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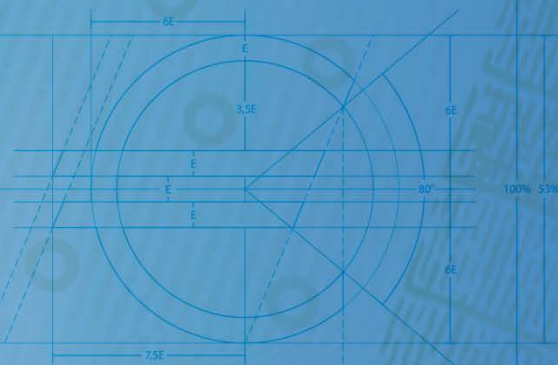
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International spillovers in
inflation expectations

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Abstract

This paper investigates the factors behind developments in inflation expectations in euro area, the U.S. and the U.K. over the sample 2005-2015. Our analysis unveils the presence of a quantitatively important spillover from euro area long-term inflation expectations onto international ones, in particular the U.S., since August 2014. This finding has some important implications. From a policy perspective, it contributes to explain the somewhat puzzling declines in financial indicators of inflation expectations since the autumn 2014 (Yellen, 2015). From a research perspective, our findings suggest that the relatively weak performance of term-structure models (and other econometric models) to explain developments in long-term inflation expectations in major economic areas over 2014-15 may be due to the omission of international factors. These two dimensions may well carry a significant weight on the ongoing and future debate on monetary policy normalisation in major central banks.

Keywords: Inflation expectations, Global inflation, International spillovers, deflation
JEL Classification: C11, C52, E31

Non-technical summary

Long-term inflation expectations are a key element in modern monetary policymaking, and developments in private sector's inflation expectations are nowadays closely monitored by policymakers and researchers. Among the wide variety of indicators of inflation expectations currently monitored by central banks, financial market indicators have gained significant prominence over the last decade.

It is therefore not surprising that the significant declines of financial market indicators of long-term inflation expectations in major economic areas since August 2014 have attracted substantial attention among policymakers and international institutions, as well as in specialised press and market commentary. While the fluctuations of oil and commodity prices can account for a large part of the decline in global inflation readings and short-term inflation expectations, the extent to which the lower oil prices, even if persistent, should exert such a strong influence in long-term inflation expectations is far less clear. Moreover, very different positions in business cycles and monetary policy stance have not prevented long-term inflation expectations measures to experience similar declines across economic areas: between August 2014 and early 2015 the five-year forward in five years, the most widely used indicator of long-term inflation expectations among central banks, fell by around 50 basis points both in the euro area and in the United States.

The purpose of this paper is to provide quantitative evidence on the importance of common (international) and area-specific (domestic) factors behind developments in global long-term inflation expectations, as well as on possible spillovers of domestic shocks among euro area, US and UK long-term inflation expectations. We use a standard Factor Structure VAR model for long-term inflation expectations to identify common and idiosyncratic shocks in the three economic areas. Then we investigate the extent to which the idiosyncratic shocks in each area are transmitted to the international inflation markets.

Our main finding is the presence of a quantitatively important spillover effect from euro area long-term inflation expectations to other major markets, notably to the US. Such a spillover seems to be crucial to explain the decline in US long-term inflation expectations since the summer of 2014, and, by correcting the model fitting errors, contribute to explain the puzzling weak performance of standard term structure models regularly employed by the Federal Reserve. We show that such asymmetric spillovers are not related to the specific use of forward IL swap rates as measure of long-term inflation expectations, for they are specific to long-term inflation expectations and cannot be found in inflation expectations at shorter horizons (i.e. 1-year forward ILS rate in one year). Moreover, they are not present either in actual inflation developments, or in the nominal yields at short and longer horizons, where the spillovers, if any, are symmetric.

The pricing in of euro area long-term inflation expectations in other areas can be rationalised by the significant deterioration in the euro area inflation outlook since mid-2014. For example, the forward inflation curve suggested that the expected length of inflation below the ECB's 2% target, rose from 7 to above 13 years between mid-2014 and January 2015, well beyond anything attributable to the influence of standard business cycle or commodity price fluctuations.

Beyond providing further support for the implementation of the additional unconventional policy measures in the euro area in 2015, our main findings may also have important policy implications outside the euro area. Indeed, to the extent that the recovery of inflation back to

levels consistent with price stability and also economic activity in the euro area is likely to be rather slow, accounting for spillovers onto global inflation and inflation expectations may be crucial to understand long-term inflation expectations in major economic areas, at least in a near future. Our results should therefore help to better interpret developments in global inflation expectations by complementing standard policy input from term structure models, and signal the inflation expectations channel as a potential source of international spillovers from the ECB's Quantitative Easing measures, two dimensions that may well carry a significant weight on the on-going and future debate on monetary policy normalisation in major central banks.

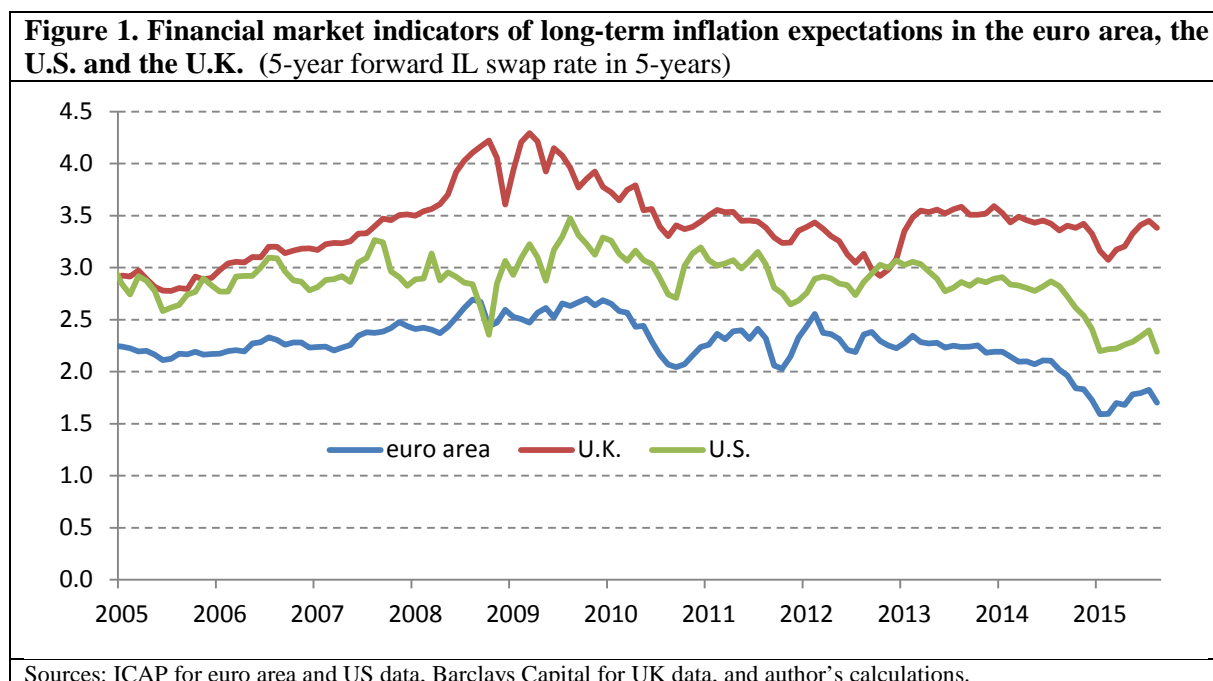
1. Introduction

Long-term inflation expectations are a key element in modern monetary policymaking. First of all, with monetary policy aimed at delivering low and stable inflation rates, the consistency of private sector's inflation expectations with such an objective at medium-to-long horizons provides a direct assessment of the credibility of monetary policy. Furthermore, in a global environment of very low inflation, particularly in developed economies, stable levels of long-term inflation expectations are crucial to bring inflation back to levels that avoid recurrent deflation fears, which have become particularly relevant after the financial crisis.

Developments in private sector's inflation expectations are therefore closely monitored by policymakers and researchers alike. Among the wide variety of measures of inflation expectations currently monitored by central banks, financial market indicators have gained significant prominence over the more traditional survey measures. Indeed, the significant deepening of markets for inflation-linked instruments worldwide over the last decade has significantly contributed to the relevance of financial indicators as fundamental source of information on inflation expectations for central banks, researchers and specialised media.

Against this background, the significant declines of financial market indicators of long-term inflation expectations in major economic areas since August 2014 have attracted substantial attention among policymakers and international institutions (Draghi, 2015; Yellen, 2015), as well as in specialised press and market commentary (e.g. *The Economist*, 2014; Morgan Stanley, 2015). A sound explanation of the key factors behind those declines remains elusive. First, while the fluctuations of oil and commodity prices can account for a large part of the decline in global inflation readings and short-term inflation expectations, the extent to which the lower oil prices, even if persistent, should exert such a strong influence in long-term inflation expectations is far less clear. Second, the decline in long-term inflation expectations was widespread across economic areas despite very different positions in business cycles and monetary policy stance: between August 2014 and early 2015 the five-year forward in five years, the most widely used indicator of long-term inflation expectations among central banks, fell by around 50 basis points both in the euro area and in the United States. In this context, understanding the factors behind recent developments in the movements of long-term inflation expectations is crucial from a monetary policy perspective.

Figure 1 plots long-term forward inflation-linked swap rates in the euro area, the U.S. and the U.K. since 2005. From a historical perspective, a great deal of commonality is clearly observed in the three series, supporting the existence of some common global factors. However, some heterogeneity in the magnitude of the reactions to particular some events – for example in the aftermath of the collapse of Lehman Brothers – and some idiosyncratic movements are also visible in the chart, which points to additional forces behind developments in global long-term inflation expectations.



Focusing on the last period, the decline in long-term forward rates between August 2014 and early 2015 is common to the three economic areas. Yet, these declines have been similar in timing and size in the euro area and the US, while in the UK they started somewhat later, and, consequently, have been more muted. In addition, comparing the current levels of long-term forward IL rates to their historical averages, the current declines in the euro area seem to reflect quite a significant episode and bring the level to historical lows. For the US the situation also appears somewhat worrying, with very low levels by historical standards since the second half of 2014. Moreover, the situation in those two economic areas seems to have deteriorated further over the summer of 2015, with renewed disinflationary concerns resurfacing in the global economy. Finally, for the UK it looks more like a relatively standard period of temporary lower long-term inflation expectations.

The purpose of this paper is to provide quantitative evidence on the importance of common (international) and area-specific (domestic) factors behind developments in global long-term

inflation expectations, as well as on possible spillovers of domestic shocks among euro area, US and UK long-term inflation expectations. We use a standard Factor Structure VAR model for long-term inflation expectations to identify common and idiosyncratic shocks in the three economic areas. Then we investigate the extent to which the idiosyncratic shocks in each area are transmitted to the international inflation markets by means of forecast error variance decompositions along the lines proposed by Stock and Watson (2005) for the study of international business cycles.

Our analysis unveils some surprising forces at work behind developments in global inflation expectations. Our main finding is the presence of a quantitatively important spillover from euro area long-term inflation expectations to other major markets, notably to the US. Such a spillover seems to be crucial to explain the decline in US long-term inflation expectations since the summer of 2014, and, by correcting the model fitting errors, contribute to explain the puzzling weaker performance of standard term structure models regularly employed by the Federal Reserve (Federal Reserve, 2015). The results nonetheless confirm the presence of strong common factors in long-term inflation expectations, possibly capturing the long-term trends in global inflation as documented for example by Ciccarelli and Mojon (2010).

We show that such asymmetric spillovers are not related to the specific use of forward IL swap rates as measure of long-term inflation expectations, for they are specific to long-term inflation expectations and cannot be found in inflation expectations at shorter horizons (i.e. 1-year forward ILS rate in one year). Moreover, they are not present either in actual inflation developments, or in the nominal yields at short and longer horizons, where the spillovers, if any, are symmetric. In addition, another important characteristic of the spillovers from the euro area to the US is that their relative importance is higher at longer forecast horizons, which suggests that these spillovers capture quite persistent influences.

The pricing of euro area long-term inflation expectations can be rationalised by the significant deterioration in the euro area inflation outlook since mid-2014. For example, the forward inflation curve suggested that the expected length of inflation below the ECB's 2% target, rose from 7 to above 13 years between mid-2014 and January 2015, well beyond anything attributable to the influence of standard business cycle or commodity price fluctuations.

Beyond providing further support for the implementation of the additional unconventional policy measures in the euro area in 2015, our main findings may also have important policy

implications outside the euro area. Indeed, to the extent that the recovery of inflation back to levels consistent with price stability and also economic activity in the euro area is likely to be rather slow, accounting for spillovers onto global inflation and inflation expectations may be crucial to understand long-term inflation expectations in major economic areas, at least in a near future. Our results should therefore help to better interpret developments in global inflation expectations by complementing standard policy input from term structure models, and signal the inflation expectations channel as a potential source of international spillovers from the ECB's Quantitative Easing measures, two dimensions that may well carry a significant weight on the on-going and future debate on monetary policy normalisation in major central banks.

The rest of the paper is organized as follows. Section 2 describes the measures of inflation expectations and the empirical methodology used in this paper. Section 3 reports the decomposition of developments in long-term inflation expectations into common, area-specific, and spillover, and highlights the time-varying nature of these factors. Section 4 offers several robustness checks, corroborating that the spillover from euro area expectations is confined to the medium-to-long-term horizons and is not present in actual inflation, short-term inflation expectations or long-term nominal yields. As rationale behind the pricing of euro area medium-to-long term inflation expectations in international inflation markets, Section 5 reports the significant deterioration of the inflation outlook in the euro area in the second half of 2014. Section 6 discusses the implications of our findings for policy and research. Section 7 concludes.

2. Data and methodology

This section briefly describes the data and the empirical methodology employed in this paper to understand the evolution of long-term inflation expectations.

2.1 Measuring long-term inflation expectations

The analysis of indicators of private sector's inflation expectations is crucial for modern monetary policymaking. In this regard, the significant development of markets for inflation-linked products worldwide has provided researchers in general and central banks in particular with a very valuable and alternative source of information to the more traditional survey data.

Financial indicators of inflation expectations offer two key advantages over survey measures: they are available at a much higher frequency and over a larger number of horizons. Nowadays readings of inflation expectations are available at trading frequency via the *break-*

even inflation rates (BEIRs henceforth) either computed through the yield spread between nominal and inflation-linked (IL) bonds or from the strongly growing IL swap markets. This higher frequency of observation, as we will show below, is crucial to identify movements in inflation expectations when they occur, changes that may only be seen after a while in survey data due to their lower frequency of collection. In addition, financial instruments allow for collecting readings of inflation expectations over a large number of horizons, both at short and long-term maturities, which allow for monitoring developments in inflation expectations at more horizons than survey indicators, and therefore identify the horizons at which relevant changes take place.

The higher frequency and large number of horizons over which financial indicators of inflation expectations are available, two dimensions crucial for monetary policy making, explain why they have gained a strong prominence in recent years. Indeed, references to market indicators of inflation expectations in central bank publications and speeches (e.g. Draghi, 2014; Yellen, 2015), research on the anchoring of inflation expectations (e.g. Gürkaynak et al. 2010; Beechey et al., 2011), and regular market commentary and analysis (e.g. Wall Street Journal, 2010) are increasingly common.

It is however important to bear in mind that standard indicators of inflation expectations extracted from financial instruments – IL swap rates or bond-based BEIRs – should be better interpreted as measures of *inflation compensation* rather than simple measures of inflation expectations, for they do incorporate a premium component that compensates investors not only for the expected level of inflation over the horizon of the contract but also for the uncertainty and risks surrounding the level of future inflation. To the extent that fluctuations in the inflation risk premia are also very relevant for monetary policy (see FOMC minutes, 2015), the analysis of financial indicators of inflation expectations offers additional insights beyond the level of long-term inflation expectations. Bearing in mind this caveat, in what follows we will refer to the forward IL swap rates as measures of *inflation expectation* more than use the somewhat less common term *inflation compensation*.

In this paper we focus on inflation-linked swap rates. An inflation swap is a financial instrument that specifies the payment of a fixed inflation rate, the fixed leg of the swap, versus a floating (or realised) cumulative inflation rate over the period specified in the contract. The fixed-leg makes a fixed payment indexed by the rate agreed at the initiation of the swap agreement. In an efficient market, the fixed-rate payment thus measures the

expected inflation rate over the life of the swap, and therefore IL swap rates can be naturally used to hedge against a rise in inflation. ILSs are actively traded for a wide range of maturities, from 1 to 30 years ahead, since early 2004. The most popular form of ILS contract is the zero-coupon, in which there is a unique exchange of cash at the maturity of the contract, and those are the ILS we use here. Specifically we use the five-year forward IL swap rates in five year (ILS5y5y) as our benchmark measure of long-term inflation expectations, an indicator that is regularly reported by most central banks and specialised market commentary.

The choice of IL swap rates over bond-based BEIRs is based on three main considerations. First, IL swap rates are less contaminated by the fluctuations in the liquidity premium of inflation-linked bonds yields compared to their nominal counterparts. This liquidity premium has been significant since the start of the financial turbulences of 2007-08 (e.g. Campbell, Schiller and Viceira, 2009, Pflueger and Viceira, 2011) and, in the case of the euro area, has been exacerbated by the sovereign crisis. Second, we insulate the changes in US inflation expectations from the effects of the direct purchase of nominal treasuries and TIPS under the Federal Reserve's LSAP programmes. Finally, the most traded IL swap rates in the three economic areas under study are direct zero-coupon swaps. Their use therefore which allows us to abstract from the estimation of the zero-coupon BEIRs, which is not so trivial as for example indicated by the fact that is currently implemented in the three central banks using different methodologies.

Table 1 provides some descriptive statistics of long-term inflation expectations in the three economic areas over our full sample (see also Figure 1) and over certain specific subsamples covering the pre-crisis period, the crisis period since the collapse of Lehman Brothers to end-2013, and the developments since 2014 on which this paper focuses.

The statistics reported in Table 1 help highlight the economic relevance of developments in long-term inflation expectations since the beginning of 2014. First, the declines in long-term inflation expectations in the second half of 2014 led to significantly lower average levels in the euro area and the U.S., even taking into account their (temporary) rebound over the spring of 2015. To put such developments in perspective, euro area long-term inflation expectations were on average 40 basis points (35 basis points in the U.S.) lower than the average since 2005, leading to some of the lowest levels ever observed for those indicators.

The volatility in long-term inflation expectations was nonetheless lower since 2014 than historical averages since 2005, and also in pre- and financial crisis periods, in the euro area and the U.K. Instead, the volatility of long-term inflation expectations rose in the U.S. market since early 2014, which point to some special factors affecting U.S. long-term inflation expectations, particularly since mid-2014. Indeed, barring the aftermath of Lehman’s collapse in the autumn of 2008, changes of that magnitude in the level and volatility of long-term inflation expectations were not observed over the crisis compared to the pre-crisis period, and despite the implementation of a series of unprecedented unconventional monetary policy measures at the time.

Table 1: Summary statistics of long-term infalction expectations in the euro area, the U.S. and the U.K.

	Central moments: different periods												Autocorrelation						
	2005M1-2015M1				2005M1-2008M8				2009M1-2013M12				2014M1-2015M7				Full-sample		
	Mean	Std	Skew	Kurt	Mean	Std	Skew	Kurt	Mean	Std	Skew	Kurt	Mean	Std	Skew	Kurt	Lag 1	Lag 2	Lag 3
Long-term inflation expectations																			
euro area	2.30	0.20	-0.29	1.07	2.30	0.13	1.07	1.04	2.35	0.18	0.29	-0.70	1.90	0.20	-0.11	-1.44	0.93	0.83	0.74
United Kingdom	3.42	0.35	0.41	0.00	3.22	0.33	0.83	0.41	3.53	0.31	0.50	0.23	3.36	0.12	-1.10	0.32	0.96	0.90	0.86
United States	2.92	0.20	-0.32	1.51	2.89	0.14	0.47	0.98	2.99	0.18	0.25	-0.20	2.57	0.26	-0.21	-1.77	0.80	0.56	0.39

Note: table statistics refer to the monthly data over the period 2005M1-2015M6 and over different periods to highlight the evolution of long-term inflation expectations in the three economic areas. Long-term inflation expectations (inflation compensation) are measured by long-term forward rates (five-year forward in five years) calculated from zero-coupon inflation-linked swap rates.

The statistics for U.K. long-term inflation expectations in contrast reveal that their declines were milder than in the other two economic areas, and do not appear to be clearly different from the pre-crisis and crisis statistics. This somewhat different pattern of long-term inflation expectations in the U.K. seems to be related to specific forces at work in that inflation market. Specifically, market intelligence points to sustained demand for inflation protection at long maturities in the UK IL swap market by a strong pension fund sector, even towards the end of our sample period. Since low inflation readings were diminishing demand for inflation protection in global markets, this institutional feature of the UK market may contribute to explain the later and more muted decline in UK long-term inflation expectations (see Domit et al, 2015, for a detailed discussion).

2.2 A Factor Structure VAR for international inflation expectations

Our empirical approach is based on a standard VAR framework that (i) models simultaneously the three countries measures of long-term inflation expectations (i.e. the IL swap 5y5y), and (ii) where the shocks are identified imposing a factor structure on the reduced-form errors.

Let y_t be the vector of monthly measures of inflation expectations and α a vector of constant terms and X_t comprises a vector of exogenous variables (oil prices and commodity price index) for which we wish to control in our analysis of inflation expectations. The reduced form VAR can then be expressed as

$$y_t = \alpha + A(L)y_{t-1} + B(L)X_t + \varepsilon_t \quad (1)$$

where the reduced-form shocks are assumed to have the following structure:

$$\varepsilon_t = \Gamma f_t + v_t \quad (2)$$

Here f_t is a $r \times 1$ vector of common international factors, where r is the number of common factors (≤ 2), Γ is a $3 \times r$ matrix of factor loadings, and v_t is a vector of country specific shocks. We assume that both f_t and v_t are white noises and that Σ_f and Σ_v are diagonal matrices.

Given the specification in (1)-(2), the common international shocks are identified as those shocks that affect inflation expectations contemporaneously in the three countries. Country-specific shocks can then lead to spillovers which are assumed to happen with at least a one-month lag. Since the country-specific and the common shocks are uncorrelated by assumption, this simple model has the desired feature of permitting a decomposition of the variances of the h-step-ahead forecast error for inflation expectation in a given country into three sources: unexpected common shocks, unexpected domestic shocks, and spillover effects of unforeseen domestic shocks to other countries.

As stressed in Stock and Watson (2005), the definition of what constitutes a common shock depends on the frequency of the data. For example, a shock that starts in one country but spills over into other financial markets within days would be identified in our monthly model as a global shock. Also, an international shock that affects one country first and the others only after one month or more would be misclassified by the model as an idiosyncratic shock, transmitted via spillovers.

We choose to conduct our baseline analysis at monthly frequency for several reasons. First, the underlying fundamental behind the financial instruments used to trade inflation expectations is the year-on-year inflation rate, which is released at monthly frequency. Since we are interested in identifying macroeconomic shocks affecting long-term inflation expectations, the monthly frequency therefore matches the news flow on inflation across the three economic areas. Second, the monthly frequency is also broadly consistent with the

central bank decision process, one of the most important drivers of long-term inflation expectations. Finally, as for any financial instrument, market conditions are likely to influence the pricing of IL swap rates over shorter periods of time. For example, a pricing distortion arising from market imbalances in the inflation market in a given day may well take several days to disappear, particularly over our sample including the crisis period. Although our IL swap rates are available at daily (and even intra-day) frequency, using monthly data allows for attenuating the high frequency volatility due to pure financial distortions and therefore make our results focus on shocks of a mainly a macroeconomic nature.

The model (1)-(2) is estimated using standard maximum likelihood methods over the sample 2005M1-2015M1. The VAR lag length is optimally chosen using a Schwarz's Bayesian Criterion. For the number of common factors we investigated different specifications using 1 and 2 factors, normalising accordingly the matrix Γ of factor loadings. While some formal tests for the number of factors (e.g. Bai and Ng, 2003) can be used to determine the optimal number of factors to summarise the information content of some data series in statistical terms, in our case the number of common factors appears to be more determined by economic considerations. In particular, in our benchmark specification with 2 factors, one seems to capture standard common movements in inflation expectations across economic areas while the second seems to be more related to the pricing of IL swap rates, possibly global trends in supply/demand imbalances on inflation protection that are common in all IL swap markets. That interpretation is based on the fact that, despite capturing common forces across markets, the second factor loadings are particularly strong for the U.K. market, with a much more muted impact on U.S. and the euro area. This result reflects that there were indeed some specific forces at play in the U.K. IL swap market in the second half of 2014, whose impact is clearly visible in Figure 1 (see Domit et al, 2015, for a detailed discussion).¹ Finally, to account for a potential drift in the parameters governing the dynamics of long-term inflation expectations, we will also estimate the model by means of rolling regressions with a 48-month window.

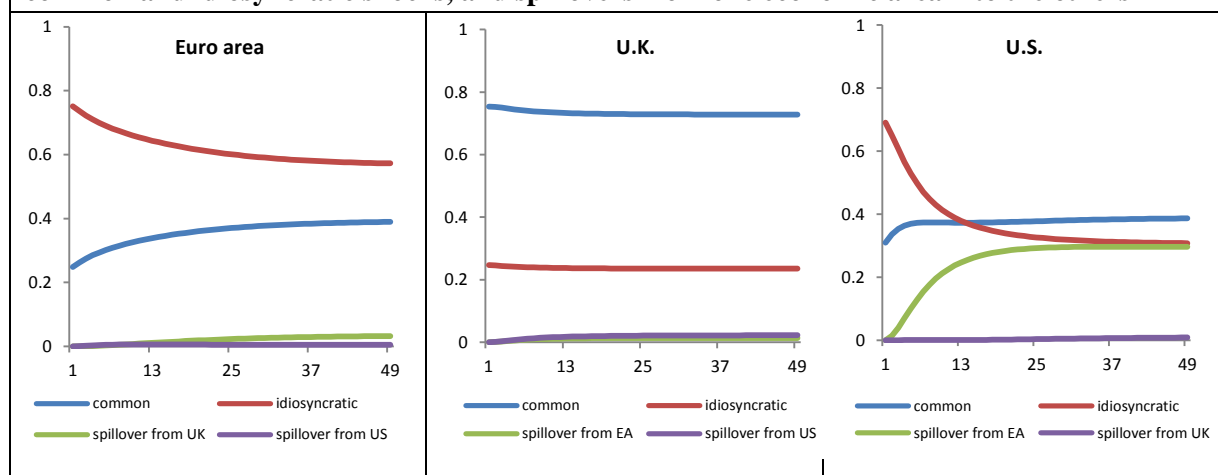
¹ Market intelligence points to sustained demand for inflation protection at long maturities, even towards the end of our sample period, in the UK IL swap market by a strong pension fund sector. Since low inflation readings were diminishing demand for inflation protection in global markets, this institutional feature of the UK market may contribute to explain the later and more muted decline in UK long-term inflation expectations.

3. Driving factors behind long-term inflation expectations

Our baseline version of the SVAR model (1)-(2) is estimated with one lag and two common factors. Other model specifications are however discussed in the next section. Figure 2 plots the variance decompositions over the full sample 2005M1-2015M1. Note that, as direct consequence of our identification approach for contemporaneous common and idiosyncratic shocks, international spillovers arising from the country-specific shocks by construction account for none of the inflation expectation forecast error variance on the current month.

The charts provide evidence of quite clear differences in the structural driving forces behind long-term inflation expectations among the three economic areas. In the euro area the volatility of long-term inflation expectations is explained by idiosyncratic (above 60%) and common shocks (almost 40%), while there is no role for international spillovers from the idiosyncratic shocks of the other two economic areas. The contribution of idiosyncratic shocks decreases and it is gradually matched by that of common shocks, but overall the contribution of the three types of shocks is relatively stable across forecast horizons.

Figure 2: Forecast error variance decompositions : percentage of variance explained by common and idiosyncratic shocks, and spillovers from one economic area into the others



Notes: The figure shows the decomposition of the forecast variance of international long-term inflation expectations based on three types of structural shocks, namely common, idiosyncratic and spillovers from one economic area onto the others. Long-term inflation expectations are measured by five-year forward IL swap rates in five years.

As regards U.K. inflation expectations, common shocks explain the bulk of the variation (above 70%) with a less relevant role for idiosyncratic shocks (around 25%). As in the case of the euro area, spillover effects from other areas however seems to play a very minor role in explaining the variation in U.K. long-term inflation expectations. As discussed above, the very strong role of common shocks in the U.K. stems from the disproportionate loadings of

the second common factor (i.e. global demand for inflation protection) compared to the other two economic areas, which appears to be related to special institutional features in the U.K. inflation market.

The factors behind U.S. long-term inflation expectations are quite different qualitative and quantitatively to the other two economic areas. Idiosyncratic (own), shocks explain the bulk of the variance of long-term inflation expectations at short horizons. Their importance however declines as the horizon increases, and other shocks gain quantitative importance gradually. Specifically, the contribution of common shocks explains a similar amount of the total variation as in the euro area (around 40%), while the main difference concerns the role of international spillovers. In the case of U.S. inflation expectations, the contribution from spillover effects increases across horizon, gradually compensating for the decreasing explanatory power of idiosyncratic shocks and reaching around 30% for horizons beyond 12 months. And, even more importantly, the origin of the international spillovers for the U.S. is the euro area, and not the U.K.

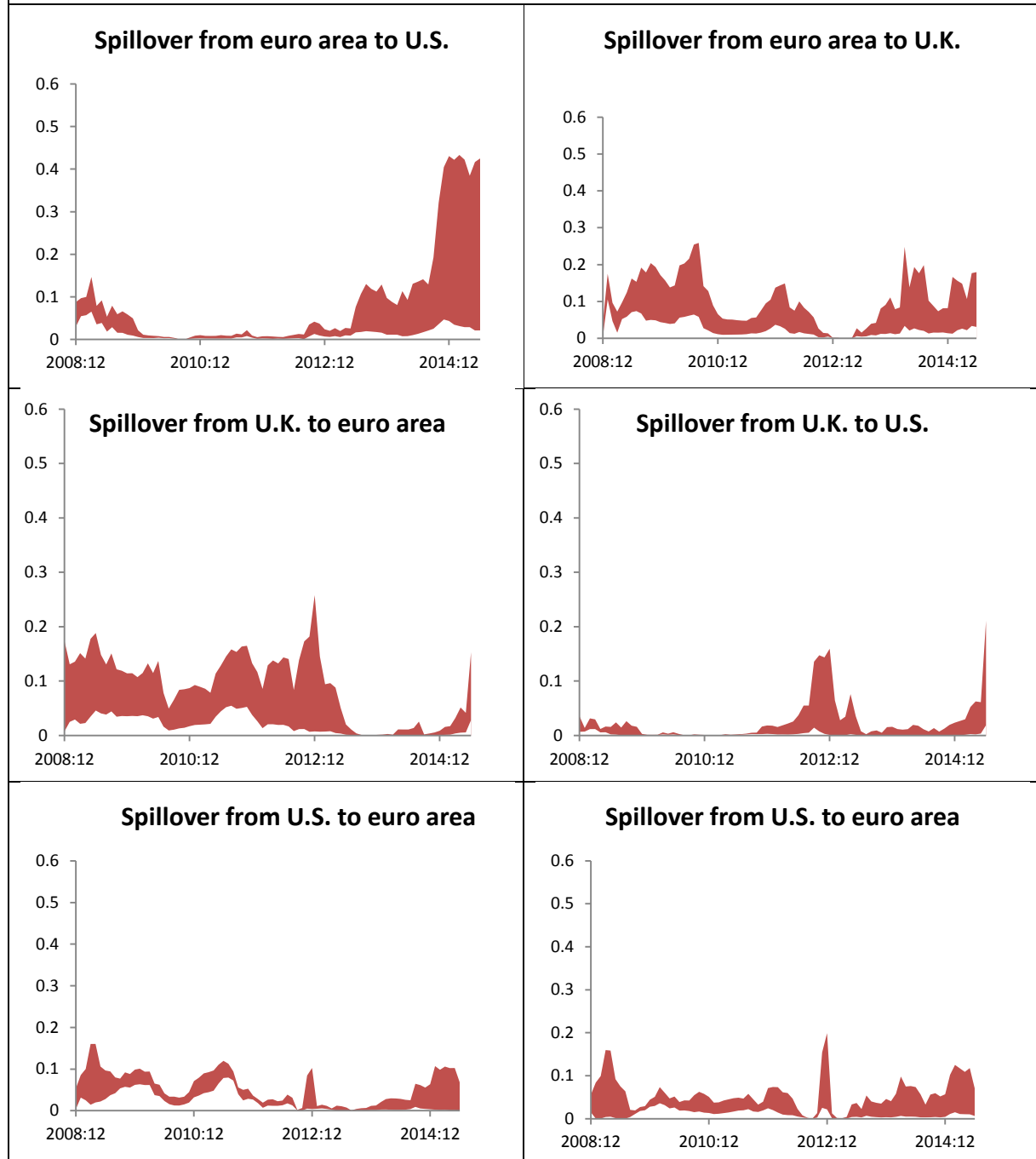
Before discussing the nature of these spillovers from the euro area particularly to the US, it is worth investigating how they have been evolving during and after the financial crisis. Figure 3 reports the time-varying spillovers from domestic shocks to the other economies computed with rolling estimates on fixed windows of 48 months.

The charts qualify the overall finding previously reported in a striking manner. In particular, the spillover from the US and UK markets to the euro area have never been higher than 30% since the onset of the financial crisis. Moreover, while the spillover from the euro area to the UK market is not unprecedented over the last 6 years, the spillover from the euro area to the US market is a phenomenon that seems to start only in the summer of 2014. Thereafter, the variance explained by euro area domestic shocks that spill over to the US market reached historical maxima of about 45% especially at horizons longer than one year.

Our findings highlight the global importance of the inflation developments in the euro area in over 2014. Netsunajev and Winkelmann (2014) also investigates the spillovers in inflation expectations between the U.S. and the euro area using bond-based BEIRs at different horizons between 2004 and 2012. Their identification approach, based on the heteroschedasticity of the data, is different from the one employed in this paper, but our results are broadly in line over their sample. Although using bond-based BEIRs may expose the analysis to a bias towards idiosyncratic shifts arising from market-specific movements in

liquidity premia, we believe that the main difference in the conclusions arises from our extended sample. Indeed our time-varying estimation provides strong evidence on the significant spillover from the euro area, particularly to the U.S. market, taking place in the second half of 2014.

Figure 3: Time-varying spillovers from domestic shocks to other economies from horizon 1 to 48



Notes: The figure shows time-varying spillovers from domestic shocks to the other economies computed with rolling estimates over rolling windows of 48 months. The area comprises all horizons of the variance decomposition.

4 Robustness checks

Before discussing in detail the reasons behind the presence of such a strong influence of international spillovers from euro area shocks onto U.S. long-term inflation expectations, we provide additional evidence supporting that the spillover effect we unveil here is specific to long-term inflation expectations.

4.1 Different specifications

It could be argued that the stylised facts discussed in the previous section may be the result of potential difficulties in the simultaneous modelling of the three inflation markets, where historical and institutional features may be not well captured by our simple empirical framework. As initial robustness check, we also carry out a decomposition of shocks in bivariate SVARs.

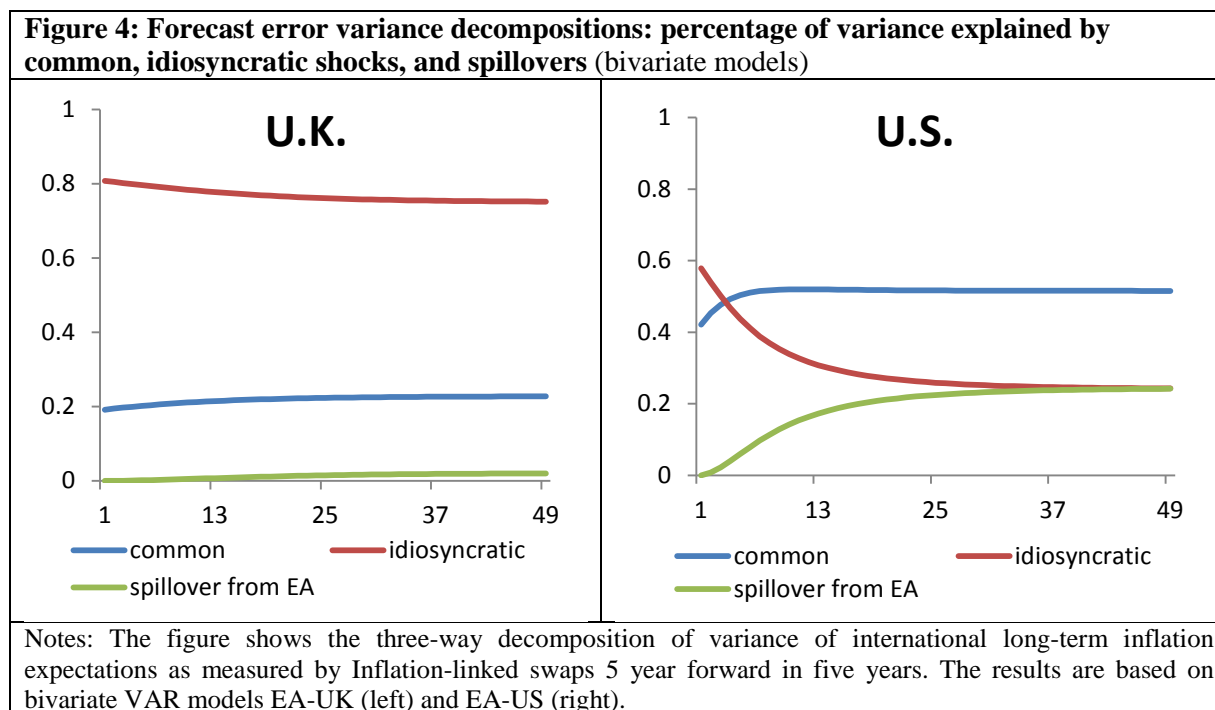


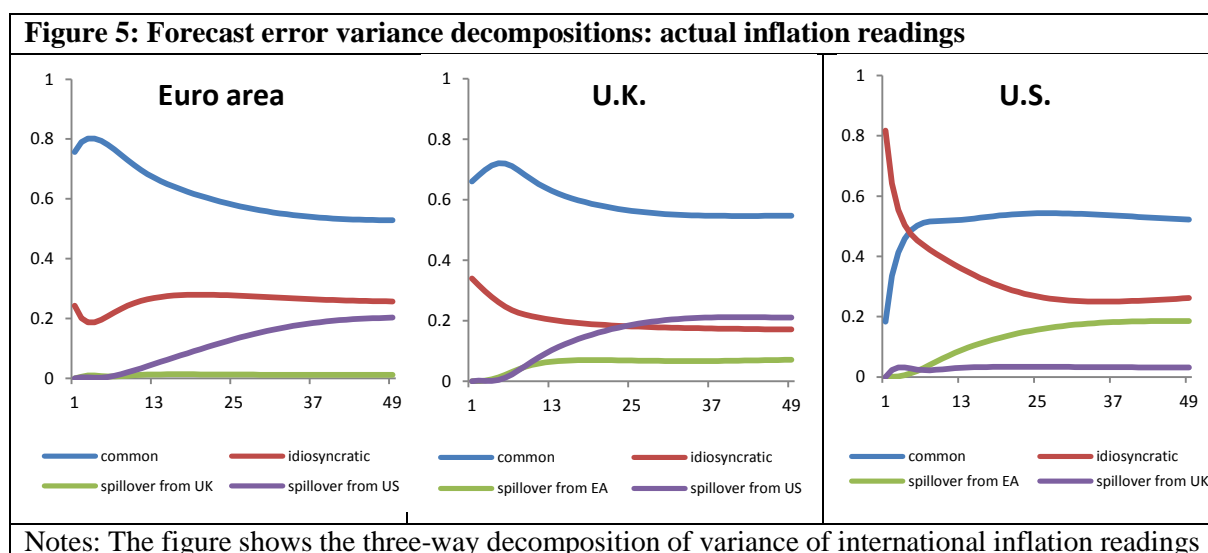
Figure 4 reports the variance decomposition of U.K. and U.S. based on the identification of common, idiosyncratic and spillovers in bivariate VARs with the euro area. The results corroborate the differences in the factor composition of euro area with those of the U.S. and the U.K. innovations to long-term inflation expectations. The same strong qualitative message emerges, namely that there is a significant spillover from the euro area to the U.S. inflation expectations. Indeed, the time profile and quantitative importance of the three types of shocks to the U.S. long-term inflation expectations in the bivariate analysis is almost identical to the multivariate evidence discussed above, with the gradual decline in the

contribution of idiosyncratic shocks across horizons being fully compensated by a larger contribution of spillovers from euro area expectations.

In the case of the U.K. the bivariate analysis however presents an apparently different picture, with a much stronger role for idiosyncratic shocks than for common shocks compared to the multivariate case. These differences between the multivariate and the bivariate SVAR analyses however arise mainly as a result of the number of common factors in the VAR innovations that can be identified (2 in multivariate and 1 in the bivariate case). Importantly for our purpose here, regardless of the number of factors used in the identification of U.K. common and idiosyncratic shocks, there is no evidence of any significant spillover from U.K. shocks onto the other economic areas.

4.2 Evidence from actual inflation dynamics

A similar SVAR analysis using actual inflation rates for the three economic areas suggests a rather symmetric factor structure (see Figure 5). International (common) shocks play a very strong role, explaining around 60% of the variance of actual inflation in all economic areas. This finding is fully in line with existing results pointing to a global inflation factor driving a substantial part of actual inflation rates (e.g. Ciccarelli and Mojon, 2010).

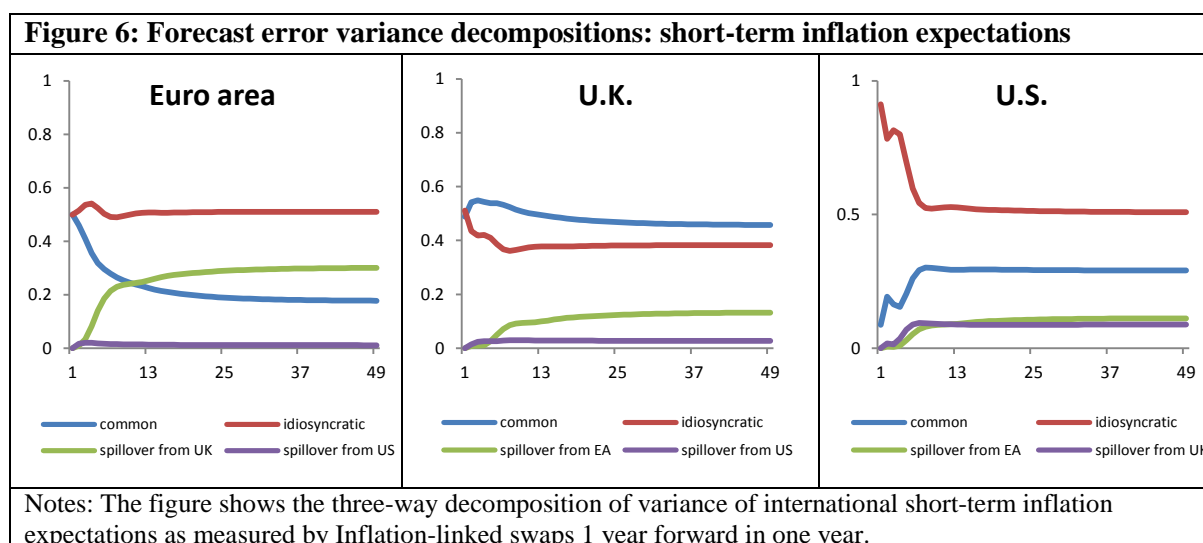


Moreover, our results suggest that the financial crisis has not significantly affected that interpretation. The financial and economic crisis therefore appears to have lowered the average observed inflation rate but has not altered significantly its main driving forces (see also Ferroni and Mojon, 2014). The remaining variance of inflation is explained by idiosyncratic shocks. Our analysis finds some spillover effects of those idiosyncratic shocks onto other economic areas, but their quantitative importance appears more limited than for

long-term inflation expectations, and, if anything, much more symmetric across economic areas.

4.3 Evidence from short-term inflation expectations

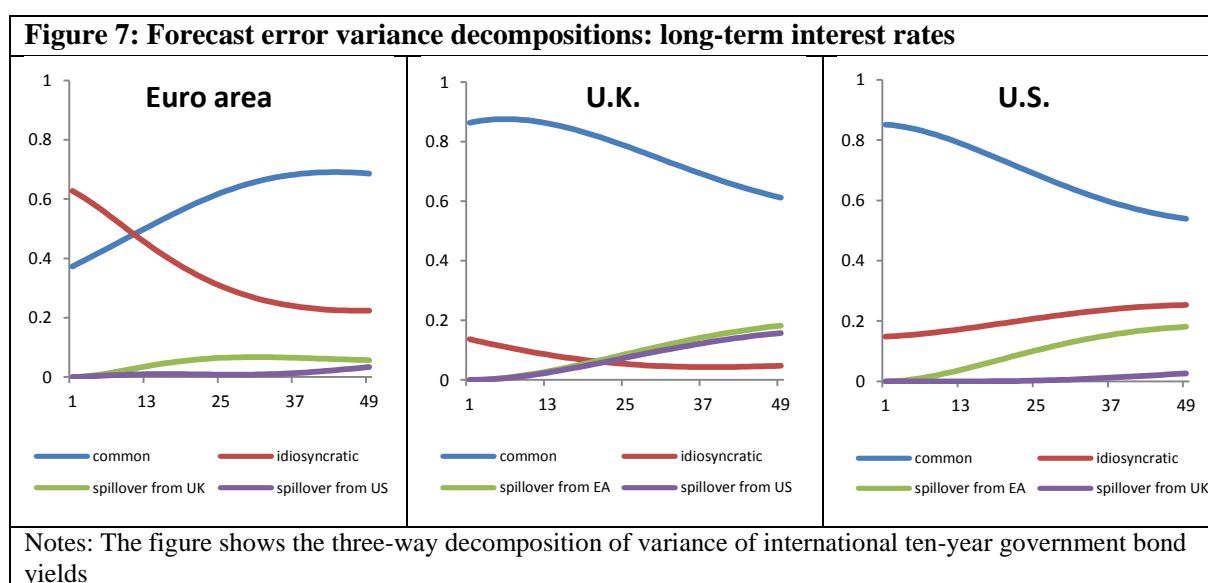
A replication of our SVAR analysis conducted at the short-end (1-year forward in one year) of the inflation swap curves shows that, contrary to our findings for long-term inflation expectations, short-term inflation expectations do behave in a very symmetric way across the Atlantic (see Figure 6), with idiosyncratic and common shocks being the most important contributors to the forecast error variance of short-term inflation expectations in UK and US. Idiosyncratic shocks play an important role in the euro area but these shocks do not appear to propagate to other markets, where the quantitative importance of spillover effects remains quite limited and more symmetric. If anything, the spillover among economic areas seems to go in the opposite direction with the most significant spillover being from the U.K. onto euro area short-term expectations.



The results for short-term inflation expectations suggest that the spillover we unveil on long-term inflation expectations is not common for inflation expectations at other horizons. This is also a noticeable finding because despite the growing role of financial indicators of inflation expectations in monetary policymaking and economic research, cross-country evidence among IL swap markets remains scarce and it is important to show that strong spillovers across economic areas are not just a standard situation in the markets, naturally linked by arbitrage considerations, but a remarkable episode to be investigated in greater detail.

4.4 Is the spillover from the euro area long-term inflation expectations just reflecting spillovers in financial markets?

The above results point to a spillover from euro area onto international markets whose asymmetry is specific of long term inflation expectations. As described in Section 2 our measure of long-term inflation expectations is derived from IL swap rates. Despite their advantages in reflecting changes in inflation expectations when they take place, IL swap rates are nonetheless a financial instrument, and, as such, their trading may well reflect not only economic factors but also overall trading conditions in financial markets. It is therefore important to ascertain whether the spillover we unveiled in long-term inflation expectations could be just a reflection of spillovers among financial instruments. To that end, Figure 7 reports the variance decomposition for long-term nominal interest rates among the three economic areas. The ten-year segment of the yield curve is often the most liquid one, particularly in the U.S. Treasury market, therefore if there is a spillover it is also a natural point to detect it.



The analysis of long-term interest rates does not reveal any strong contribution of spillovers from the euro area, or from any economic area, onto the others. This is particularly relevant given that over a substantial part of our sample the three central banks have implemented a large number of unconventional policy measures with a direct impact on financial markets. It is important to note that those results do not suggest that there is no interconnection between global financial markets. Financial markets are obviously linked by arbitrage considerations, in particular deep and mature markets as the ones in our study. Indeed there is a very strong role for common shocks in the three areas, and even stronger in the U.S., which reflects the

fact that shocks to U.S. ten-year yields are readily priced in in all markets of the world. It does not mean either that only U.S. rates are priced in, and indeed there is a substantial proportion of the variance that reflects an idiosyncratic component in those markets.

We interpret the results in Figure 7 as reflecting the advantages of our modelling strategy through the SVAR identification procedure and the use of monthly frequency in our analysis. We believe both features contribute to diminish the influence of purely financial spillover effects in the data and allow to identifying shocks and influences of mainly economic nature on long-term inflation expectations. Results from estimation at a higher frequency than that of inflation releases (e.g. daily and weekly) indeed capture the presence of quantitative relevant spillovers among interest rates that we interpret as mainly of financial nature and that we seek to avoid in our analysis of inflation expectations.

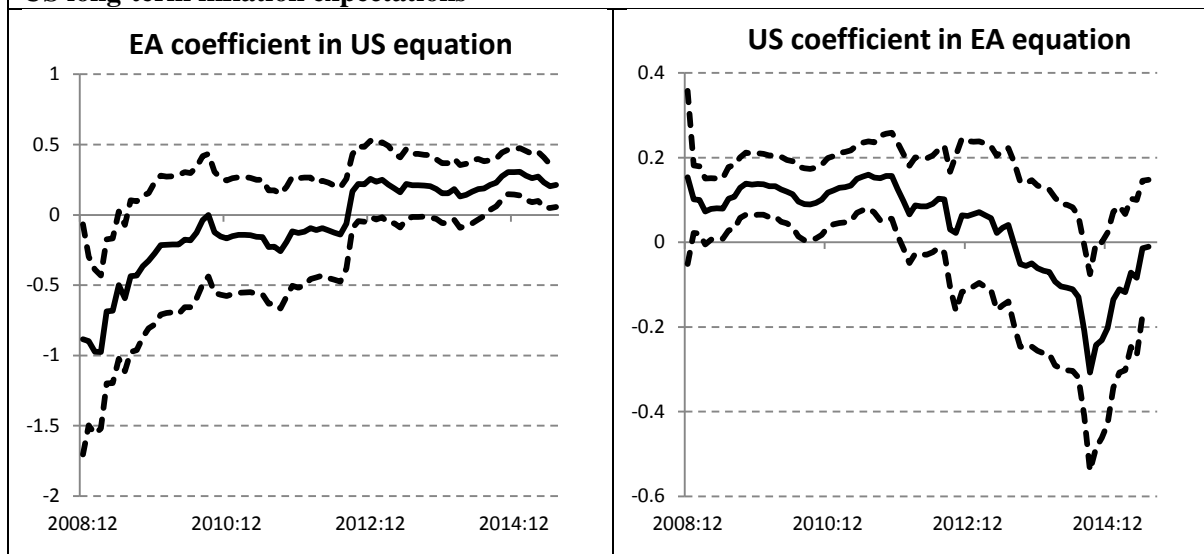
4.5 Evidence on time-variation in the pricing of international inflation expectations

A time-varying estimation of our SVAR framework offers some additional insights on the mechanism at work in the propagation of spillovers from the euro area onto the US long-term inflation expectations. Indeed, there is a significant variation in the size of (i.e. the sum of) coefficients in our VAR equations over the sample (see Figure 8). Focusing only on the euro area and the US equations, the increase in the quantitative importance of spillover shocks coincides with a long-lasting rise in the magnitude of the parameters capturing the effects of euro area long-term inflation expectations on US ones, with two jumps one in mid-2012, and one, more clearly, since the summer of 2014.

In contrast, the magnitude of the VAR innovations in the euro area equation is not significantly different for the average sample ones. This evidence suggests that the magnitude of the spillover from euro area low inflation expectations to US long-term ones is reflecting a change in the pricing of global low inflation/disinflationary pressures in global markets stemming from the euro area, rather than from the perception of an extraordinary negative shock to euro area long-term inflation expectations.

US market participants indeed point to concerns about the global growth outlook and disinflationary pressure abroad, particularly in the euro area, as one of the factors behind recent downward pricing of US long-term inflation expectations (Federal Reserve Monetary Policy Report to U.S. Congress, 2015; Survey of Primary Dealers, 2014).

Figure 8: Time-varying estimates of the coefficients in the VAR equations for euro area and US long-term inflation expectations



Notes: evolution of the VAR coefficients from long-term inflation expectations in one area in the equation for the other one computed with rolling estimates on fixed windows of 48 months.

Moreover, market participants in euro area markets also point to an unprecedented attention, not only among inflation market participants but in all financial market segments, to the euro area five-year forward IL swap rate in five years, which followed the remarks of the ECB's president at the Jackson Hole Symposium, when it declined below the 2% mark (Draghi, August 2014). The timing of Mr Draghi's speech indeed fits well with the increase in the parameter in our time-varying VAR.

5. The rationale behind the spillovers on inflation expectations

The analysis presented in previous sections unveils a somewhat puzzling spillover from euro area long-term inflation expectations to other major markets, notably the US, and especially since the late summer 2014. Available evidence suggests that such asymmetric spillover effects are a characteristic of long-term inflation expectations, for, at shorter horizons (i.e. 1-year forward IL swap rate in one year), the cross-country effects of idiosyncratic shocks are much more symmetric. Moreover, the evidence of short-term inflation also shows that the asymmetric spillovers are not related to the specific use of forward IL swap rates as measure of long-term inflation expectations. Furthermore, despite the prominence of the euro area five-year forward IL swap rate in five years as indicator of long-term inflation expectations, similar results for other measures, i.e. the ten-year spot IL swap rates or the one-year forward IL rate in four years, suggest that it is the pricing of inflation expectations at medium-to-long term horizons and not of a specific indicator that has changed since the second half of 2014.

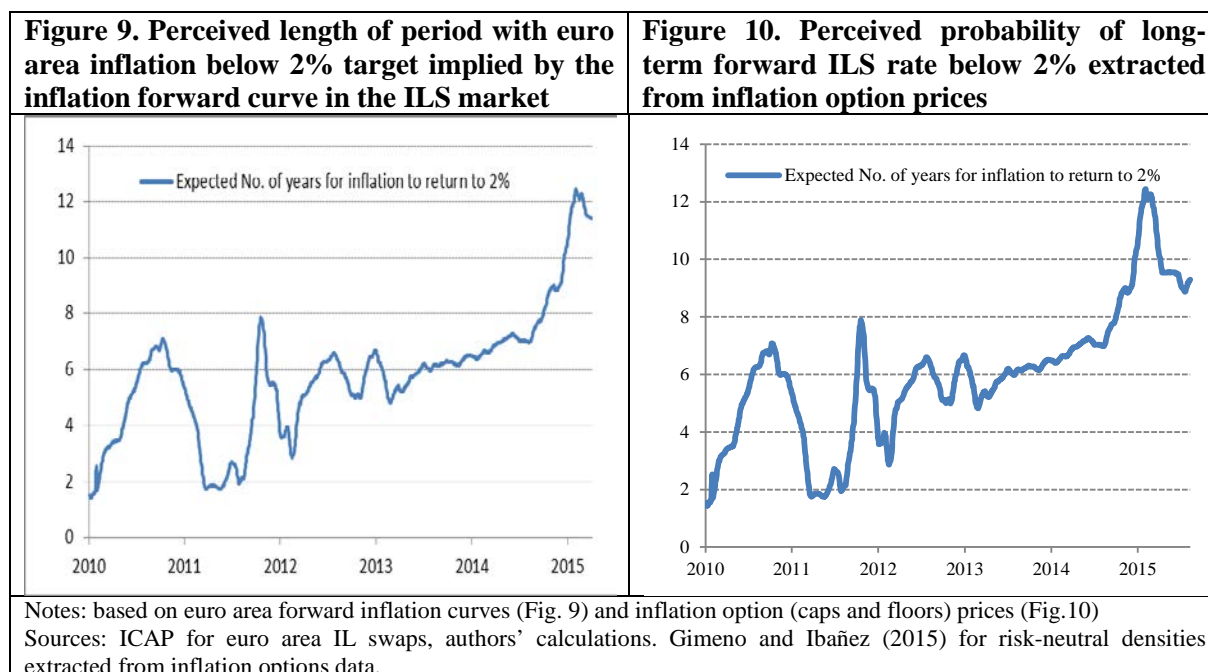
In the light of those considerations, we interpret the surge in the international spillover effect from the decline in euro area long-term inflation expectations since late summer 2014 as signalling market perceptions of a protracted period of low inflation and possibly also quite a subdued economic recovery. A potential de-anchoring of inflation expectations in the event of actual inflation staying below ECB's quantitative definition of price stability of 2% for an extended period – in the case of the euro area overall HICP inflation had been below the 2% level and in a declining trend since January 2013 – was already perceived as a risk in the spring of 2014 with potential implications also outside the euro area, mainly for economies in the region whose currencies were pegged to the euro (Spillover Report, IMF 2014; Euro Area Article IV Staff Report, IMF 2014).

The inflation outlook in the euro area however deteriorated significantly in the summer 2014. Despite the credit easing measures announced by the ECB in June 2014, euro area inflation fell below 0.5% in July, and continued to decline thereafter. Inflation expectations were revised further down, and since mid-August 2014 the euro area long-term forward IL swap rate (five-year forward in five years) started being recorded below the 2% mark (see Figure 1).

The deterioration in inflation expectations at medium-to-long horizons was priced in across the full universe of inflation-linked products. First, the forward inflation curve suggested that the perceived risks of inflation below target, which were on a mild upward trend already since early 2013, rose sharply since August 2014, moving from 7 years in mid-July 2014 to a peak above 13 years in mid-January 2015 (see Figure 9). Such a horizon is well beyond anything attributable to the influence of standard business cycle or commodity price fluctuations and highlights the perception, at least among market participants, of the secular nature of the downward drift in medium-to-long inflation expectations in the euro area.

Moreover, not only baseline scenarios, but also risks as measured by inflation options (caps and floors) displayed a significant deterioration towards the end of the summer: The probability of the long-term forward IL rate being below 2% rose from around 45% to above 60% by early 2015 (see Figure 10). Importantly, the deterioration in both baseline scenarios and risks to long-term inflation expectations are unprecedented in the history of the euro area under the single monetary policy and did not even occur during the most acute episodes of the financial and euro area debt crisis. It is therefore not surprising that such deterioration

started being priced-in in global inflation markets since the summer of 2014, even in the case of an incipient economic recovery in other major economic areas, notable the US economy.



While the recovery in the US economy may proceed at good pace, in a context of subdued inflationary pressures worldwide, low inflation in the euro area is likely to exert some downward pressure to price increases outside the euro area due for example to international competitiveness considerations, de facto lowering them as the analysis of short-term expectations suggest. Yet, given that the protracted period of low inflation for the euro area outlook at short-to-medium horizons is translated into lower long-term euro area inflation expectations, the influence may be also spilling over to longer-term US (and international) inflation expectations. Moreover, any macroeconomic scenario leading to a further decoupling in economic performance in both sides of the Atlantic is likely to be further reflected in the exchange rate, which if anything would reinforce the exchange rate and competitiveness channel outlined above, and therefore further underpin the spillover.

Our aim here is mainly the measurement of such spillovers within a relatively simple empirical framework, and the analysis of the transmission of such spillovers using techniques to explore network effects and better identify the channels through which such spillovers are propagated are beyond the scope of this paper.

6. Discussion and implications

To our knowledge, there is no precedent of a spillover of inflation expectations among some of the largest world economy areas in the world, at least over recent decades, as the one documented above. We argued above that our findings are likely to be related to the unusual deterioration of the perceived inflation outlook in the euro area, particularly over the summer of 2014. This unusual event poses a number of research and policy challenges that are discussed next.

Research implications

The unprecedented international spillovers in medium-to-long term inflation expectations raises new research questions on the channels through which such influences to global inflation expectations may propagate. The variance decomposition reveals another important characteristic of the spillover effects from the euro area to the US, namely that their relative importance is higher the longer the horizon at which the decomposition takes place, which suggests that the spillover effect captures persistent forces at work.

Despite the significant progress over the last decade in the development of empirical models for the analysis of the term structure of interest rates, the interpretation of developments of financial indicators of inflation expectations (and inflation compensation measures) remains challenging. Understanding the decline in long-term forward inflation compensation in major economic areas since the summer of 2014 has been indeed difficult in all economic areas, The U.S. Federal Reserve has been particularly explicit about how puzzling such developments were in the light of the evidence from the term structure models regularly employed (Federal Reserve, 2015).

Abrahams et al. (2012), Christensen et al. (2010) and D'Amico et al. (2014) provide three different empirical strategies for modelling the US term structure of interest rates and decompose inflation compensation measures. For our purpose in this paper their results offer a testable implication for the quantitative relevance of the spillover effect of euro area on US inflation compensation measures. As most term structure models, those models are solely estimated on domestic data, and therefore the spillovers from euro area inflation expectations should load on the fitting errors from those models. Indeed, for most of 2014 the estimated long-term bond yields and inflation compensation have been persistently above the observed values, which, in the case of break-even inflation rates since August 2014 has added to the controversy in the interpretation of their declines (FOMC, 2015).

Figure 11. Coefficient of EA inflation expectations on fitting errors for US long-term inflation expectations in term structure models (rolling regressions)

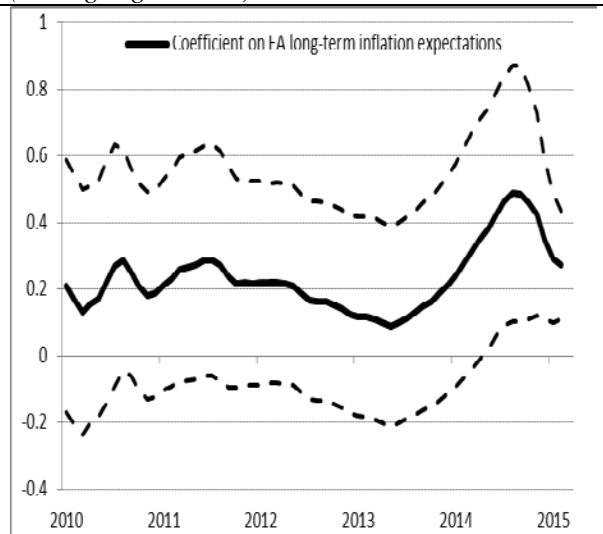
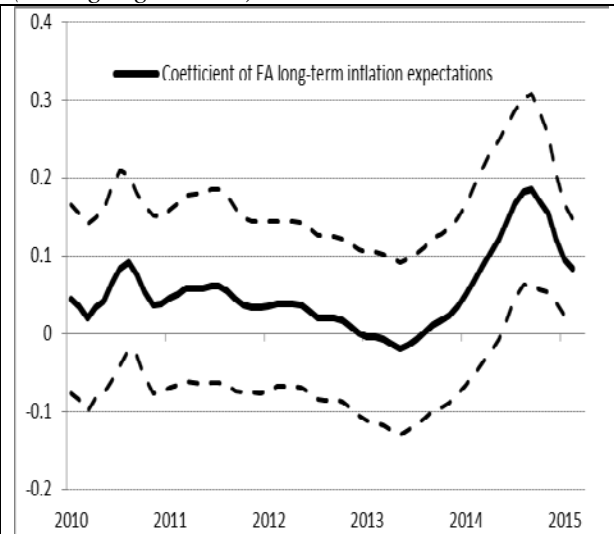


Figure 12. Coefficient of EA inflation expectations on fitting errors for US ten-year inflation expectations in term structure models (rolling regressions)



Notes: Dependent variable is the first principal component of the fitting errors of the Fed's models by Abrahams et al. (2012), Christensen et al. (2010) and D'Amico et al. (2014). EA inflation expectations are measured by the long-term forward IL swap rate (five-year forward in five years). The regression for the ten-year spot also includes euro area actual inflation to control for potential influences at short-term horizons.

Figures 11 and 12 show that, accounting for the spillovers from euro area inflation expectations contributes to solve the puzzling decline in US medium-to-long inflation expectations since August 2014. To check how the influence of euro area inflation expectations has changed over time, we regress the first principal component of the fitting errors of the three term structure models on the euro area inflation expectations using rolling estimation techniques.² Specifically, Figure 11 shows the time variation in the coefficient of euro area long-term inflation expectations on the unexplained part of the long-term US break-even inflation rate (five year forward in five years), while Figure 12 shows the results for the unexplained part of the 10-year spot US break-even inflation rate. The regression analysis suggests that there has been indeed an increase in the explanatory power of euro area inflation expectations over 2014, with the coefficient becoming statistically significant from mid-2014. Importantly, the explanatory power of euro area inflation expectations also holds for the unexplained part of the observed nominal yields in the term structure models we consider and is not related to the specific identification of inflation compensation measures.

In line with the evidence documented in the previous sections, the main conclusion is that accounting for the spillover from euro area inflation expectations can help understand the puzzling decline of US medium-to-long term inflation expectations since the summer of

² Same qualitative findings are found using the fitting errors of each of the term structure models individually.

2014. But beyond understanding that specific episode, in the context of highly globalised economies, our findings point to the benefits of taking into account international factors and spillovers, at least in certain extreme circumstances. Looking forward, this may be particularly relevant for the interpretation of research tools such as the term structure models that are mainly analysed in the light of domestic factors. Fortunately, as our analysis shows, the newly developed global markets for inflation products offer a very valuable source of information on international spillovers.

Policy Implications

International spillovers on long-term inflation expectations also have important implications for monetary policymaking. First, as argued in the previous section, they contribute to a better understanding of the declines in global long-term inflation expectations from the second half of 2014. In the context of the current debate on the start of the normalisation of monetary policy conditions in the US, and to a less extent in the UK, such influences are important to bear in mind, both for the overall inflation compensation and the weight placed in their decompositions into the level of expected inflation and inflation risk premia.

Second, the decline in euro area long-term inflation expectations was one of the reasons behind the additional expansionary policy measures adopted by the ECB in early 2015. These measures aim at restoring the anchoring of long-term inflation expectations in order for them to support the recovery of actual inflation developments towards levels consistent with the quantitative definition of price stability. In this context, and in the light of our findings, it is likely that the effects from the ECB's Asset Purchase Programmes (APP) spill over to other economic areas via long-term inflation expectations, and, somewhat paradoxically, possibly in a more significant way than the asset purchase programmes conducted by the US Federal Reserve and the Bank of England since 2009.

Moreover, the effects of the ECB's APP are likely to feed through only gradually, and therefore it should be taken into account that the effects of the spillover of euro area long-term inflation expectations on global expectations may be present for a protracted period. Two pieces of information support this interpretation. First, the euro area inflation currently priced in shorter-term IL swap rates suggests a rather protracted period of low inflation. According to end-March 2015 data, that is, already nine weeks after the announcement of an extension of the ECB's APP on 22 January 2015 and three weeks after the start of its implementation, the profile for euro area inflation implied by IL swap rate rates is 0.4%,

0.7% and 1% one, two and three years ahead. Furthermore, the five-year spot IL swap rate suggests that euro area inflation over the next five years would average 1%. And at even longer horizons the outlook also remains worrisome: the ten-year spot IL swap rate suggests average inflation of 1.3% over the next 10 years. Furthermore, the recovery of euro area long-term inflation expectations after the announcement and implementation of the APP, although on-going, proceeds slowly (see Figures 8 and 9). Under such a scenario, it is hardly surprising that global inflation markets continue pricing in the euro area long-term forward IL swap rates for as long as they remain at relatively low levels, e.g. below historical average of 2.3%, for a considerable period of time.

Second, risks of a protracted period of low inflation and, to a less extent low growth, are not only implied by market expectations but widespread. The probability assigned to euro area inflation below 1% in the probability distributions of the 2015 Q1 round of the ECB's Survey of Professional Forecasters (SPF) is around 70% and 40% one and two years ahead respectively. And the chance of real GDP growth below 1% at those horizons is 35% and 20% respectively, and, although somewhat firming, the recovery is still perceived as fragile. Moreover, at the longest available horizon (five years ahead) the economic outlook is not particularly bright either: while the probability of both inflation and real growth below 1% decreases to around 15%, the probability of observing values above 3% remains below 5%.

In this context, taking into account the spillovers into long-term inflation expectations in other economies seems crucial for the appropriate conduct of monetary policy also outside the euro area.

7. Concluding remarks

This paper investigated the factors behind developments in long-term inflation expectations in euro area, the U.S. and the U.K. by means of a factor structural VAR framework that identifies common and idiosyncratic shocks, and then investigates the extent to which the idiosyncratic shocks for each area are transmitted to the international inflation markets. Our analysis unveils a somewhat surprising spillover effect from euro area long-term inflation expectations to the US one since the summer of 2014. We also show that such asymmetric spillovers are a characteristic of long-term inflation expectations, and are not present at shorter horizons or for actual inflation developments. Our results suggest that the significant deterioration of the inflation outlook for the euro area since the summer of 2014 seems to be behind the presence of such a spillover effect.

Our findings have some important policy and research implications. First, to the extent that the recovery of inflation back to levels consistent with price stability in the euro area is likely to be rather slow, accounting for spillovers onto global inflation and inflation expectations may continue to be crucial to understand long-term inflation expectations in major economic areas. This is of particular relevance for most term structure models currently employed for the analysis of financial indicators of inflation expectations, which do not necessarily account for any international effects.

Second, while our results do not show any significant evidence of spillover from the unconventional policy measures implemented by the US Federal Reserve or the Bank of England on euro area long-term inflation expectations, it is instead likely that the impact of the expansion of the ECB's APP announced in January 2015 may have some international effects via long-term inflation expectations. In this regard, our results could open new avenues to explore in the debate on international policy coordination and the impact of policy spillovers across economic areas.

Finally, further investigation on the reasons why such a spillover may take place is also necessary. In a deeply interrelated world, with highly correlated asset prices and relatively limited scope for monetary policy reaction, international spillovers as the ones we identify in this paper are an important factor to take into account. Our analysis also suggests that the newly developed global markets for inflation products offer a very valuable source of information to identify such international spillovers.

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