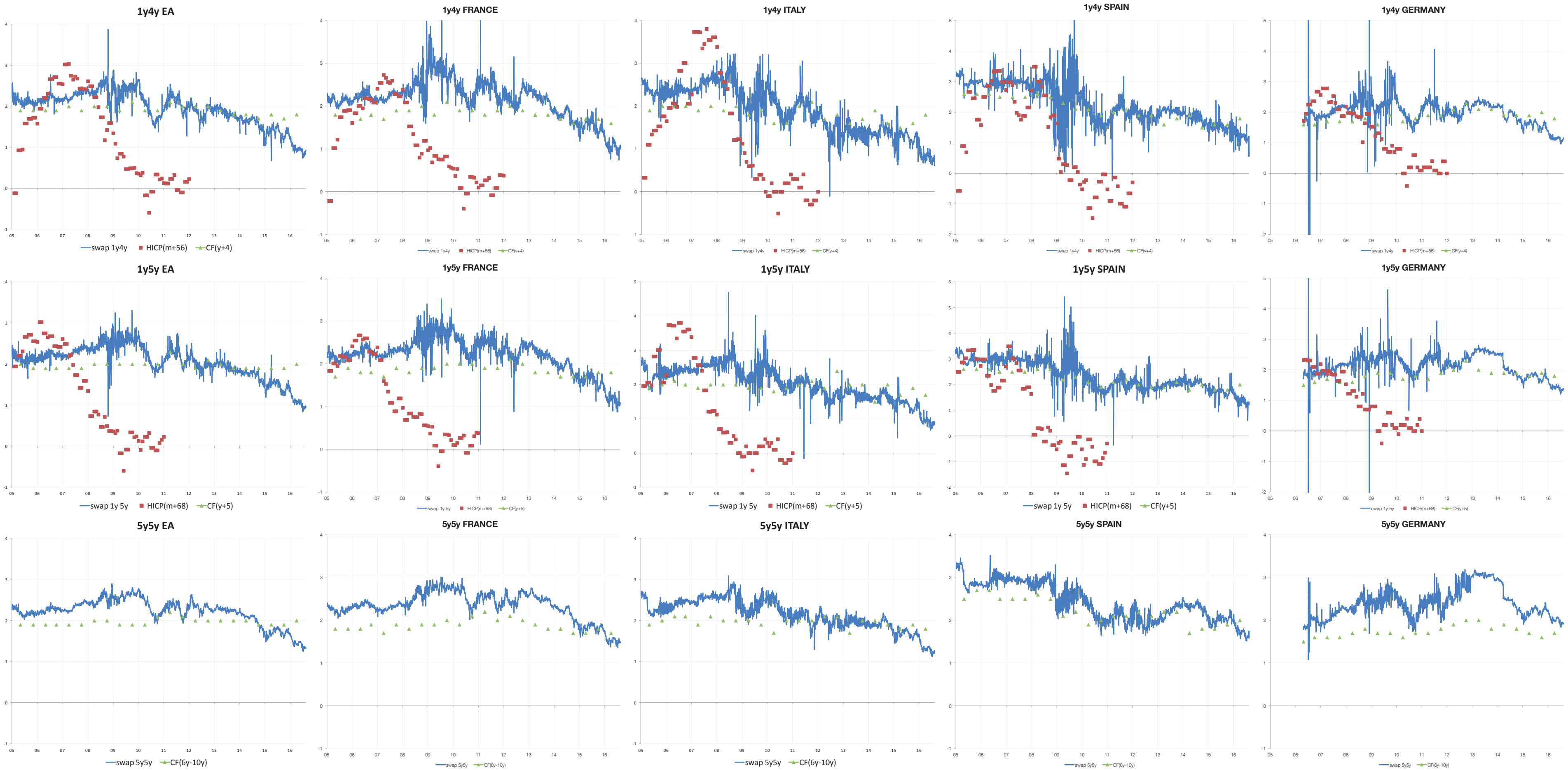


Table 1 shows some descriptive statistics from ILS-based and CF survey-based inflation expectations at various horizons. The correlation between the 1-y inflation swaps, swap1y, and the survey expectations for the current year, CF(y), in Figure 1 ranges from 0.49 for Germany to 0.80 for Spain, taking a value of 0.60 for the Euro area aggregate inflation. A similar high correlation is observed for next year's annual inflation in the CF survey, CF($y+1$), vs the forward 1-year inflation swap 1-year ahead (swap 1y1y), and to a somewhat lesser extent for longer horizons. Even at longer horizons, the correlation between ILS-based and CF survey-based inflation expectations is high, staying above or close to 0.60 for the 1-year forward inflation rates up to 4-years ahead for all countries (except Germany, for reasons of data quality which we comment below).

Comparing survey- vs financial market-based information at different horizons, there doesn't seem to be any systematic bias in any of the two at the shorter horizons; they move close to each other. At longer maturities, though, the sample mean of swap rates tends to be, on average, somewhat higher than survey forecasts: the latter stay closer to the "close but below 2%" reference related to the ECB target the longer the forecasting horizon, while the swap rates show wider fluctuations even at long maturities. The standard deviations of expected inflation in all countries and sources of information is lower the longer the horizon, where the liquidity improves. Swaps tend to have larger volatility than survey expectations (except for the spot one year swaps, swap1y), especially at the longest horizons.[8]

In terms of country differences, Figures 1 and 2 show that French swap inflation rates seem to incorporate a positive gap with respect to survey expectations in the longer horizons. In the case of Italy and, especially, Spain there is a positive inflation bias in ILS rates with respect to CF at longer horizons until the crisis and then it essentially disappears. It is actually remarkable how closely ILS rates and CF survey forecasts track each other's inflation rates in Spain even at very long maturities. In the case of Italy, there is a substantial deviation between the two sources of inflation expectations from 2013 onwards at short-to-medium horizons: swaps rates lie under survey forecasts, with large discrepancies at times, hinting at a substantial disinflation risk being priced in in swap markets for that country.

[8]Part of the ILS high volatility in long horizons is a consequence of the way forward rates are constructed: forward rates are analog to the derivative of the spot rates, so any disturbance in those spot rates tends to be exacerbated in the forward measures.

Finally, the case of Germany deserves some attention. While, in general, swap rates for German inflation seem to have a reasonable evolution, especially at shorter maturities, outliers are more abundant than in the other countries and high frequency volatility essentially disappears in 2012 for all maturities. We interpret this outcome as a consequence in the reduction of data contributors to this market segment. This would imply that the analysis of German swaps after 2012 have to be taken with great caution because of the lower quality of the data. For this reason, we have opted to use German swaps rates only until May 2012 in the estimation of the multi-country model of Section 3.

In terms of how well the two information sets forecast actual inflation, only at the shortest horizons depicted in Figure 1, they seem to forecast inflation successfully. This makes both measures of inflation expectations valuable in terms of monitoring and forecasting inflation, since they are available with a considerable lead and, in the case of swaps, also with a high frequency with respect to realized inflation. However, for longer horizons graphical inspection of Figure 2 suffices to predict a bad forecasting record. Table 1 reports simple measures of the forecasting record such as the Mean Absolute Forecast Error and the Root Mean Squared Forecast Error. The forecast error measures are computed for the difference between the swap rates or the CF forecasts and the corresponding realized future HICP inflation rates, with the appropriate lag in each case. When trying to forecast annual HICP inflation for the next months, swap rates incur in smaller forecast errors than Consensus Forecast survey in all countries. However, beyond the one year ahead horizon, survey expectations obtain in general smaller forecast errors.

The lack of good forecasting performance for longer horizons does not mean that neither ILS nor CF produce any useful information about inflation expectations. Market participants may have some ex-ante expectations about future inflation that may or may not coincide with ex-post realized inflation. This is especially the case in periods like the crisis or the posterior low-inflation environment, which were not predicted by market participants or analysts.

Table 1. Descriptive statistics of alternative measures of annual inflation expectations: financial markets-based (Inflation Linked Swaps) and survey-based (Consensus Forecasts).

ITALY

	CF	# obs	mean	S.D.	Swap	# obs	mean	S.D.	Corr.	MAFE CF	MAFE Swaps	RMSFE CF	RMSFE Swaps
current year infl forecast	CF(y)	142	1.81	0.89	Swap1y	137	1.54	0.74	0.70	0.84	0.72	1.09	0.93
1 year ahead infl forecast	CF(y+1)	142	1.76	0.46	Swap1y1y	137	1.73	0.74	0.77	1.00	1.01	1.20	1.14
2 years ahead infl forecast	CF(y+2)	24	1.80	0.24	Swap1y2y	137	1.78	0.68	0.70	0.96	1.11	1.11	1.23
3 years ahead infl forecast	CF(y+3)	24	1.80	0.22	Swap1y3y	137	1.88	0.61	0.56	1.04	1.06	1.20	1.23
4 years ahead infl forecast	CF(y+4)	24	1.83	0.18	Swap1y4y	137	2.00	0.52	0.64	0.99	1.21	1.11	1.41
5 years ahead infl forecast	CF(y+5)	24	1.95	0.16	Swap1y5y	137	2.12	0.43	0.15	1.07	1.35	1.21	1.57

SPAIN

	CF	# obs	mean	S.D.	Swap	# obs	mean	S.D.	Corr.	MAFE CF	MAFE Swaps	RMSFE CF	RMSFE Swaps
current year infl forecast	CF(y)	142	2.05	1.36	Swap1y	137	2.07	1.14	0.80	1.35	1.10	1.72	1.40
1 year ahead infl forecast	CF(y+1)	142	1.99	0.73	Swap1y1y	137	2.34	1.01	0.91	1.39	1.37	1.65	1.71
2 years ahead infl forecast	CF(y+2)	24	2.03	0.53	Swap1y2y	137	2.34	0.79	0.94	1.28	1.46	1.59	1.80
3 years ahead infl forecast	CF(y+3)	24	2.11	0.43	Swap1y3y	137	2.32	0.69	0.93	1.45	1.51	1.76	1.83
4 years ahead infl forecast	CF(y+4)	24	2.16	0.38	Swap1y4y	137	2.38	0.61	0.86	1.37	1.66	1.72	2.06
5 years ahead infl forecast	CF(y+5)	24	2.23	0.30	Swap1y5y	137	2.44	0.53	0.92	1.31	1.59	1.65	1.95

FRANCE

	CF	# obs	mean	S.D.	Swap	# obs	mean	S.D.	Corr.	MAFE CF	MAFE Swaps	RMSFE CF	RMSFE Swaps
current year infl forecast	CF(y)	142	1.48	0.74	Swap1y	137	1.45	0.60	0.68	0.79	0.63	1.09	0.81
1 year ahead infl forecast	CF(y+1)	142	1.54	0.27	Swap1y1y	137	1.77	0.54	0.66	0.86	0.94	1.03	1.15
2 years ahead infl forecast	CF(y+2)	24	1.71	0.17	Swap1y2y	137	1.97	0.43	0.73	0.92	1.12	1.12	1.30
3 years ahead infl forecast	CF(y+3)	24	1.78	0.14	Swap1y3y	137	2.11	0.37	0.77	0.96	1.22	1.17	1.46
4 years ahead infl forecast	CF(y+4)	24	1.83	0.12	Swap1y4y	137	2.22	0.34	0.57	0.98	1.34	1.21	1.63
5 years ahead infl forecast	CF(y+5)	24	1.84	0.13	Swap1y5y	137	2.27	0.30	0.51	0.81	1.19	1.04	1.53

GERMANY

	CF	# obs	mean	S.D.	Swap	# obs	mean	S.D.	Corr.	MAFE CF	MAFE Swaps	RMSFE CF	RMSFE Swaps
current year infl forecast	CF(y)	142	1.54	0.66	Swap1y	115	1.73	0.72	0.49	0.69	0.64	0.91	0.82
1 year ahead infl forecast	CF(y+1)	142	1.65	0.36	Swap1y1y	115	1.66	0.38	0.19	0.80	0.77	0.97	1.01
2 years ahead infl forecast	CF(y+2)	24	1.75	0.23	Swap1y2y	115	1.74	0.36	-0.23	0.84	0.85	1.07	1.04
3 years ahead infl forecast	CF(y+3)	24	1.79	0.22	Swap1y3y	115	1.83	0.31	-0.15	0.81	0.75	1.03	0.97
4 years ahead infl forecast	CF(y+4)	24	1.81	0.20	Swap1y4y	115	2.05	0.27	0.18	0.67	0.83	0.89	1.06
5 years ahead infl forecast	CF(y+5)	24	1.77	0.19	Swap1y5y	115	2.20	0.28	0.35	0.67	1.05	0.89	1.37

EURO AREA

	CF	# obs	mean	S.D.	Swap	# obs	mean	S.D.	Corr.	MAFE CF	MAFE Swaps	RMSFE CF	RMSFE Swaps
current year infl forecast	CF(y)	142	1.70	0.86	Swap1y	137	1.85	0.45	0.60	0.83	0.76	1.11	0.94
1 year ahead infl forecast	CF(y+1)	142	1.67	0.34	Swap1y1y	137	1.73	0.54	0.77	0.97	0.91	1.14	1.11
2 years ahead infl forecast	CF(y+2)	24	1.74	0.21	Swap1y2y	137	1.94	0.38	0.67	0.92	0.97	1.12	1.19
3 years ahead infl forecast	CF(y+3)	24	1.84	0.12	Swap1y3y	137	2.03	0.34	0.61	0.96	1.03	1.17	1.26
4 years ahead infl forecast	CF(y+4)	24	1.91	0.10	Swap1y4y	137	2.12	0.32	0.64	0.98	1.17	1.21	1.44
5 years ahead infl forecast	CF(y+5)	24	1.96	0.09	Swap1y5y	137	2.27	0.24	0.29	0.81	1.15	1.04	1.46

Notes: The sample is June 2004-August 2016. ILSwaps data start in June 2004 for Italy, Spain and France, and the EuroArea aggregate, and in April 2006 for Germany. Corr refers to the contemporaneous correlation between CF and Swap rates. Mean Absolute Forecast Erros (MAFE) and Root Mean Squared Forecast Errors (RMSFE) are obtained comparing inflation expectations for different horizons from CF and ILSwaps to their corresponding actual HICP inflation, with the adequate lag.

2.1 The liquidity of inflation linked swaps

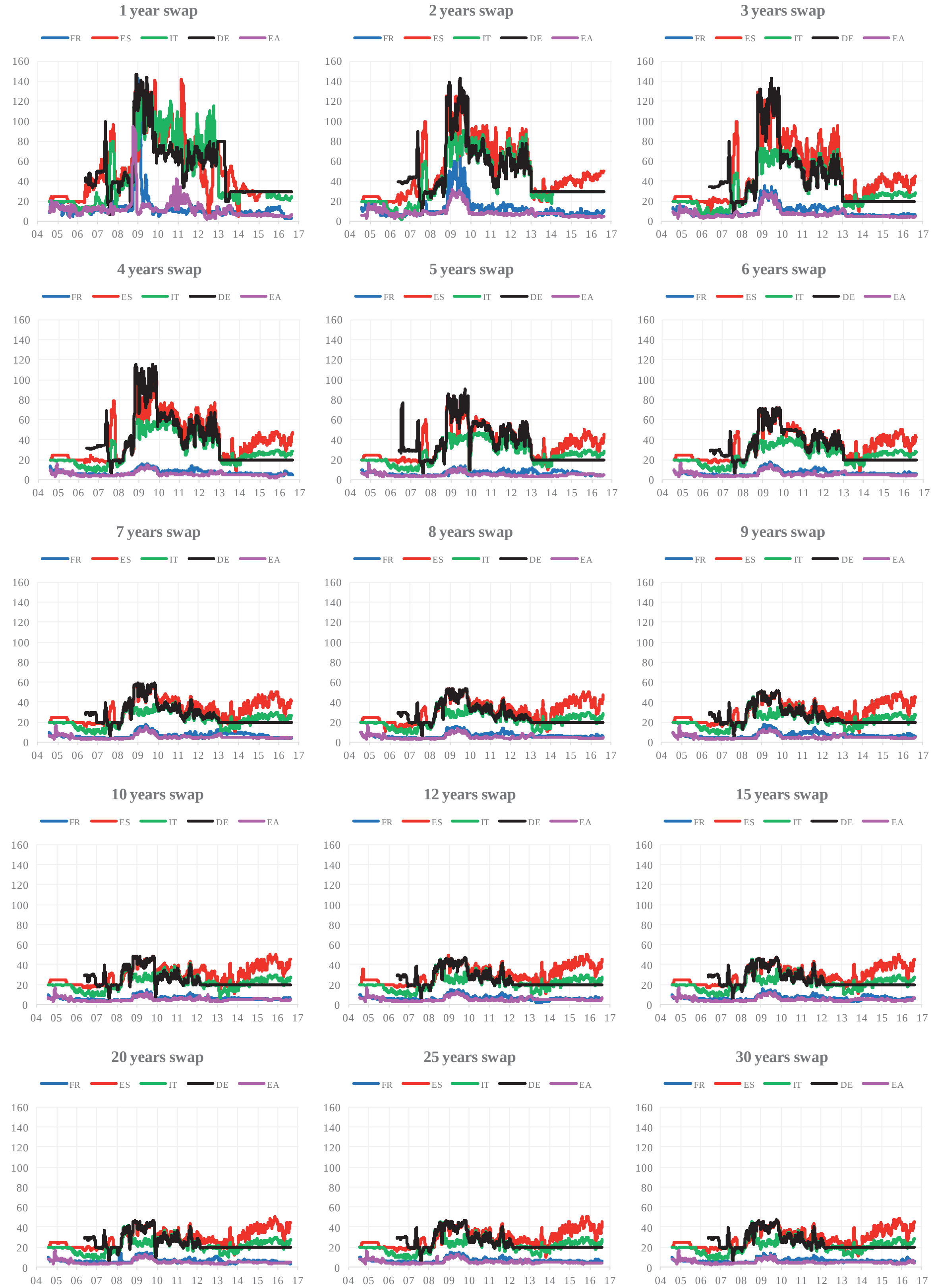
Contrary to survey data, ILS data is available at a much higher frequency and for a more complete set of horizons, and hence seems more suitable for empirical analysis on inflation expectations. Moreover, the descriptive analysis above suggests that ILS are comparable to survey-based measures of inflation expectations in terms of forecasting performance or other basic properties. Nevertheless, as mentioned in the previous section, the inflation expectations signal in swap rates may be hidden by an excess of volatility. One important source for this volatility in forward rates can be the existence of low levels of liquidity in the inflation swap markets. They are clearly less liquid markets than other swap markets (especially interest rate swaps like the OIS).

It is generally accepted that the Euro area inflation swap is the most liquid among the inflation swap markets, but country-specific contracts may have lower levels of liquidity. Although there is no information available on traded volume, there is daily information on the closing bid-ask spread of the inflation swaps for each country and maturity. Such spreads can be used to estimate a potential liquidity risk (i.e., the loss over the mid price in case that an investor wants to close a current position in inflation swaps), and has been used for this purpose in other markets (e.g., Amihud and Mendelson, 1991). Figure 3 plots these series for each country and the Euro area for all available maturities.[9] As can be seen, the level of the bid-ask spread varies considerably between countries, and is clearly time-varying (reaching a maximum during the peaks of the financial crisis). It is also clear that those contracts with higher maturity are the more liquid ones, where the bid-ask spreads are smallest.

Looking by country, French swaps enjoy a level of liquidity similar to those of the Euro area aggregate, while Spanish and Italian swaps have much higher bid-ask spreads. The case of German swaps deserve especial consideration. Before 2012, the evolution of the bid-ask spreads at all maturities is similar to those of Spain and Italy, but, afterwards, there is no change in those spreads. As mentioned before, we interpret this outcome as a consequence in the reduction of data contributors to this

[9] Given their high volatility, the bid-ask spreads are represented using rolling windows of 20 days.

Figure 3. Bid-Ask spreads (in bp) if inflation linked swaps by maturity and country (20-day rolling window of daily data).



market segment. This would imply that the analysis of German swaps after 2012 have to be taken with great caution because of the lower quality of the data. For this reason, we have opted to use German swaps rates only until May 2012 in the estimation of the multi-country model of Section 3.

In addition to being a measure of potential liquidity risk, the spread between bid and ask has a direct repercussion into the swap rate. Swap rates are computed as the mid-quote (the average of the bid and the ask), and therefore the bigger the spread the higher the measurement error in the swap rate data. Hence, we will include the bid-ask spreads directly affecting both measurement error and liquidity risk premia within the more complete model of inflation expectations term structure of the next section.

2.2 Term premium in Inflation Linked Swaps

There is also the possibility that market participants may be willing to pay/demand a compensation for increasing inflation uncertainty the longer the duration of the contract. Although the descriptive analysis in section 2 suggests that ILS produce inflation expectations overall as reliable as survey forecasts, their identification with pure inflation expectations implies that objective and risk-neutral measures coincide. Otherwise, information contained in ILS may be contaminated by a term premium mixed with the pure inflation expectations.

The literature has tried a variety of ways to extract the risk component from financial market-based information on inflation expectations. See, e.g., Gürkaynak et al. (2010) for the US case; García and Werner (2010) for the inflation risk premia in the Euro area; or Coroneo (2015) for the liquidity premium in US TIPS markets. All these papers relate to bond markets (i.e. inflation linked bonds) where investors hold mainly long positions, investors are protecting themselves against high inflation. However, in the ILS market, direct investors (once we extract the market makers that offer prices in both sides of the contract) may be long or short. This means that a term premium could be positive (if demand pressure for inflation protection dominate the market), negative (if supply pressure for inflation protection dominate the market) or null (if demand and supply are even). Additionally, the level of uncertainty that a term premium would compensate might be affected by the credibility of the central bank. In the case of a credible monetary policy with well anchored inflation expectations, one should expect that uncertainty would be higher for the short run than for an average of a longer horizon. In that case, the term premium should be inverted (higher for a zero coupon ILS with shorter maturity, than for a zero coupon ILS with a long maturity). By contrast, a period of deanchoring would imply an increase in inflation uncertainty and a potential increase in the term premium at longer maturities.

In order to assess the possible presence of a term premium we first estimate a model of inflation expectations in the following Section 3 and then we compare the implied forward rate in the observed ILS rates with a model-based forecast obtained with such model. In absence of a term premium, the expected rate should be equivalent to the forward rate (i.e. pure expectations hypothesis. See Fama and Bliss, 1987). In contrast, differences between model-based forecasts and observed forward rates can be mostly associated with a term premium.

3 A multicountry model of inflation expectations

Once analyzed the basic properties of inflation expectations data, we turn to the main questions of this paper: How are inflation expectations formed across countries that share their monetary policy? What is the behavior of market-based inflation expectations across countries in the European Monetary Union (EMU)? Do they share common features at the various horizons or do expected inflation differentials across Euro area countries emerge at different horizons, say, more at shorter than longer horizons? Has the degree of common behavior changed over time? And, in terms of direct monetary policy implications, has the long-run expected inflation remained well anchored across these countries at the European Central Bank (ECB) target of below, but close to 2%?

In order to answer these questions, we use ILS daily data on mid-quotes and bid-ask spreads to estimate a dynamic factor model. The model builds on the Diebold et al. (2008) multi-country model but it includes two additional latent factors.

The original Diebold et al. (2008) model was based, in turn, in the Nelson and Siegel (1987) term structure model, where rates are determined by equation 2. In Nelson and Siegel (1987), the three factors are identified as the long term level ($\lim_{m\to\infty} r_t(m) = L_t$), the slope or difference between short term rates and long term ones ($\lim_{m\to 0} r_t(m) = L_t + S_t$) and the curvature, or distortion in the medium term over the convergence of short term rates into long term rates (see, for instance, Gimeno and Nave (2009)).

$$r_t(m) = L_t + S_t \left(\frac{1 - e^{-\frac{m}{\tau}}}{\frac{m}{\tau}} \right) + C_t \left(\frac{1 - e^{-\frac{m}{\tau}}}{\frac{m}{\tau}} - e^{-\frac{m}{\tau}} \right) \tag{2}$$

Diebold and Li (2006) linearized equation (2) by replacing τ by a constant (i.e., $\tau = 2$ in this paper).[10] Later, Diebold et al. (2006) transformed Diebold and Li (2006) model into a dynamic latent factor model. And finally, the multi-country model of Diebold et al. (2008) was built based on the Diebold et al. (2006) model, but preserving only the level (L_t) and slope (S_t) factors, and removing the curvature (C_t) factor in order to reduce the number of estimated parameters. By contrast, we have opted to keep this curvature factor in the model, because it provides relevant information about the persistence of short term inflation shocks into medium term expectations. This addition of a third global factor is in line with the extension of Abbritti et al. (2013). Although in the case of Abbritti et al. (2013) the model was estimated on interest rates, they found that this third factor was related precisely with inflation expectations.

Our second addition to Diebold et al. (2008) is a factor that accounts for liquidity distortions in quoted swap rates. These distortions might be especially relevant in our case, since as we showed in section 2.1, the swaps we are using in the model have quite different bid-ask spreads across countries, maturities and time periods. Amihud and Mendelson (1986) showed that stock returns are positively correlated with the bid-ask spreads, while Amihud and Mendelson (1991) also found a liquidity risk premium in fixed income assets. Following both papers, we have added a liquidity factor (R_t) that takes into account the potential effect of the bid-ask spreads into the inflation swap rates. The main difference with stock returns and bonds is that in the case of swaps the premium for less liquid ILS might be positive or negative,

[10] Parameter τ in Nelson and Siegel (1987) determines the speed of convergence, but under the Diebold and Li (2006) linearization, changes in the speed of convergence are reflected in the value of the time-varying curvature parameter.

depending on whether the contract is protecting from high inflation or low inflation, respectively. Thus, in our case, we do not restrict this factor to be positive.

Therefore, we assume that the observed zero-coupon inflation compensation at each maturity m and for each country i, π_{it}^{m}, can be represented as (i.e., measurement equation):

$$\pi_{it}^{m} = H_m F_{it} + u_{it}^{m} \tag{3}$$

where $u_{it}^{m} \backsim N\left[0, \sigma_{imt}\right]$ is the measurement error for each ILS. Berenguer et al. (2014) showed that differences in liquidity can produce heteroskedasticity, so we allow the standard deviation to depend on the corresponding bid-ask spread for each country and maturity BA_{it}^{m}, that is, $\sigma_{imt} = e^{(\beta_{im} + \beta_{BA} \cdot BA_{it}^{m})}$. Vector F_{it} contains the latent factors (i.e., level L_{it}, slope S_{it}, curvature C_{it}, and price of liquidity risk R_{it}) while H_m is a vector of coefficients:

$$H_m = \begin{pmatrix} 1 & \frac{1-e^{-\frac{m}{2}}}{\frac{m}{2}} & \frac{1-e^{-\frac{m}{2}}}{\frac{m}{2}} - e^{-\frac{m}{2}} & BA_{it}^{m} \end{pmatrix}. \tag{4}$$

The structure defined by H_m does not need to be estimated, since coefficients are known, and also ensures the identification of the latent factors. The first three latent factors in F_{it} correspond to the term structure curves for inflation expectations in the swap rates. The level L_{it} represents the asymptotic long run value for the inflation rate, that is, the end point of the curve ($\lim_{m \to \infty} H(m) = \begin{bmatrix} 1 & 0 & 0 & BA \end{bmatrix}$). The slope S_{it} is the difference between the level and the shortest maturity, which is the starting point of the curve ($\lim_{m \to 0} H(m) = \begin{bmatrix} 1 & 1 & 0 & BA \end{bmatrix}$). Therefore, the level plus the slope determine the short-term expected value for the ILS rates. Finally, the curvature C_{it} determines the shape of the curve, the speed of convergence of short-term to long-term inflation expectations, i.e. negative values will delay the convergence to the long run level while positive ones will accelerate the convergence. This third element in $H(m)$ has the shape of an inverted U, with a maximum around 3.5 years.

Following the multi-country structure of Diebold et al. (2008), we decompose the unobserved time-varying factors in F_{it} into their global (G) and national components (N). That is,

$$
\begin{aligned}
L_{it} &= GL_t + NL_{it}, \\
S_{it} &= GS_t + NS_{it}, \\
C_{it} &= GC_t + NC_{it}.
\end{aligned} \tag{5}
$$

Identification can be an important problem with this decomposition, but we can circumvent this by making use of the information available specific to the global factors. Since inflation swaps are also traded for the Euro area as a whole, we will have that for ILS_{EA},

$$
\begin{aligned}
L_{EAt} &= GL_t, \\
S_{EAt} &= GS_t, \\
C_{EAt} &= GC_t.
\end{aligned}
$$

Furthermore, as mentioned above, the model extends Diebold et al. (2008) by allowing for a fourth global factor which tries to capture the price of liquidity risk in the ILS rates. The model-based measure of time-varying risk premium is composed of an observed measure of liquidity risk –the bid-ask spread observed for each inflation swap contract for country i and maturity m, BA_{it}^m, times its unobserved price R_{it}. Contrary to the other unobserved factors –level, slope and curvature–, we consider that country-differences in R_{it} do not make much sense given the possibility for any agent to participate in any of these inflation swaps markets, and hence we interpret that R_{it} is essentially common across the Euro area, that is, there is only a common global component (GR_t) to it and not different national components. To take into account the potential different level of depth in each country ILS market, we just transform the global price of liquidity risk (GR_t) into each country price of risk (R_{it}) by multiplying it by γ_{Ri} coefficients.[11]

$$
R_{it} = \gamma_{Ri} GR_t
$$

For the state equation, we assume that all latent factors (GL_t, GS_t, GC_t, NL_{it}, NS_{it}, NC_{it}, and GR_t) follow a random walk, where $\varepsilon_t \backsim N[0, Q]$ and Q is restricted to be diagonal and constant.

$$
F_t = F_{t-1} + \varepsilon_t \tag{6}
$$

[11] In order to identify both GR_t factor and γ_{Ri} coefficients, we impose the standard deviation of ε_{Rt} to be equal to 1.

In equation (6) we are imposing that other countries' inflation expectations do not affect national components except through the global ones. Additionally, we are also assuming that even inside the same country, level, slope and curvature are independent, in line with the estimation results in Diebold and Li (2006) and Diebold et al. (2006).

Once both global and country specific components are estimated, we can decompose each inflation swap rate into four parts: the global component ($H_m G_{it}$), the country specific component ($H_m N_{it}$), the liquidity risk premium ($BA^m_{it} R_{it}$) and the noise or measurement error (u^m_{it}). By inspecting the relative size of country and global components across maturities, whether they change through time, and whether significant differences emerge across countries, we can already provide some answers to the questions posed in this paper.

Latent factors can be computed using a Kalman Filter, while the parameters in the model can be estimated using maximum likelihood. We estimate the model jointly on Zero-Coupon Inflation Swap rates for Italy, Spain, France, Germany, and the Euro area, as well as their corresponding bid-ask spreads, using twelve years of daily observations (from June 2004 to August 2016, except for Germany whose sample is April 2006-May2012) for all 15 maturities available: 1 to 10y, 12y, 15y, 20y, 25y and 30 years. Even after all the restrictions included in the model, we need to estimate a very high number of parameters: in the measurement equation we need to estimate β_{im} for each ILS plus a single β_{BA} (76 parameters); we also need to estimate a γ_{Ri} for each country (5 parameters); and in the state equation the diagonal coefficients in matrix Q, one per latent factor (16 parameters). We have also reduced the optimization load by fixing the initial values of the latent factors to be equal to 0 and the initial covariance matrix to be equal to a diagonal matrix with coefficients equal to 0.001, and discard the first 100 observations. However, to obtain the maximum likelihood estimators for the 97 parameters traditional optimization algorithms are not a good approach (as Diebold et al. (2008) states), so we have used a genetic algorithm similar to the one proposed by Gimeno and Nave (2009). Table 2 reports the full set of estimated parameters and standard errors for both the measurement equation (3) and the state equation (6).

Table 2: Maximum likelihood estimates for the parameters in the model of section 3. Numbers in parenthesis represent the standard errors.

Meaurement Equation

	ES	FR	IT	DE	EA
Global Factors					
Level	1	1	1	1	1
	-	-	-	-	-
Slope	1	1	1	1	1
	-	-	-	-	-
Curvature	1	1	1	1	1
	-	-	-	-	-
Price of Risk	0.043	0.010	0.024	0.039	0.010
	(0.000)	(0.000)	(0.000)	(.023)	(0.000)
Standard measurement errors (in b.p.)					
Maturity	ES	FR	IT	DE	EA
1	26.134	22.373	23.699	20.715	17.119
	(0.000)	(2.686)	(0.000)	(0.000)	(0.000)
2	8.393	4.913	6.099	5.551	3.849
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
3	4.934	2.077	4.040	4.226	2.496
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
4	3.508	2.318	3.618	3.266	2.930
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5	3.044	1.610	2.450	4.650	2.285
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
6	2.019	1.426	1.568	3.033	1.233
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
7	1.836	1.464	1.267	2.311	1.194
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
8	2.459	1.431	1.467	2.292	1.638
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
9	1.871	1.954	1.682	2.733	2.270
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
10	2.923	2.154	2.167	3.611	2.535
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
12	3.945	2.147	2.344	3.403	2.798
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
15	2.821	1.285	2.028	3.954	2.241
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
20	3.197	3.445	2.152	4.354	0.045
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
25	4.419	6.320	3.386	6.045	2.942
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
30	7.413	7.805	5.804	6.635	4.880
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
BAS	0.387	0.387	0.387	0.387	0.387
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

State Space Equation

$X_t = M + F^* X_{t-1} + u_t$

	Level	Slope	Curvature	Price of Risk
M				
Global	0	0	0	0
	-	-	-	-
ES	0	0	0	
	-	-	-	
FR	0	0	0	
	-	-	-	
IT	0	0	0	
	-	-	-	
DE	0	0	0	
	-	-	-	
F				
Global	1	1	1	1
	-	-	-	-
ES	1	1	1	
	-	-	-	
FR	1	1	1	
	-	-	-	
IT	1	1	1	
	-	-	-	
DE	1	1	1	
	-	-	-	
Q				
Global	0.023	0.053	0.064	0.021
	(0.000)	(0.000)	(0.000)	(0.000)
ES	0.026	0.092	0.125	
	(0.000)	(0.000)	(0.000)	
FR	0.008	0.037	0.048	
	(0.000)	(0.000)	(0.000)	
IT	0.042	0.077	0.070	
	(0.000)	(0.000)	(0.000)	
DE	0.029	0.131	0.105	
	(0.000)	(0.000)	(0.000)	

4 Model estimation results

What does the model tell us about the behavior of market-based inflation expectations across countries in the European Monetary Union? A good way of summarizing the estimation results of the above model is Figure 4a, which represents the common (in pink) and country-specific (red for Spain, blue for France, green for Italy and black for Germany) components of the level, slope and curvature estimates. Figure 4b represents the same factors (solid lines) with their 95% confidence intervals (dotted lines), showing that all factors are estimated with high precision. It is interesting to note also that, as discussed in Section 3, the estimated common price of liquidity risk (bottom right panel in Figure 4a) effectively shows both positive and negative values, depending on whether ILS contracts are protecting from high inflation or from low inflation, as well as a high volatility.

4.1 Do inflation swap rates share common features across EMU countries at the various horizons?

It is immediate to see that the national components of the level, that is, the cross-country differences in the asymptotic long run value expected for the inflation rate, are really small compared to the common part. This confirms the intuition that, in the long run, agents in countries belonging to a monetary union should expect the same inflation rate. Contrary to the mostly common level estimates, differences across countries emerge through time in the term structure parameters that determine short-term inflation swap rates (slope) or the speed of convergence of these towards the long-run (curvature). In the case of the slope, different countries show movements in their country-specific component of the slope at different times and of different intensity, even at periods where the levels where stable, reflecting changes in their shortest-run inflation expectations not necessarily shared in other economies. Finally, in the case of the curvature the cross-country disparities seem highest.

Figure 4a. Common and country-specific components of the level (top left panel), slope (top right panel) and curvature (bottom left panel) factors estimated in the multi-country model using Zero-Coupon Inflation Swap yields for Italy, Spain, France, Germany and euro area. The estimated common price of liquidity risk is displayed in the bottom right panel.

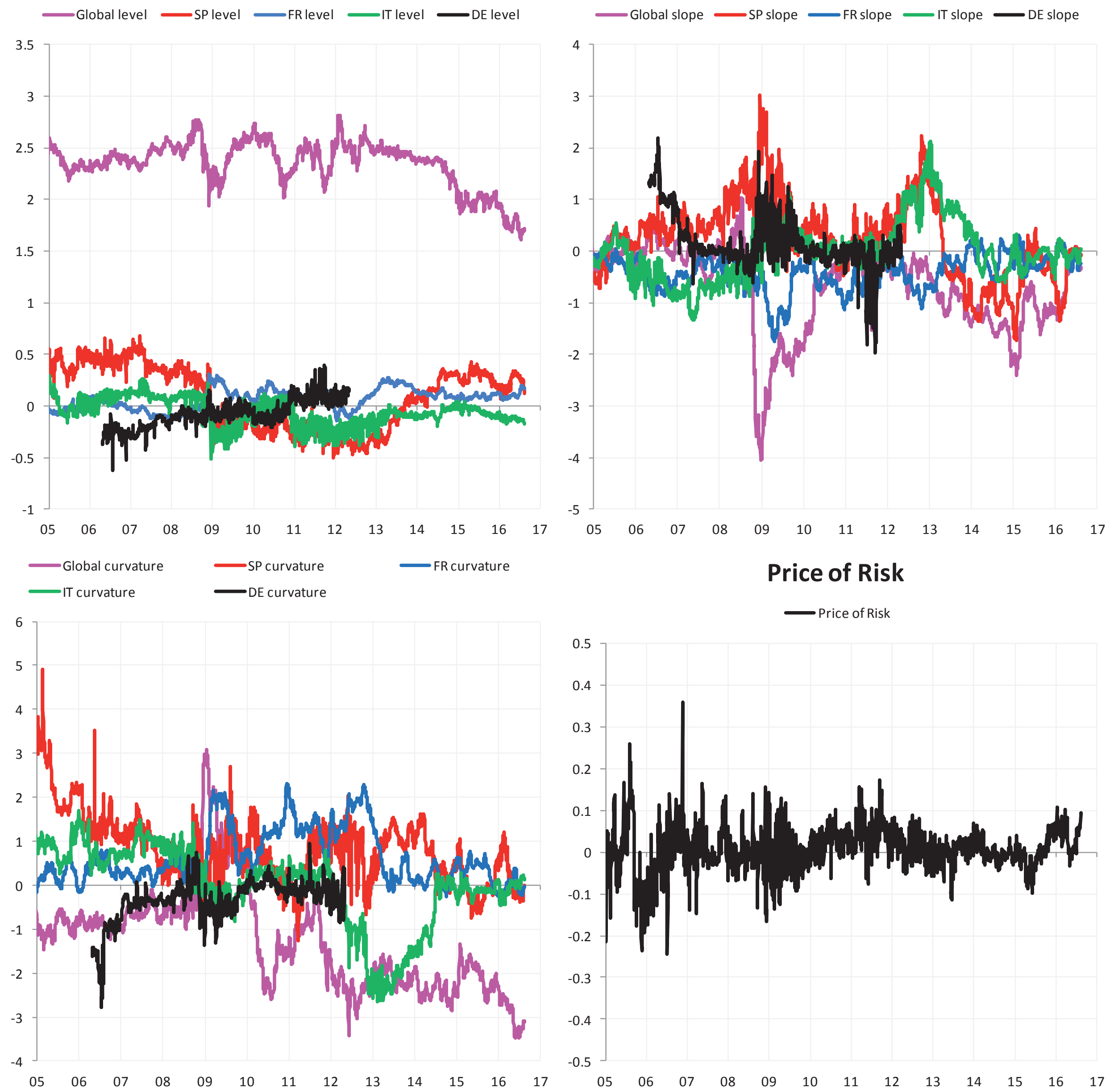
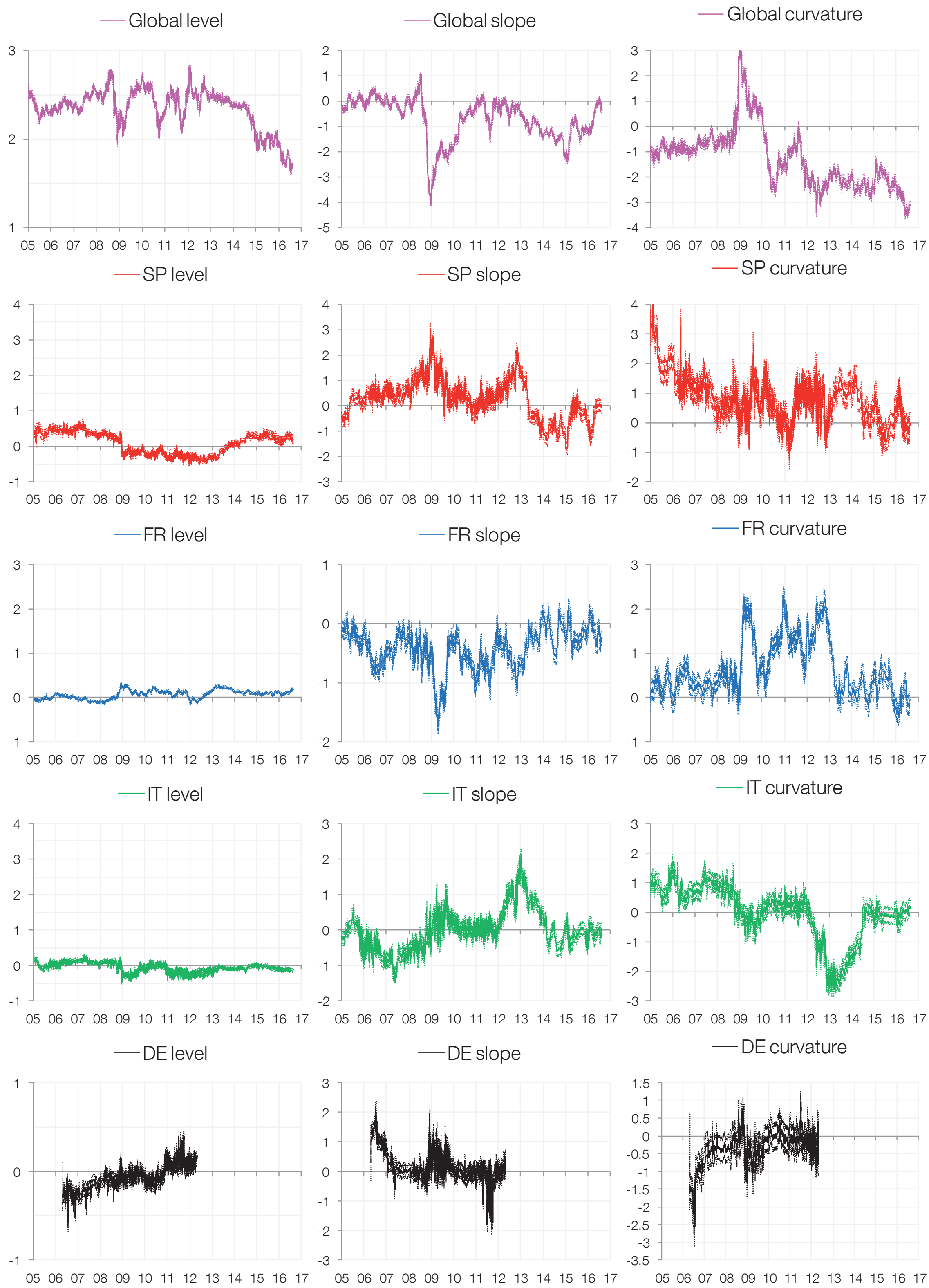


Figure 4b. Common and country-specific components of the level, slope and curvature factors estimated in the multi-country model using Zero-Coupon Inflation Swap yields for Italy, Spain, France, Germany and euro area, with 95% confidence intervals.



4.2 Has the degree of common behavior changed over time?

Figure 4 shows that throughout the sample period the common component of the level is larger than the country ones, but this common very long-run expected inflation rate varies through time, and lies since late 2014 below the values estimated before. The fall in the common component of the level estimates coincides with the raised concerns of a possible risk of de-anchoring of long-term inflation expectations. In 2015 the fall stopped, coinciding with the announcement and implementation of the ECB's unconventional monetary policy measures. However, it restarted around year-end and continues in 2016.

At shorter horizons, the evolution of the common slope has a varying relative importance through time. During 2009, the fall in the shorter end of the inflation expectations curve was common across the EMU as reflected by a large negative common slope. Since 2013 a common negative slope reappeared, larger than the country components, which moved in different directions and with different timing but showing a general trend of larger falls in the shortest maturities of inflation swaps relative to longer ones. In 2015, the general steepening of the inflation expectations curve eased but did not disappear. In the case of the curvature, since mid-2012 a larger common component emerged, with sustained negative values up until now indicating that the convergence of short-term to long-term inflation expectations gets delayed to longer and longer maturities.

This general findings are confirmed when we turn to particular examples of different ILS rates for different countries and horizons. Figures 5 to 8 decompose the Zero-Coupon Inflation Swap yields for Spain, Italy, France and Germany, respectively, for both spot rates (1y, top left, and 10y, top right) and forward rates (5y5y in the bottom left panel, and 1y4y in the bottom right). Each swap rate is decomposed into the common component across countries (in yellow), the country specific component (in blue) and the model-based measure of liquidity risk premium (in red), as estimated by the model laid out in the previous section.

Three main results emerge from Figures 5 to 8. Firstly, a common component dominates across EMU countries inflation swap rates, at all maturities and throughout the years. This common part is especially dominant in the longer horizons. As could be expected, this confirms that countries sharing their monetary policy form their inflation expectations jointly too.

Figure 5. Decomposition of **Spanish** Inflation Swaps at 1 year maturity (swap1y, top left); 10 year maturity (top right); 1-year forward 4 years ahead (swap1y4y, bottom right); and 5-year forward 5 years ahead (swap5y5y, bottom left).

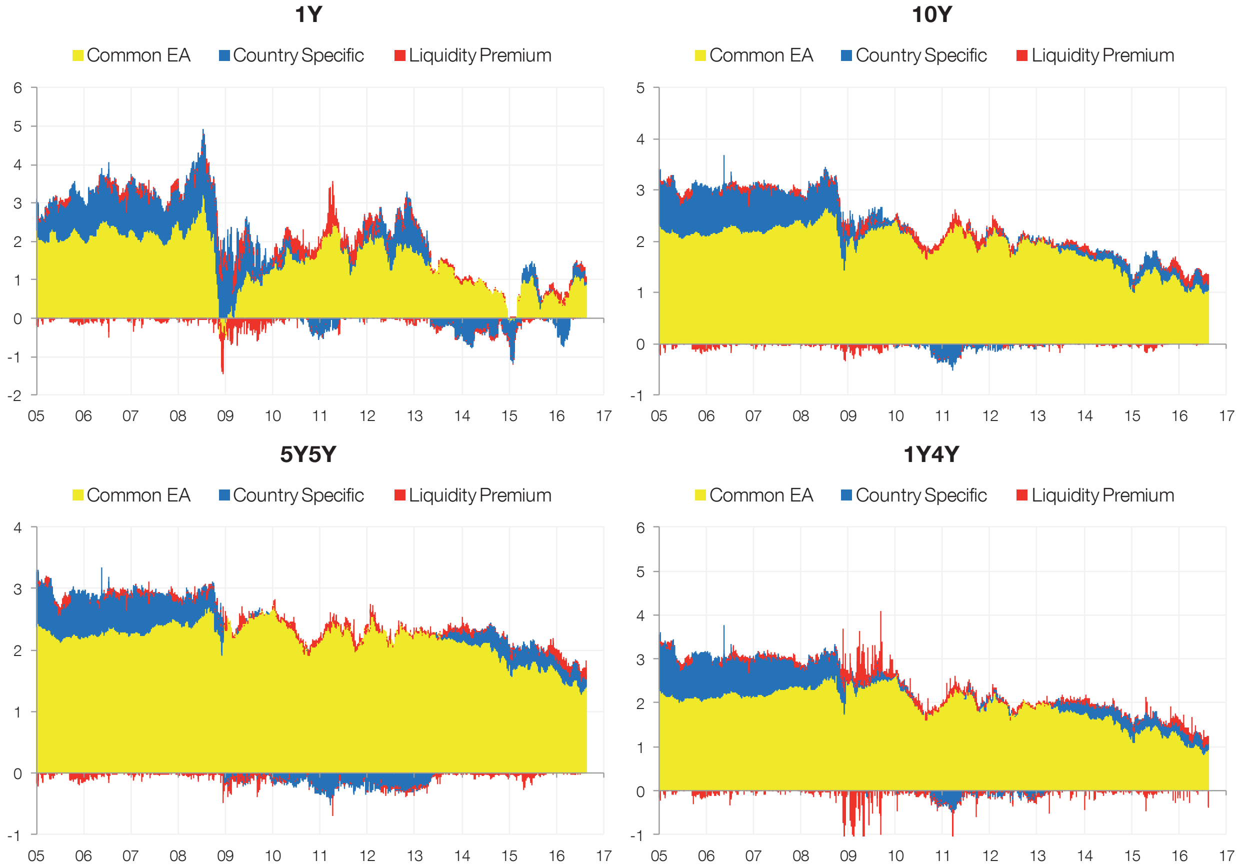


Figure 6. Decomposition of **Italian** Inflation Swaps at 1 year maturity (swap1y, top left); 10 year maturity (top right); 1-year forward 4 years ahead (swap1y4y, bottom right); and 5-year forward 5 years ahead (swap5y5y, bottom left).

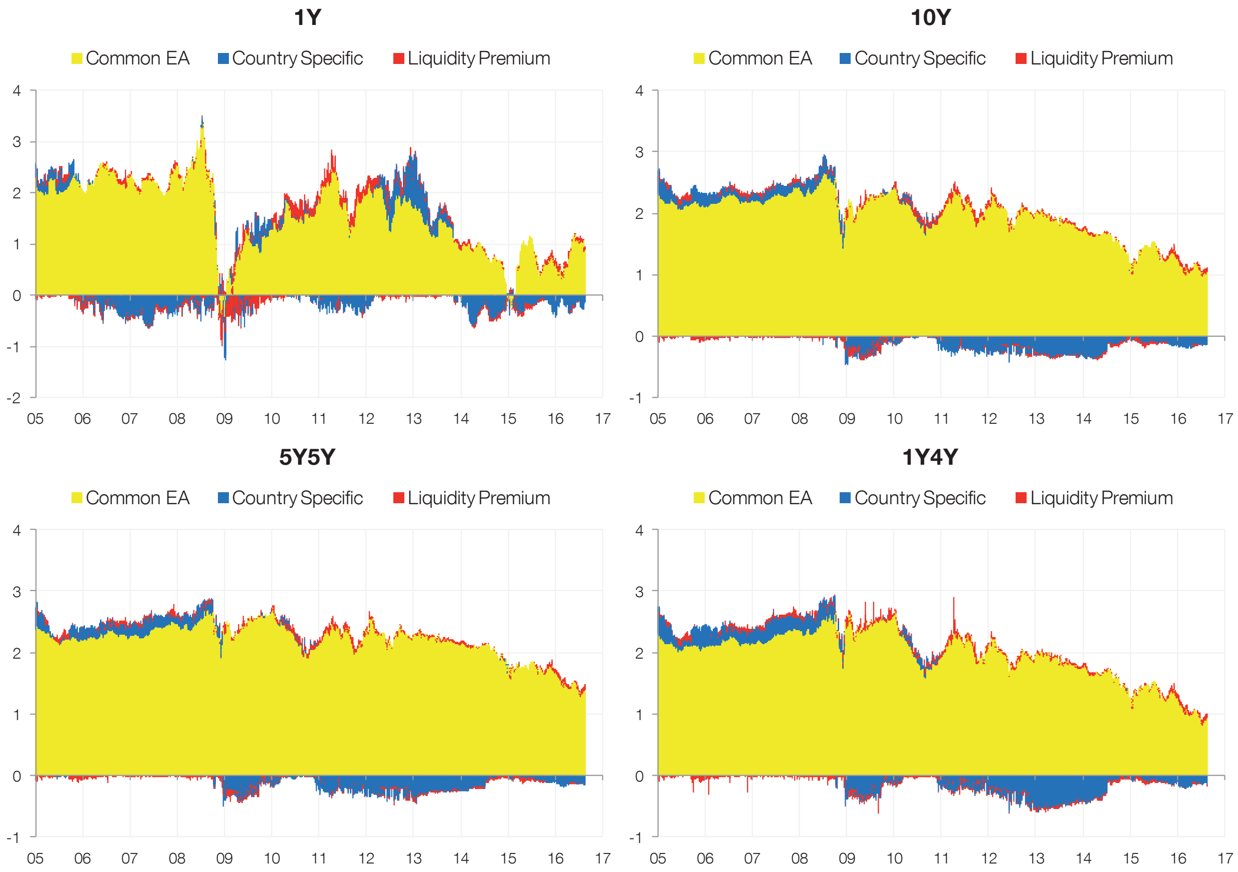


Figure 7. Decomposition of **French** Inflation Swaps at 1 year maturity (swap1y, top left); 10 year maturity (top right); 1-year forward 4 years ahead (swap1y4y, bottom right); and 5-year forward 5 years ahead (swap5y5y, bottom left).

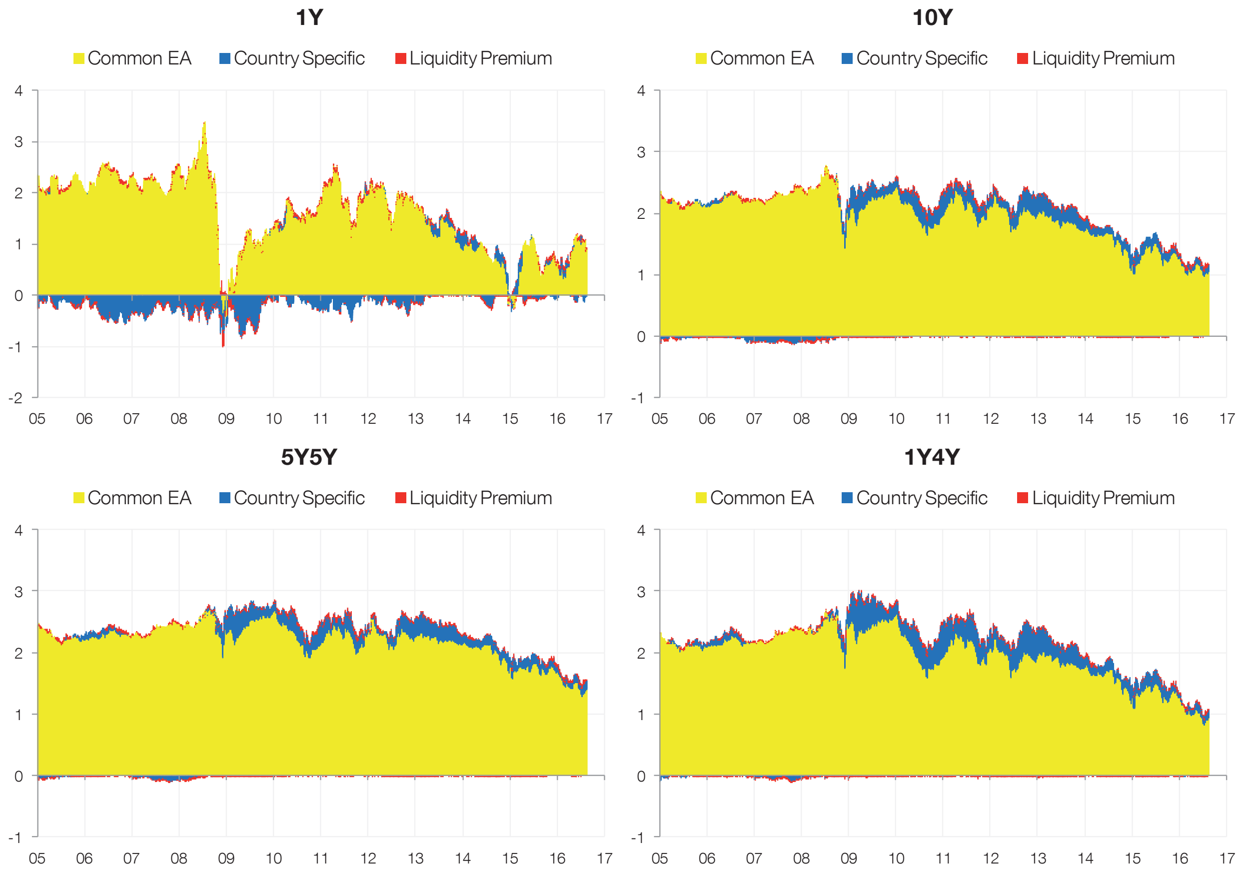
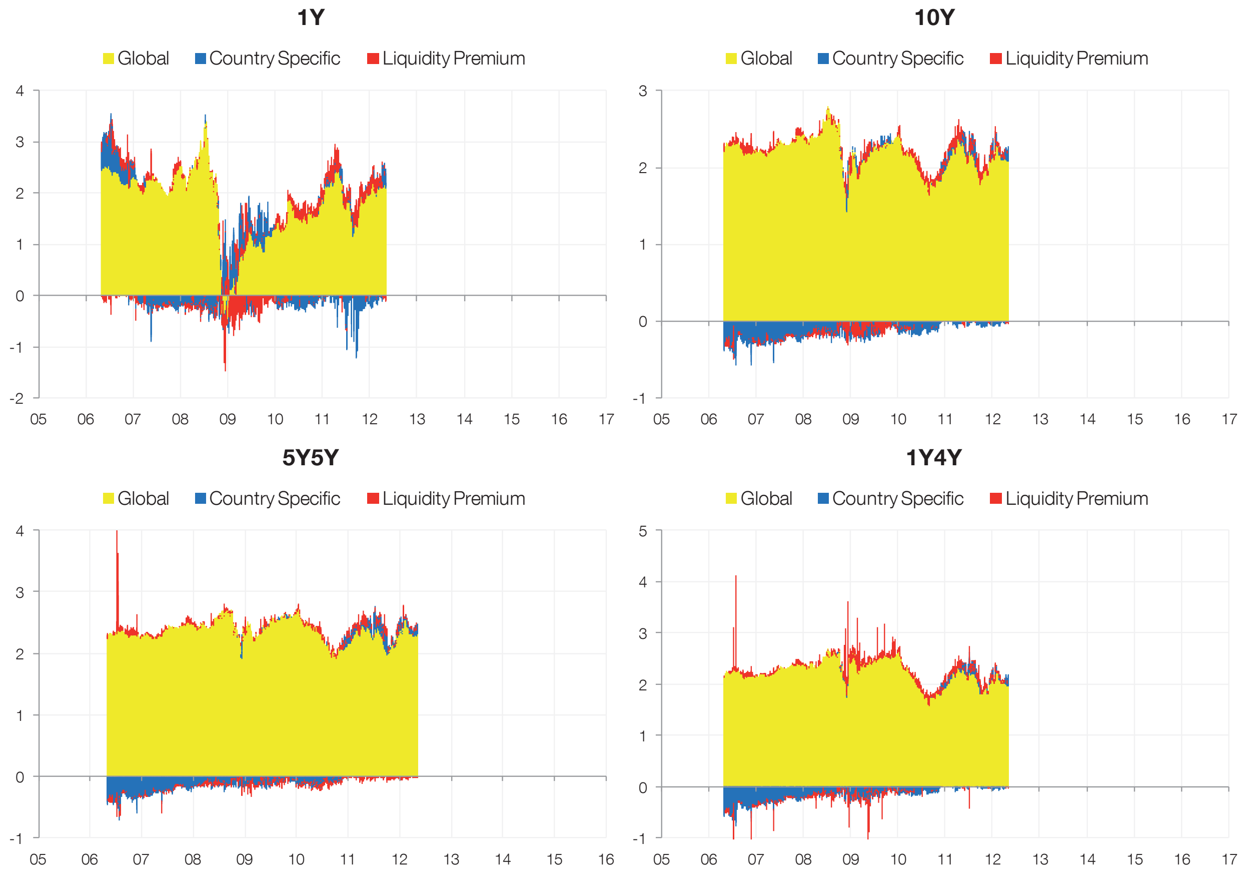


Figure 8. Decomposition of **German** Inflation Swaps at 1 year maturity (swap1y, top left); 10 year maturity (top right); 1-year forward 4 years ahead (swap1y4y, bottom right); and 5-year forward 5 years ahead (swap5y5y, bottom left).



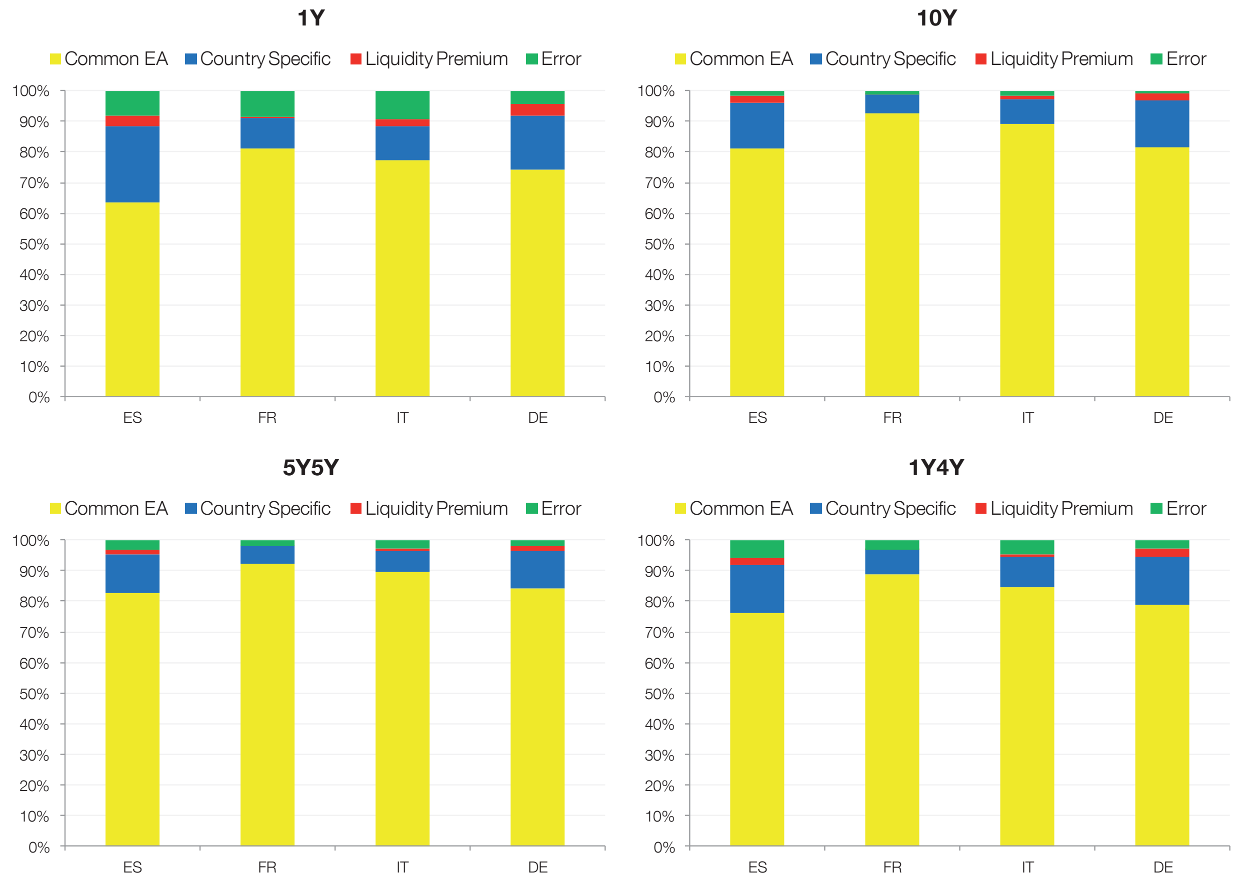
Secondly, there is also a smaller country-specific component whose relative size varies across countries. It is largest in the case of Spain, especially at shorter maturities and during crisis periods. In Italy there is also a sizable positive contribution of the national component in the shortest horizon during the sovereign crisis. However, the longer horizons exhibit a negative sustained contribution of the country specificities into inflation expectations, possibly linked to Italy's long period of stagnation. The same is found in Germany, especially prior to the crisis. While the opposite is found for France: the country-specific contribution to longer term inflation expectations is positive.

Thirdly, liquidity risk is found relatively small and very volatile in all cases, albeit larger at short maturities, and almost inexistent in France. It is worth noting that the estimated risk premium has been negative during the Lehman crisis and the recent low inflation times.

Figure 9 helps summarizing the above results. On average during the sample period, the contribution of the common Euro area component range from 63.5% (Spain) to 81.3% (France) of the 1-year ILS inflation rates, and raises to 81.1% (Spain) and 92.5% (France) of the 10-year ILS inflation rates. In contrast, the the contribution of the country-specific component ranges from 9.9% (France) to 24.8% (Spain) at the 1-year maturity, and from 6.2% (France) to 15.3% (Germany) at the 10-year ILS. Liquidity premium are relative small, higher in the short maturities and smaller in the long ones, with the smallest weight for the French ILS and higher for German and Spanish ones. In the case of the noise, it is higher for the shorter maturities, and representing less than 2% for all cases in the 10 years ILS.

All in all, the model estimates seem to confirm that sizable differences in inflation expectations term structures across Euro area countries may be found at short maturities, while they are similar at the longer horizons.

Figure 9. Contribution of Common EA, Country Specific, Liquidity Premium and estimation error for ILS swaps 1 year maturity (top left); 10 year maturity (top right); 1-year forward 4 years ahead (swap1y4y, bottom right); and 5-year forward 5 years ahead (swap5y5y, bottom left).



4.3 What are the direct monetary policy implications of these results? Has the long run expected inflation remained well anchored across these EMU countries?

The common level estimate of the model (see Figure 4) shows that the common expected very long-run inflation fell around 40 bp in the second half of 2014, stayed at that lower level during most 2015 and resumed its downward movement in late 2015. A very persistent fall in the common component of the level estimates could be associated to a shift in the perceived target of the European Central Bank, and to an increased risk of de-anchoring of long-term inflation expectations. However, this has not been translated into larger or diverging country-specific contributions to the long-run inflation expectations. Indeed, the absence of divergence in the country-specific components of long-term inflation expectations goes against a loss of credibility of the single monetary policy.

In addition, curvature estimates turning negative over time, mainly through their common component, indicate that the convergence of short-term to long-term inflation expectations gets delayed to longer and longer maturities. In 2015-16 the common curvature estimate continued to turn more negative. In a situation of falling inflation expectations, this can be interpreted as an increased persistence of low inflation rather than a fall in the perceived target of the monetary authority.

4.4 Is there an inflation premium in ILS?

As we showed in section 2, ILS have small divergences from CF surveys, and the forecasting accuracy of both are similar, although slightly higher for the CF in the longer horizons. This might be a signal of a small inflation premium, as explored in bond markets by Gürkaynak et al. (2010) for the US and García and Werner (2010) for the Euro area. Thus, we use the model proposed in section 3 to empirically test the presence of sizeable term premia in our data of ILS in the Euro area. In particular, we compare the implied forward rate in the observed data with the model-based forecast. In absence of a term premium, the expected rate should be equivalent to the forward rate (i.e. pure expectations hypothesis. See Fama and Bliss, 1987). In contrast, differences between model-based forecasts and observed forward rates can be mostly associated with a term premium. We have opted for this approach instead of an affine specification as in Gürkaynak et al. (2010) or

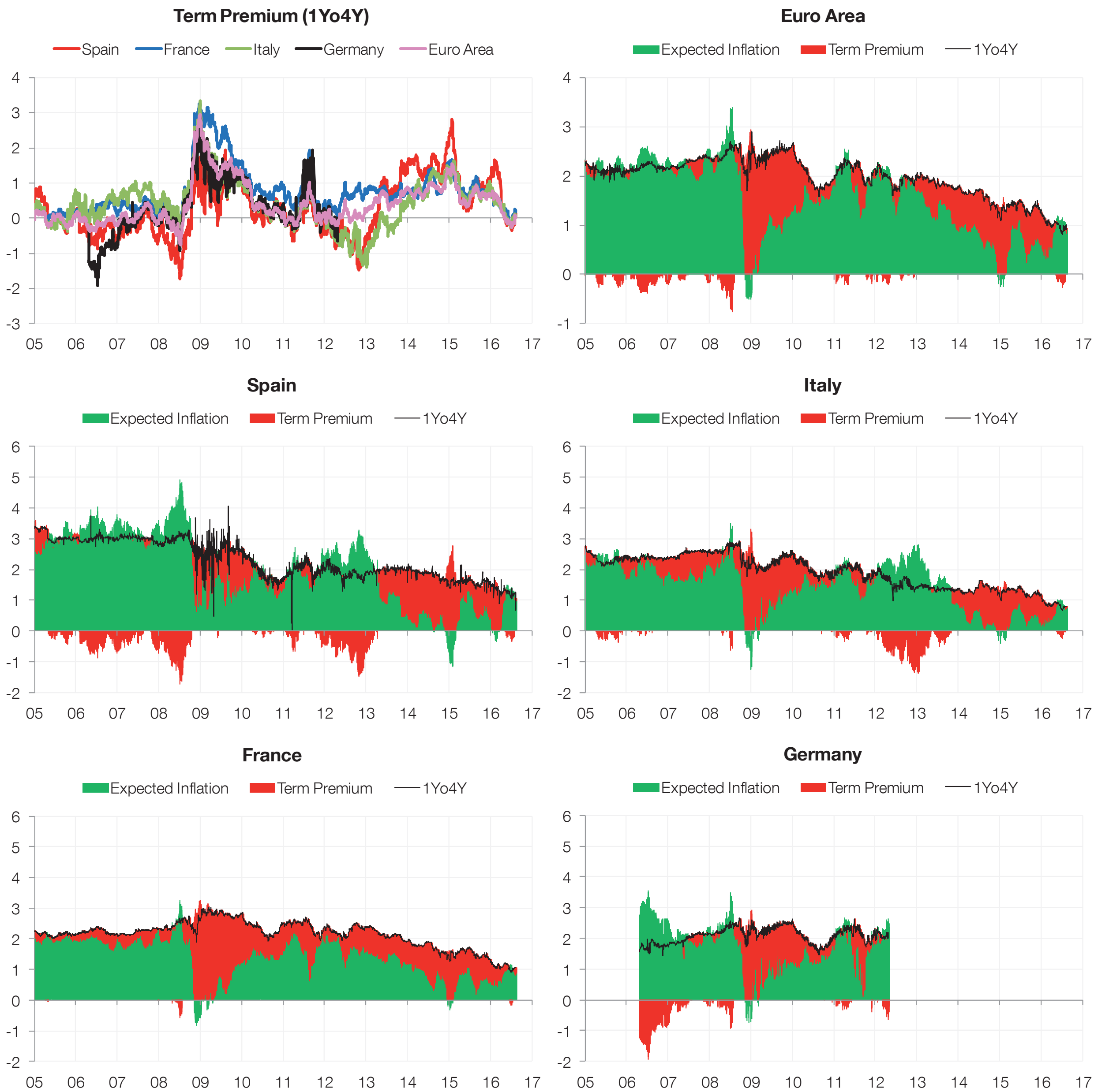
García and Werner (2010), because the no-arbitrage restrictions of those models do not provide additional information on the model for forecasting purposes, at least in the bond market literature (Duffee, 2011; Joslin et al., 2011, 2013).

We compare forward inflation measures at different horizons: 5 years on 5 years (the 5 years forecast of the 5 year inflation), 1 year on 4 years (the 4 years forecast of the 1 year inflation) and 1 year on 9 years (the 9 years forecast of the 1 year inflation); with model forecasts of the following spot measures: 5 year spot rate in 5 years, 1 year spot rate in 4 years, and 1 year spot rate in 9 years. Thus, the term premium is obtained as the difference between the observed forward, and the expected spot rate. As Figure 10 (top left panel) show, the estimated term premium peaked during the Lehman crisis, and to a lesser extent during the sovereign debt crisis, but has been in decline since the beginning of 2015 and would be now close to zero. If we decompose the expectations and term premium component in the 1Yo4Y forward inflation measures for each country (Figure 10), we can observe how in spite of general declining in observed forward inflation measures over the past two years and, coinciding with the ECB's expanded asset purchase programme, actual expectation measures have been increasing for the same period, although this evolution have been quite offset by the drop in the term premium. If we associate an increase in the term premium at the longer maturities with de-anchoring, this evidence would suggest that at least in the mid-term de-anchoring risks have recently decreased substantially in the Euro area.

However, this exercise is based on assuming that the difference between forecast inflation rates and forward inflation rates are due to the term premium and not to prediction errors. In order to asses if differences between both measures are consistent with no term premium (that is, if forward inflation rate are inside forecast confidence intervals), for each day, we have run 10.000 simulations to obtain a full density forecast. Then, for each day we compare the forward rate with the corresponding density forecast.[12] In figure 11, we present the order position of each observed forward inflation measure, compared with the full density forecast from the model. Thus, a 50% value implies that 50% of the forecasts are above the forward rate and 50% are bellow the forward rate. As can be seen, for all countries and forward measures, the forward rates are inside the 95% confidence intervals of the density forecasts; we are not able to reject the hypothesis that the forward rates are

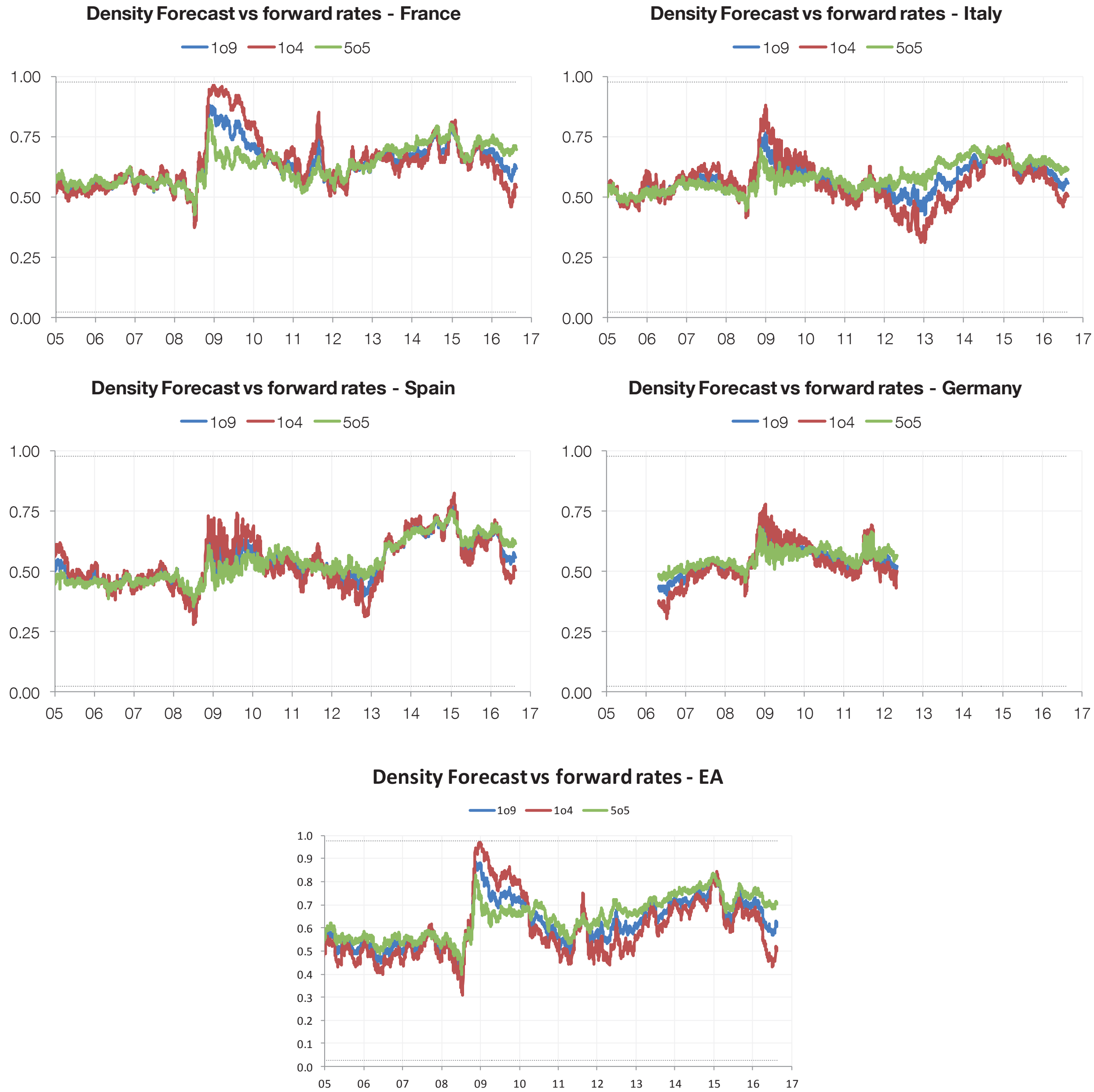
[12] These are in-sample density forecast. Out of sample densities would have implied greater bands, confirming what we observe for the in-sample. Moreover, the purpose of the exercise is not the forecast but to detect the presence of a potential term premium.

Figure 10. Term Premium estimated as the difference between the forward inflation rate (1Yo4Y) and the forecast of the 1Y inflation rate with a horizon of 4 years. Top left panel show the evolution of the Term Premium for the 4 countries and the whole Euro Area. The other panels show the decomposition of the 1Yo4Y forward inflation rate into expected inflation and term premium for the Euro Area (Top right), Spain (Center left), Italy (Center right), France (Bottom left), and Germany (Bottom right).



within the limits of the densities estimated. This means that, in spite of the term premium estimates in Figure 10, there is no clear evidence of sizable bias in the observed forward ILS rates and that, therefore, there doesn't seem to be on average a term premium different from zero in the ILS in the Euro area.

Figure 11. Comparison of the Forward rates (1y9y, blue, 1y4y, red, and 5y5y, green) with the density forecast of the model proposed in section 3. Density forecasts are obtained with 10.000 simulations. The value reported is the proportion of those simulated forecasts that lie below the corresponding observed forward rates.



5 Conclusions

This paper explores the behavior of inflation expectations across countries that share their monetary policy, in particular the European Monetary Union, using market-based data from inflation swaps and comparing them to survey-based information from Consensus Forecasts. Specifically, we are interested in the possible common features at the various horizons, as well as differentials, across Euro area countries.

We are also interested in determining whether the long-run expected inflation has remained well anchored across these countries.

A multi-country dynamic factor model based on Diebold et al. (2008) is developed and estimated using daily data from inflation swaps for Spain, Italy, France, Germany and the Euro area aggregate for a wide range of horizons. The model presented in this paper differs from the one in Diebold et al. (2008) by the number of factors considered (Diebold et al. (2008) do not include a curvature factor) and by the addition of a model-based measure of time-varying liquidity risk premium. The later feature allows us to use a wide range of ILS taking into account their different data quality produced by differences in trading activity.

The model allows to compute the proportion of common vs country-specific components in the term structure of inflation expectations. Sizable differences in inflation expectations across the main Euro area countries are found only at short maturities, and particularly during crisis periods, while in general a common component dominates across countries at all maturities and throughout the years. Liquidity risk is relatively small and very volatile, taking negative values during the Lehman crisis and the recent low inflation period.

More recently, the common long-run level of inflation expectations is estimated to have fallen (since mid-2014) while a common movement of increased persistence of lower expected inflation and for longer is identified since 2012. In a situation of falling inflation expectations, this can be interpreted as an increased persistence of low inflation rather than a clear sign of a fall in the perceived target of the monetary authority.

We have found that in the last two years (2015-2016) and in the mid-term horizon the decline in forward inflation rates in all countries considered, as well as the Euro area as a whole, can be related to a decline in the term premium that has almost disappeared by now. However, from our analysis, it is not clear that we can reject the hypothesis that the term premium is equal to zero in inflation swaps, since differences between forward and forecast measures are well inside forecast confidence intervals. Further research on the issue is in our agenda.

References

Abbritti, M., Dell'Erba, S., Moreno, A., and Sola, S. (2013). Global factors in the term structure of interest rates. *IMF Working Paper*, 223.

Amihud, Y. and Mendelson, H. (1986). Asset pricing and the bid-ask spread. *Journal of financial Economics*, 17(2):223–249.

Amihud, Y. and Mendelson, H. (1991). Liquidity, maturity, and the yields on us treasury securities. *The Journal of Finance*, 46(4):1411–1425.

Berenguer, E., Gimeno, R., and Nave, J. M. (2014). Term structure estimation, liquidity-induced heteroskedasticity and the price of liquidity risk. *Banco de España Working Paper*, 1308.

Coroneo, L. (2015). Tips liquidity premium and quantitative easing. University of York, mimeo.

Diebold, F. X. and Li, C. (2006). Forecasting the term structure of government bond yields. *Journal of econometrics*, 130(2):337–364.

Diebold, F. X., Li, C., and Yue, V. Z. (2008). Global yield curve dynamics and interactions: a dynamic nelson–siegel approach. *Journal of Econometrics*, 146(2):351–363.

Diebold, F. X., Rudebusch, G. D., and Aruoba, S. B. (2006). The macroeconomy and the yield curve: a dynamic latent factor approach. *Journal of Econometrics*, 131(1–2):309–338.

Duffee, G. (2011). Forecasting with the term structure: The role of no-arbitrage restrictions. *John Hopkins University Working Paper*, 576.

Fama, E. F. and Bliss, R. R. (1987). The information in long-maturity forward rates. *The American Economic Review*, 77(4):680–692.

García, J. A. and Werner, T. (2010). Inflation risks and inflation risk premia. *ECB Working Paper*, 1162.

Gimeno, R. and Nave, J. M. (2009). A genetic algorithm estimation of the term structure of interest rates. *Computational Statistics & Data Analysis*, 53(6):2236–2250.

Gürkaynak, R. S., Sack, B., and Wright, J. H. (2010). The tips yield curve and inflation compensation. *American Economic Journal: Macroeconomics*, 2(1):70–92.

Joslin, S., Le, A., and Singleton, K. J. (2013). Why gaussian macro-finance term structure models are (nearly) unconstrained factor-vars. *Journal of Financial Economics*, 109(3):604–622.

Joslin, S., Singleton, K. J., and Zhu, H. (2011). A new perspective on gaussian dynamic term structure models. *Review of Financial Studies*, 24(3):926–970.

Nelson, C. R. and Siegel, A. F. (1987). Parsimonious modeling of yield curves. *Journal of Business*, 60(4):473–489.

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