Missing Disinflation and Missing Inflation: A VAR Perspective*

Elena Bobeica and Marek Jarociński
European Central Bank

In the immediate wake of the Great Recession we didn't see the disinflation that most models predicted and, subsequently, we didn't see the inflation they predicted. We show that these puzzles disappear in a vector autoregressive model that properly accounts for domestic and external factors. This model reveals strong spillovers from U.S. to euro-area inflation in the Great Recession. By contrast, domestic factors explain much of the euro-area inflation dynamics during the 2012–14 missing inflation episode. Consequently, euro-area economists and models that excessively focused on the global nature of inflation were liable to miss the contribution of deflationary domestic shocks in this period.

JEL Codes: E31, E32, F44.

1. Introduction

The dynamics of inflation since the start of the Great Recession has puzzled economists. First, a "missing disinflation" puzzle emerged when inflation in advanced economies failed to fall as much as expected given the depth of the recession (see, e.g., Hall 2011 on the United States and Friedrich 2016 on the rest of the advanced

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economies). Then came the "missing inflation" puzzle, particularly manifest in the euro area, where inflation was unexpectedly low after 2012 (see, e.g., Constâncio 2015; International Monetary Fund 2016). These puzzles have led economists to question and reassess the relation between real activity and inflation, and reconsider the global nature of inflation. These studies used small reduced-form models (e.g., Ball and Mazumder 2011; Coibion and Gorodnichenko 2015) or structural dynamic stochastic general equilibrium (DSGE) models (e.g., Christiano, Eichenbaum, and Trabandt 2015; Del Negro, Giannoni, and Schorfheide 2015; Gilchrist et al. 2015). In this paper we investigate the puzzles using reduced-form and structural Bayesian vector autoregressions (VARs) as the tools to interpret the data. This investigation sheds new light on the puzzles.

We specify a medium-sized VAR with domestic and external variables that does not suffer from the puzzles. That is, when we estimate the model on the pre-crisis sample, the forecasts conditional on the actual path of domestic real activity do not underpredict inflation in the missing disinflation period in the euro area and the United States. Furthermore, analogous forecasts do not overpredict inflation in the euro-area missing inflation. We compute forecasts conditional on either external or domestic variables, and in each episode some of these forecasts match inflation well. Hence, it is interesting to ask what this model says about the properties of inflation and about the two episodes.

Our conditional forecasts reveal a strong relation between the U.S. and euro-area inflation rates. Moreover, we find that in the Great Recession this relation is not fully explained by the price of oil and other commodities, and by the global co-movement in real activity. These puzzling findings echo the lessons of the literature on the increasingly global nature of inflation (Borio and Filardo 2007; Wang and Wen 2007; Ciccarelli and Mojon 2010; Mumtaz and Surico 2012; Henriksen, Kydland, and Sustek 2013). In a parallel paper Laseen and Sanjani (2016) also find that external variables provide the best conditional forecast of the U.S. inflation in the Great Recession, out of many other groups of variables that they try. We extend this finding to the euro area and use structural VARs to interpret it. In light of our structural VARs, the co-movement of U.S. and euro-area inflation rates in the Great Recession is likely to be driven by U.S. shocks that spilled over quickly to the euro area.

By contrast, we show that the second euro-area disinflation is domestically driven. While in the first disinflation (2008–11) the forecast conditional on external variables matches inflation much better than the forecast conditional on domestic real activity, in the second disinflation (2011–14) this ranking is reversed. The same lesson follows from two structural VARs, where we separate domestic from external shocks using restrictions on either the timing or the co-movement of external and domestic variables. The first episode is driven more by external shocks, and the second one more by domestic shocks. A striking picture emerges when we compare the contributions of different shocks to the euro-area inflation with the inflation forecast errors made by professional forecasters: in the missing inflation period, the forecast errors and the contributions of domestic shocks follow a similar pattern. A plausible story of the "missing inflation" is that economists, attuned to the global nature of inflation, overlooked the effect of domestic deflationary shocks.

Our paper is related to several current economic debates.

First, economists disagree to what extent the Great Recession calls for a structural break in the standard linear economic models. Cheng, Liao, and Schorfheide (2016) detect a structural break in their dynamic factor model of the U.S. economy, and Aastveit et al. (2017) find that VAR conditional forecasts of the U.S. macroeconomic variables are disturbingly far from the actual outcomes in the post–Great Recession period. The notions of "missing disinflation" and "missing inflation" reinforce the view that structural breaks are needed to account for inflation in particular. But there is also evidence from dynamic factor models and large Bayesian VARs suggesting that economic relationships have not changed in the crisis. See Stock and Watson (2012) and Laseen and Sanjani (2016) for the United States, while Giannone et al. (2014) and Bańbura, Giannone, and Lenza (2015) provide some euro-area results.[1] This paper is the first to provide summary evidence for both the United States and the euro area using, for full comparability, basically the

[1]An important difference between the VARs of Aastveit et al. (2017) and the other papers is that the VARs of Aastveit et al. (2017) are much smaller (include fewer variables). An important difference between the factor model of Stock and Watson (2012) and of Cheng, Liao, and Schorfheide (2016) is that the former normalize the size of the factor loadings and the latter the variance of the factors.

same medium-sized econometric model for each economy, and it is the first to cover both the missing disinflation and the subsequent missing inflation. Moreover, we exploit the double-dip recession in the euro area to study the stability of the slope of the Phillips curve, broadly understood as a relation between a vector of real activity indicators and inflation in a VAR. We show that in our model the slope is remarkably constant throughout this volatile period.

We also acknowledge the related literature that compares the Great Recession with the recessions in the 1970s and earlier, and finds a flatter Phillips curve more recently (e.g., IMF 2013; Blanchard, Cerutti, and Summers 2015) and increasing inflation persistence (e.g., Watson 2014). We analyze the euro area and the United States in a fully comparable setup so we focus on a shorter sample that only includes the 1990s and 2000s, given the short history of the euro area. Consequently, we do not add to the study of the long-term trends. What we show is that, notwithstanding any long-term trends, the preceding two decades provide a reliable guide to the economic relationships in the Great Recession, as witnessed by the good fit of our conditional forecasts.

Second, we contribute to the literature on the global nature of inflation by documenting and interpreting the spillovers from U.S. to euro-area inflation in the wake of the Great Recession. Most of the global inflation papers cited above focus on secular trends in long samples. By contrast, we provide a detailed case study of the post–Great Recession period. The economic mechanism behind the cross-border spillovers of inflation that we document, which are not explained by world commodity prices and real activity, is worth further study. Henriksen, Kydland, and Sustek (2013) provide a candidate explanation.

Our euro-area results provide also a cautionary tale against overreliance on the global nature of inflation. The global inflation literature highlights the importance of external factors, and long-term studies of the Phillips curve suggest that it has flattened, so taken together they downplay the connection between inflation and domestic real activity. While we do not question these long-term findings, we put them in perspective by isolating a recent episode, the missing inflation period in the euro area, when domestic real activity was crucial for explaining inflation dynamics.

Finally, a sequence of DSGE papers argues that the missing disinflation puzzle disappears in models that realistically account for the dynamics of a richer set of variables. In Christiano, Eichenbaum, and Trabandt (2015) interest rate spreads increase costs via the working capital channel, and, in addition, productivity falls. In Gilchrist et al. (2015) firms raise prices when facing liquidity problems. In Del Negro, Giannoni, and Schorfheide (2015) forward-looking agents expect the central bank to prevent future marginal cost declines. In Bianchi and Melosi (2017) agents factor in an increasing probability of a switch to the fiscally led policy mix. All these complementary mechanisms imply that inflation does not fall in the Great Recession as much as a simple Phillips curve would suggest. We also find it important to incorporate a richer set of variables. We find that financial and uncertainty indicators, such as the credit spreads and excess bond premium of Gilchrist and Zakrajsek (2012), and the macroeconomic uncertainty indicator of Jurado, Ludvigson, and Ng (2015) improve forecasts of inflation conditional on real activity alone. Our VARs, being linear, might still underestimate the role of these variables (see, e.g., Balke 2000).

In the rest of this paper, section 2 investigates the missing disinflation and missing inflation episodes using conditional forecasts, section 3 identifies structural shocks and studies their contributions to inflation in the two episodes, and section 4 concludes.

2. Conditional Forecasts of Inflation

In this section we ask whether inflation dynamics was indeed unusual during the missing disinflation and missing inflation episodes, from the point of view of a Bayesian VAR estimated on the data preceding these episodes. We condition on the actual realizations of either domestic or external variables and compare the resulting conditional forecasts of inflation with the actual outcomes.

We specify a medium-sized VAR, with a consumer price index, eight indicators of domestic real activity, eight external variables, and eight (euro-area) or nine (U.S.) variables related to financial markets and uncertainty. Real activity indicators are the real GDP and its main components, total employment, the unemployment rate, and survey-based indicators: capacity utilization, consumer confidence, and the Purchasing Managers' Index (PMI). External variables are the rest-of-the-world real GDP, oil and commodity prices, exchange rates, foreign real GDP, prices, and short-term interest rate, where "foreign" means "euro area" in the U.S. VAR and "US" in the euro-area VAR. Financial and uncertainty indicators are the short-term interest rate, two- and ten-year government bond spreads, mortgage lending spreads, corporate credit spreads, and uncertainty indicators. For the United States we take the "GZ credit spread" and the excess bond premium (EBP) calculated by Gilchrist and Zakrajsek (2012). For the euro area we take a similarly constructed "GM credit spread" by Gilchrist and Mojon (2017) and, in the absence of the excess bond premium, the "GM bank credit spread" which, Gilchrist and Mojon argue, is a particularly relevant indicator of euro-area financial tensions. Uncertainty is captured by the stock volatility index (U.S. VIX or euro-area VSTOXX), the economic policy uncertainty index of Baker, Bloom, and Davis (2016), and the macroeconomic uncertainty index of Jurado, Ludvigson, and Ng (2015). The last one is available for the United States only, so the U.S. VAR has twenty-six variables, compared with twenty-five for the euro area. All the variables are listed in table 1.[2]

We do not include direct measures of inflation expectations. This is because we want to understand the relative importance of external and domestic factors, and inflation expectations combine both. For example, a rise in inflation expectations might at one point in time reflect expectations of higher oil prices (an external factor) and at another point in time reflect expectations of a surge in domestic demand. Furthermore, even without an explicit measure of inflation expectations, our VAR can be thought of as a reduced form of a structural model that features a New Keynesian Phillips curve where current inflation is determined in part by expected

[2]When choosing the variables, we started with the most relevant ones according to the ranking derived in Jarociński and Maćkowiak (2017) and applied several constraints: we use the same specification for the euro area and the United States; we want to separate domestic from external variables (so we omit exports and imports); for a priori reasons we want the number of external variables to be similar to the number of domestic real activity variables, so we end up including some external variables even though they were low in the ranking; and we included several spreads and uncertainty indicators that either became available or gained prominence more recently.

Table 1. VAR Specification

Variable	Transformation
Price Index	
US: Consumer Price Index (CPI)	Log
EA: Harmonized Index of Consumer Prices (HICP)	Log
Domestic Real Activity Variables	
Real GDP	Log
Real Consumption	Log
Real Investment	Log
Total Employment	Log
Unemployment Rate	None
Capacity Utilization	None
Consumer Confidence	None
Purchasing Managers' Index (PMI)	None
External Variables	
Rest-of-the-World Real GDP	Log
Price of Oil	Log
Commodity Prices	Log
Nominal Effective Exchange Rate (NEER)	Log
USD/EUR Exchange Rate	Log
Foreign* Real GDP	Log
Foreign* Consumer Price Index	Log
Foreign* Short-Term Interest Rate	None
Financial Variables and Uncertainty	
Short-Term Interest Rate (US: Federal Funds Rate/EA: EONIA)	None
Two-Year Government Bond Spread	None
Ten-Year Government Bond Spread	None
Mortgage Bank Lending Spread	None
Corporate Credit Spread (US: GZ Credit Spread/EA: GM c.s.)	None
US: Excess Bond Premium (EBP)/EA: GM Bank Credit Spread	None
Stock Volatility Index (US: VIX/EA: VSTOXX)	Log
Economic Policy Uncertainty (EPU) Index	Log
US: JLN Macroeconomic Uncertainty	None

(*continued*)

Table 1. (Continued)

Prior Hyperparameters in the Sims and Zha (1998) Notation
Overall Tightness $\lambda_1 = 0.2/\xi$ Decay $\lambda_2 = 1$ "Other Weight" $\lambda_3 = 1$ Standard Deviation of the Constant Term $\lambda_4 = 10^4/\xi$ Weight on the No-Cointegration (Sum of Coefficients) Dummy Observations $\mu_5 = 1 \times \xi$ Weight on the One Unit Root Dummy Observation (Initial Dummy Observation) $\mu_6 = 1 \times \xi$, where $\xi = 4$ for the Euro Area and $\xi = 5$ for the United States

Notes: "US" denotes the U.S. VAR, "EA" denotes the euro-area VAR. *"Foreign" means "US" in the euro-area VAR and "euro area" in the U.S. VAR. Government bond and mortgage lending spreads are calculated as the relevant interest rate minus the short-term interest rate. The GZ credit spread and excess bond premium for the United States come from Gilchrist and Zakrajsek (2012). The GM credit spread and GM bank credit spread for the euro area come from Gilchrist and Mojon (2017). The economic policy uncertainty indexes come from Baker, Bloom, and Davis (2016), at http://www.policyuncertainty.com. JLN macroeconomic uncertainty comes from Jurado, Ludvigson, and Ng (2015) and is available only for the United States. See the online appendixes for further details on the data set.

inflation. The VAR contains a rich information set reasonably approximating the information set based on which economic agents form expectations.

The variables are observed at the quarterly frequency over the sample starting in 1990:Q1. The real variables, as well as the price indexes, are seasonally adjusted (the online appendixes, available at http://www.ijcb.org, contains details on the construction of some of the series and the data sources). As is the common practice in quarterly VARs, we include four lags of the endogenous variables. All the VARs include an intercept.

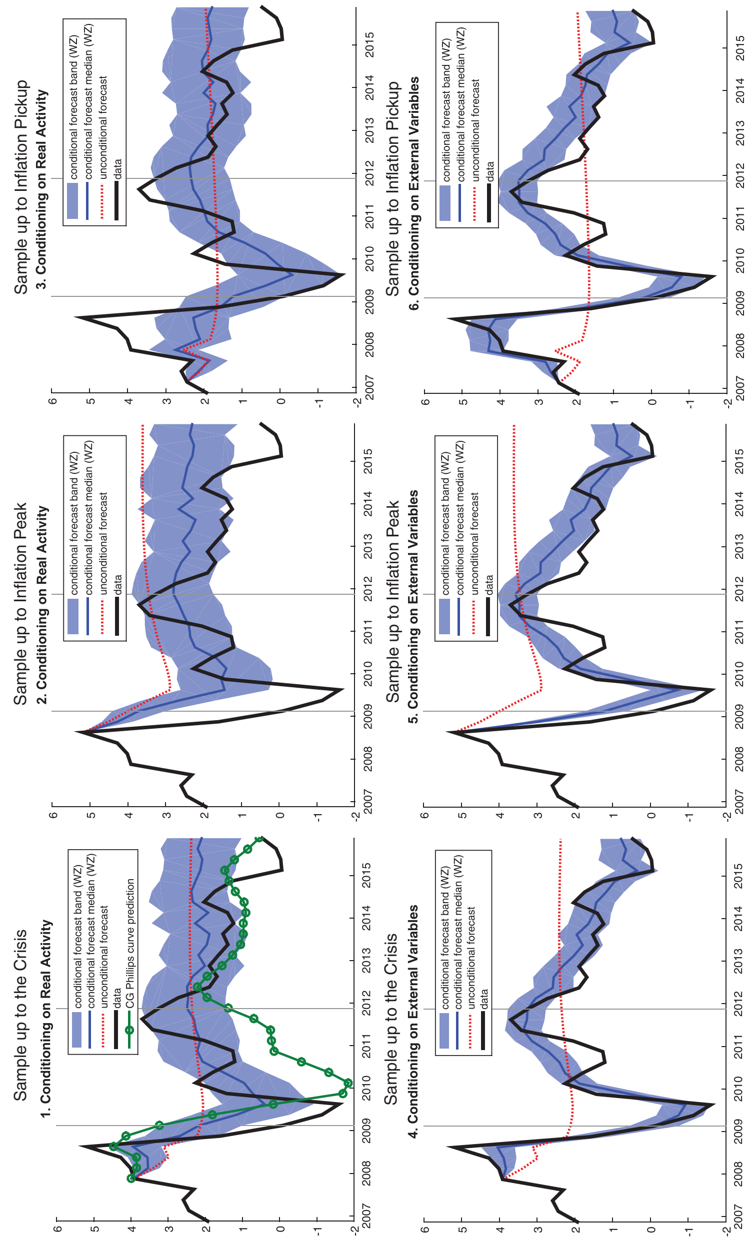
We estimate the VARs using the Bayesian approach in the tradition of Sims. More precisely, we include all variables in (log) levels and we use Bayesian priors of Litterman (1979) and Sims and Zha (1998). Since the VAR is relatively large, we follow the advice of Bańbura, Giannone, and Reichlin (2010) and Giannone, Lenza, and Primiceri (2015), and use tighter priors than what is standard in smaller VARs. When setting the priors, we start with the prior hyperparameters of Sims and Zha (1998) and scale them by a factor of 4 (euro area) or 5 (United States); see table 1. When the prior is too loose, the unconditional forecast implies an exploding rate of inflation in the long run, so we tighten the prior until the unconditional forecast implies that inflation stabilizes in the long run. It turns out that to achieve this we need a factor of 4 in the euro-area VAR and 5 in the U.S. VAR. When computing the conditional forecasts, we use the Gibbs sampler of Waggoner and Zha (1999) (see also Jarociński 2010 for details on the implementation).[3]

We start with attempts to replicate with our VAR the missing disinflation puzzle in the United States. We estimate the VAR using the data up to the peak before the Great Recession, dated by the National Bureau of Economic Research (NBER) at 2007:Q4. Then we forecast consumer prices conditionally on the actual path of the real activity variables in the Great Recession and afterwards. We plot the forecast with the 68 percent posterior uncertainty band, along with the actual data, in the first panel of figure 1. The VAR is specified in terms of the level of the price index, but for the purpose of reporting we transform the levels into year-on-year growth rates. The two vertical lines mark the first quarter of 2009 and the fourth quarter of 2011, delimiting the period of the missing disinflation puzzle as defined, e.g., in Coibion and Gorodnichenko (2015).

We can see that the VAR does not exhibit the missing disinflation puzzle: based on the joint dynamics of all the variables prior to the Great Recession and the real activity in the Great Recession, the VAR does not underpredict inflation. If anything, it overpredicts it. The conditional forecast in the first panel stands in contrast with the predictions of reduced-form Phillips curves, which—as shown, e.g., in Coibion and Gorodnichenko (2015)—tend to be much lower. For example, the green line with circles, labeled "CG Phillips curve prediction," shows the prediction of their baseline Phillips-curve

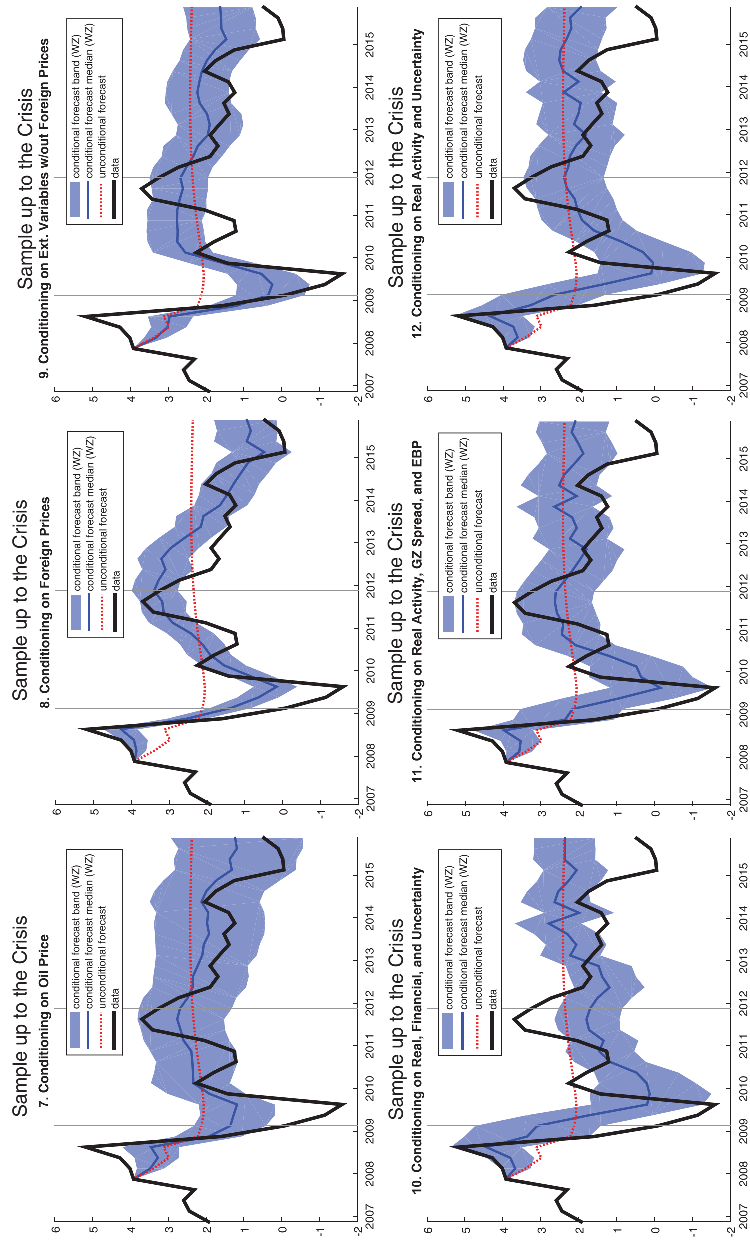
[3]None of our conclusions depends on whether the scenario of the conditional forecast updates the posterior, as in the Waggoner and Zha (1999) sampler, or not. Unless we state otherwise, we report the results from the Waggoner and Zha (1999) sampler because this is the default Bayesian procedure.

Figure 1. Conditional Forecasts of U.S. CPI (year-on-year growth)



(continued)

Figure 1. (Continued)



specification, which is indeed much lower.[4] (For the color version of this and other figures, see http://www.ijcb.org.) We have tried altering the set of variables and the priors, but we always conditionally predicted significantly more inflation than the above reduced-form Phillips curve.

Part of the reason why we don't underpredict inflation is the inertia that our VAR captures. In particular, inflation was temporarily high just before the crisis, and this raises the whole forecast path. If, instead of starting the conditional forecast at the NBER-dated peak of real activity before the recession, we start in 2008:Q3, when inflation peaked, we predict even higher inflation (see panel 2). By contrast, if we start in 2007:Q1, before inflation picked up, the conditional forecast of inflation is substantially lower (see panel 3). The lesson on the importance of inertia is consistent with Watson (2014), who argues that a secular increase in inflation persistence explains much of the missing disinflation.

Our next point is on the global nature of inflation. When instead of conditioning on real activity we condition on external variables the forecast becomes almost perfect irrespective of when we start the forecast (panels 4–6). After the first three plots one might have suspected that the conditional forecasts from this VAR are not very responsive to the conditioning assumptions, either because our sample does not include enough variation in the variables or because the Bayesian prior is too tight and suppresses all relations between variables. However, panels 4–6 show that this is not the case. The forecast conditional on external variables deviates far from the unconditional forecast, implying that the VAR does capture a strong relation between external variables and domestic inflation based on the pre-crisis data.

We investigate the information content of external variables in more detail. Coibion and Gorodnichenko (2015) argue that the price of oil is crucial for understanding inflation in the Great Recession. Therefore, in panel 7 we condition on the price of oil alone. The resulting forecast is much worse than the forecast based on the full

[4] We have replicated their figure 1, panel B. The only reason why the figures look different is that the plot in their paper shows annualized quarterly inflation while the plot in this paper shows annual inflation.

vector of external variables, so the VAR fails to produce a “smoking gun” evidence in favor of the role of oil prices.

Instead, the euro-area consumer prices turn out to be very informative about U.S. consumer prices. When we condition the forecast on the euro-area consumer prices alone, the resulting forecast (panel 8) becomes about as good as when we condition on all the remaining external variables (panel 9). Adding euro-area consumer prices to the other external variables visibly improves the conditional forecast (compare panel 4 with panel 9).

In summary, we have two puzzling findings related to the global nature of inflation. First, the information content of external variables for U.S. inflation is very high even though the United States is a large and relatively closed economy. Second, U.S. and euro-area inflation rates are related beyond what is explained by the price of oil and other commodities, and by the global co-movement in real activity. We are not the only ones to encounter these puzzles. In a related conditional forecasting exercise, Laseen and Sanjani (2016) also find that external variables provide the best conditional forecast of U.S. inflation in the financial crisis, out of many other groups of variables that they try. The literature on the global nature of inflation documents similar findings also outside the financial crisis. Ciccarelli and Mojon (2010) show that the cross-country co-movement of inflation rates is not fully explained by commodity prices. Wang and Wen (2007) and Henriksen, Kydland, and Sustek (2013) show that it is not fully explained by co-movement in real activity. In the next section we return to the relation between U.S. and euro-area inflation and shed more light on it with the help of a structural VAR.

In the next panels we bring financial and uncertainty variables into the picture. The structural accounts of the Great Recession in Christiano, Eichenbaum, and Trabandt (2015) and Del Negro, Giannoni, and Schorfheide (2015) suggest that interest rates and spreads are important for inflation; many narratives of the crisis stress also the role of uncertainty. We find that adding financial and uncertainty variables to real activity makes some difference (panel 10).[5] Unlike in Christiano, Eichenbaum, and Trabandt (2015) and Del Negro,

[5]The forecast of inflation conditional on financial and uncertainty variables alone deviates little from the unconditional forecasts.

Giannoni, and Schorfheide (2015), the resulting inflation forecast is lower than the one conditional on real activity alone (panel 1). Moreover, the additional predicted disinflation comes too late, in 2010 and 2011, when inflation was already recovering. Looking at subsets of these variables, we find that the GZ credit spread and the excess bond premium of Gilchrist and Zakrajsek (2012) appear to contain a more timely signal: adding the GZ credit spread and excess bond premium to the information on real activity revises the forecast downwards in 2009, when it is needed, and hence improves the fit slightly (panel 11).[6]

A VAR, being a linear model, might underestimate the information content of financial variables for inflation. For example, Balke (2000) argues that a non-linear model is needed to study the relation between the financial sector and the macroeconomy. The structural papers on the Great Recession (Christiano, Eichenbaum, and Trabandt 2015; Del Negro, Giannoni, and Schorfheide 2015) introduce various degrees of non-linearity in the DSGE models, while in our VAR this element is missing.

When we add to the real activity the three uncertainty proxies—the VIX, the economic policy uncertainty index, and the JLN macroeconomic uncertainty index—the forecast is also revised downwards in 2009, slightly improving the fit in this period (panel 12; compare with panel 1). We have verified that the JLN macroeconomic uncertainty index is the most informative of the three, while VIX and EPU alone hardly affect conditional forecasts at all.[7]

To sum up, our medium-sized VAR estimated up to the Great Recession does not find the actual inflation to be too high in light of the observed real activity developments, the match of this conditional forecast is reasonable, and certain financial and uncertainty indicators improve the forecast further. The conditional forecasts

[6]Laseen and Sanjani (2016) find that a set of financial variables including the excess bond premium is second only to external variables when it comes to conditionally forecasting U.S. inflation in the crisis.

[7]We have also tried including fiscal volatility shocks constructed by Fernández-Villaverde et al. (2015), but these shocks did not affect the conditional forecasts of inflation. This result is consistent with Fernández-Villaverde et al. (2015). They find strong responses of inflation to fiscal volatility shocks in the sample that includes the 1970s, but no response of inflation in the sample that exclude the 1970s.

are, however, particularly close to the actual data when we condition on external variables. This confirms the global nature of inflation.

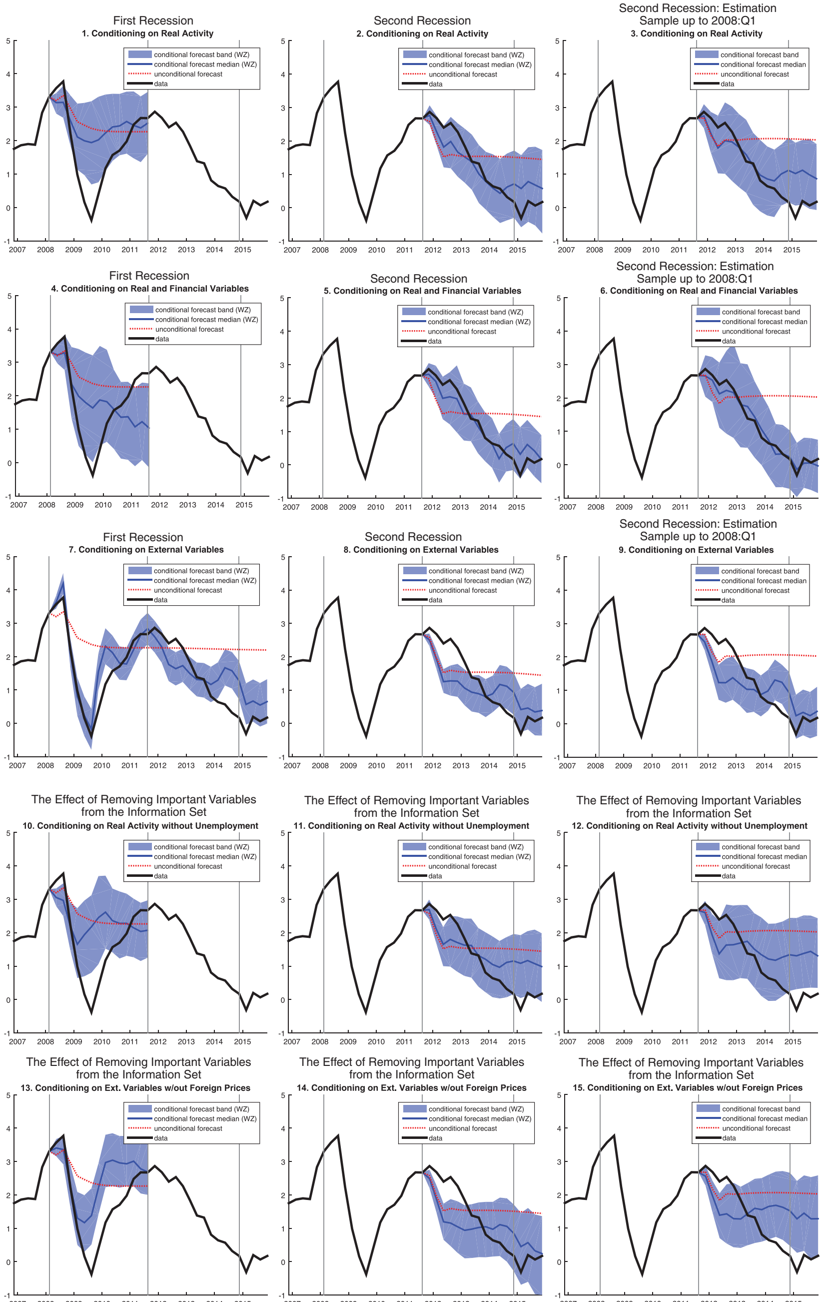
We now turn to the missing disinflation and missing inflation puzzles in the euro area. Figure 2 presents the conditional forecasts of euro-area inflation generated with the euro-area VAR. The first column focuses on the missing disinflation puzzle, while the second and third columns focus on the missing inflation puzzle. We start with the missing disinflation.

Panel 1 shows that there is no missing disinflation in the data according to the euro-area VAR either. We estimate the VAR on the data up to the peak before the first recession, dated by the Center for Economic Policy Research (CEPR) at 2008:Q1 (and marked by a vertical line in the plot). We forecast inflation conditional on actual domestic real activity during the recession and afterwards. We focus first on the period up to the peak before the second recession, dated by the CEPR at 2011:Q3 (and marked by the second vertical line in the plot). Based on the sample 1990:Q1–2008:Q1, a researcher who learns about the extent of the first euro-area recession expects inflation to fall only by about 0.5 percentage point compared with his or her unconditional forecast. This is much less than the 4 percentage points fall actually observed. Adding the financial variables to the conditioning set yields a lower inflation forecast after some delay (panel 4), but the match with the actual inflation data is still poor.

Instead, disinflation appears to be externally driven: when in the same VAR we condition on the actual path of the external variables, the forecast matches the actual outcomes very well (panel 7).

The missing inflation period is very different. This can be seen in the second column of plots in figure 2. For the purpose of this paper we define the missing inflation period as 2011:Q3–2014:Q4 (the end of this period is marked with the third vertical line). In this column we reestimate the VAR on the data up to 2011:Q3, the peak before the start of the second recession according to CEPR. In the missing inflation period the forecast based on the actual path of real activity variables matches the outcomes very well (panel 2). The VAR predicts a steady fall in inflation, similar to what was observed, and hence implies no missing inflation puzzle in actual

Figure 2. Conditional Forecasts of Euro-Area HICP (year-on-year growth)



data. The conditional forecast improves further after incorporating financial variables in the conditioning set (panel 5).

This time the forecast conditional on the external variables matches the outcomes poorly (panel 8). This forecast is too low initially, but then stays above 1 percent at the time when the actual inflation was falling steadily.

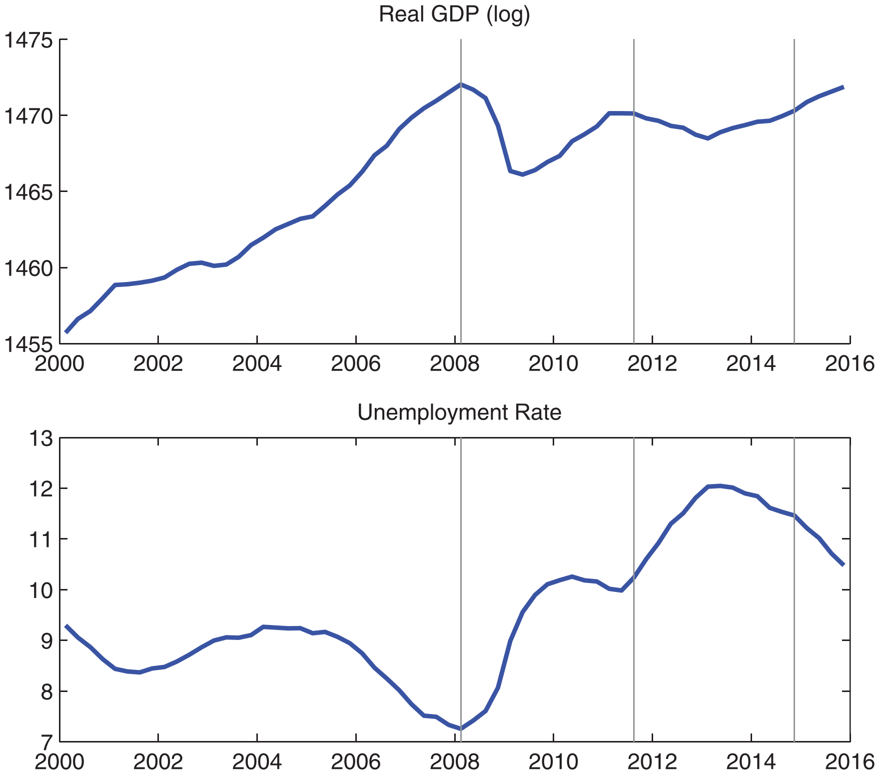
At the end of the sample, after 2014:Q4, external variables again appear to be relevant for inflation. Recall that in this period the price of oil dropped substantially and the Chinese economy slowed down. These developments can be seen in the shape of the conditional forecasts based on external variables—they turn sharply downwards.

Comparing plots 1 and 2, one might suspect that the slope of the Phillips curve changed in the Great Recession. According to this interpretation, a VAR estimated on the pre-crisis sample would imply a weak relation between real activity and inflation, i.e., a flat Phillips curve. Then, after incorporating the data from the first recession, when inflation fell sharply, the VAR parameters would change to imply a steeper Phillips curve. However, the third column of figure 2 shows that this is not the case, i.e., there is no evidence of a change in the slope of the Phillips curve implied by the VAR. In the third column we conditionally forecast inflation starting in 2011:Q3, but using the posterior of the VAR parameters based on the data up to 2008:Q1.[8] Comparing panel 3 with panel 2, we see that the disinflation conditional on the second recession is roughly the same in the VAR estimated up to 2008:Q1 and in the VAR estimated up to 2011:Q3, suggesting that the relation between real activity and inflation remained roughly constant across the two VARs. The similarity of panels 5 and 6 suggests that the relation between real and financial variables, and inflation, also remained roughly constant.

In the lower part of figure 2 we report what happens after removing important variables from the information set. In the euro area the unemployment rate turns out to be the most important real activity indicator: when we omit the unemployment rate, the match

[8] To keep the experiment clean, this time we sample directly from this posterior, instead of using the Gibbs sampler of Waggoner and Zha (1999) that would update the posterior with the information contained in the scenario.

Figure 3. Real GDP and the Unemployment Rate in the Euro Area, 2000–15



of the conditional forecast in the second disinflation gets noticeably worse (panel 11). Our intuition is that the unemployment rate matters because it sharpens the inference about the economic slack, or the output gap. We think in terms of a Phillips curve where the slack, and not the GDP level or growth per se, matters for inflation. Figure 3 illustrates how the unemployment rate sharpens the inference about the slack. Looking at the real GDP in the top plot of figure 3, one can think of many different smooth trend lines with different implications for the slack. In particular, it is not obvious whether the first or the second recession was worse. However, the unemployment rate plot (the bottom plot) clarifies that the amount of slack in the economy was much larger in the second recession.[9,10]

Returning to the lower part of figure 2, we find that, as in the U.S. case, the inflation rate of another major economy (here: United States) is the most informative external variable. When we exclude the U.S. inflation from the information set, the forecast conditional on the remaining variables gets further from actual inflation (see the bottom row of figure 2). However, in the first recession this forecast is still better than the forecast conditional on real activity (panel 13). Overall, when we omit the most important variables, the picture becomes somewhat less clear but is still consistent with the narrative that the first disinflation was more externally driven and the second more domestic.

Figure 4 presents the conditional forecasts based on the VAR estimated up to 2008:Q1; here these forecasts extend to the end of 2015. This figure is a concise illustration of the point that the first disinflation appears to be driven more by external variables (the two bottom plots fit the first disinflation better) and the second more by domestic variables (the two top plots fit the second disinflation better).

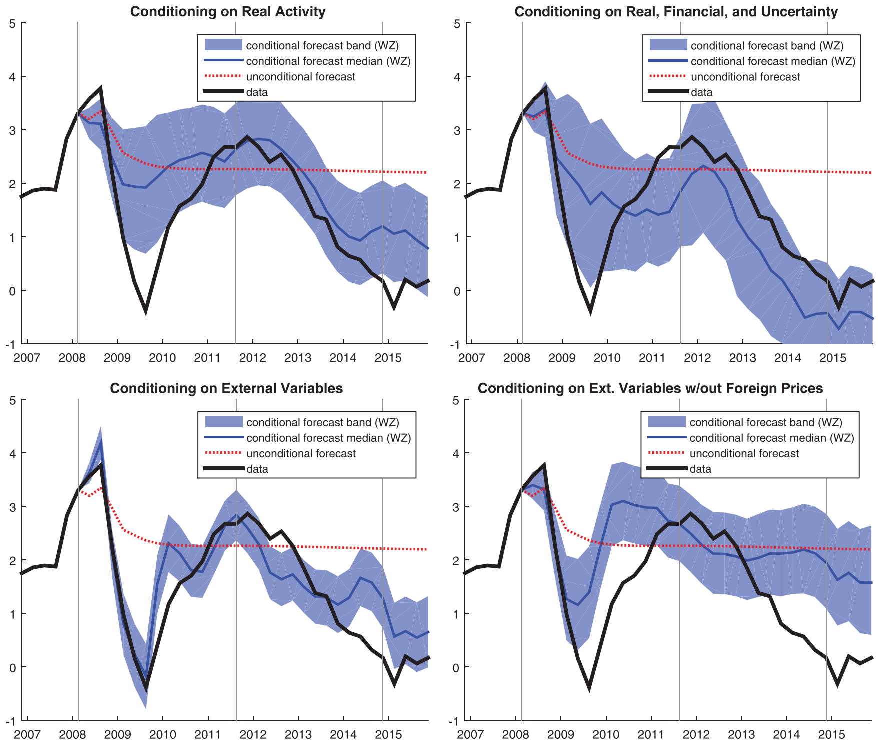
To summarize, in light of our VAR, the euro-area missing disinflation and missing inflation episodes are very different from each other, but none of them appears to be puzzling. The first disinflation can be explained by the dynamics of the external variables. The second can be explained by the weak domestic real activity. Furthermore, adding the data on the Great Recession to the pre-crisis sample does not lead to a material reassessment of the relation between real activity and inflation.

The above discussion of the nature of the inflation fluctuations since the Great Recession, while suggestive, is reduced form and does

[9]For a detailed analysis of the euro-area output gap, see, e.g., Jarociński and Lenza (2016). For another empirical example where the unemployment rate sharpens the inference about the slack beyond what we can learn from GDP alone, see, e.g., Basistha and Startz (2008).

[10]In the United States, omitting the unemployment rate does not make a big difference in the conditional forecasts of inflation in the Great Recession because the unemployment rate and real GDP convey similar information in this period. Here we do not study the subsequent period when the jobless recovery conundrum emerges.

Figure 4. Conditional Forecast of Euro-Area HICP (year-on-year growth) Extended to the End of 2015, VAR Estimated on the Sample up to 2008:Q1



not warrant conclusions on the types of shocks driving inflation in the two episodes. To identify the shocks, we move on to structural VARs.

3. Structural Approach: Shock Identification and Historical Decompositions

In this section we identify external and domestic structural shocks and ask what their contributions are to the dynamics of prices since the start of the Great Recession. This helps us interpret the conditional forecasts from the previous section. There are two main lessons. First, it is plausible that the strong co-movement of U.S. and euro-area inflation during the Great Recession was driven by

U.S. shocks that quickly spilled over to the euro area and the rest of the world. Second, domestic shocks played a large role in the second euro-area disinflation, confirming the lessons from the conditional forecasts.

Since identifying shocks becomes more complex as the number of variables increases, in this section we limit the number of variables to ensure the tractability of the structural model. We use two VARs with seven variables each. The first set of variables is geared towards those that were most important in the conditional forecasts of the previous section. With the second set of variables we replicate two identification schemes proposed in the recent literature. We use standard Bayesian priors with the same hyperparameter values as Sims and Zha (1998) (in terms of table 1, we set $\xi = 1$).

The first VAR includes, in this order, foreign consumer prices (where "foreign" means "euro area" in the U.S. VAR and "US" in the euro-area VAR), rest-of-the-world GDP, real GDP, unemployment rate, consumer prices, short-term interest rate, and the excess bond premium (United States) or the GM bank credit spread (euro area). Foreign consumer prices, unemployment rate, and the excess bond premium turned out to be particularly relevant in the conditional forecasts for either the United States or the euro area, and the rest are standard external and domestic macroeconomic indicators.[11] We compare two identification schemes that use either timing restrictions (Cholesky) or sign restrictions to distinguish the two types of shocks.

We start with a simple benchmark: the Cholesky identification. The first two variables are external, so we label their Cholesky shocks as external and we label the remaining shocks as domestic. This identification relies on a timing restriction: external shocks affect all variables immediately, while domestic shocks affect external variables only with a delay. The results of the Cholesky identification may be biased towards finding large contributions of external shocks, because any co-movement between external and domestic variables is automatically interpreted as a result of external shocks.

[11] The JLN macroeconomic uncertainty index was among the most relevant variables too but is available only for the United States. In a robustness check we include it in the U.S. VAR and find that all the lessons are unchanged.

This identification may be particularly questionable in the case of a large economy, such as the United States.

The sign-restrictions identification relaxes the strong assumption that domestic shocks affect external variables with a delay. Instead, we distinguish the two types of shocks based on the relative amplitude of price changes. Namely, we assume that domestic shocks affect the domestic prices more than foreign prices, and vice versa for external shocks. To implement this identification, we replace the foreign consumer prices, $\log(p)$, with the ratio of domestic to foreign consumer prices, $\log(p/p^*)$, and impose a sign restriction. When $\log(p)$ moves in the same direction as $\log(p/p^*)$, the shock is domestic. When they move in opposite directions, the foreign prices move by more and hence the shock is external. Table 2 presents this sign restriction in panel A. This is a partially identified VAR, in the sense that we only distinguish two groups of shocks and we do not separate and label individual shocks within the groups.

Figure 5 presents the historical decompositions of inflation showing aggregated contributions of external and domestic shocks. As before, although our VARs are in levels, we transform the prices and the contributions of shocks and report them in terms of year-on-year inflation. The vertical lines represent the same dates as before: in the United States the dates are 2009:Q1 and 2011:Q4 (the notional beginning and the end of the missing disinflation) and in the euro area the dates are 2008:Q1 (the peak before the first CEPR recession), 2011:Q3 (the peak before the second CEPR recession), and 2014:Q4.

The two plots for the United States are useful for interpreting the co-movement of U.S. and euro-area inflation in the Great Recession. Euro-area and U.S. prices co-moved very tightly (we can see this by comparing the U.S. inflation on the left with the euro-area inflation on the right). Hence, the benchmark Cholesky identification by construction assigns a large role to external shocks. However, in the U.S. case this result does not survive the relaxation of the zero restrictions in the Cholesky identification. We can see that in the Great Recession the U.S. prices move by more than the euro-area prices (take into account the difference in the scale of the two plots). Hence, our sign-restriction scheme interprets the shocks driving this disinflation as predominantly domestic, as shown in the bottom-left

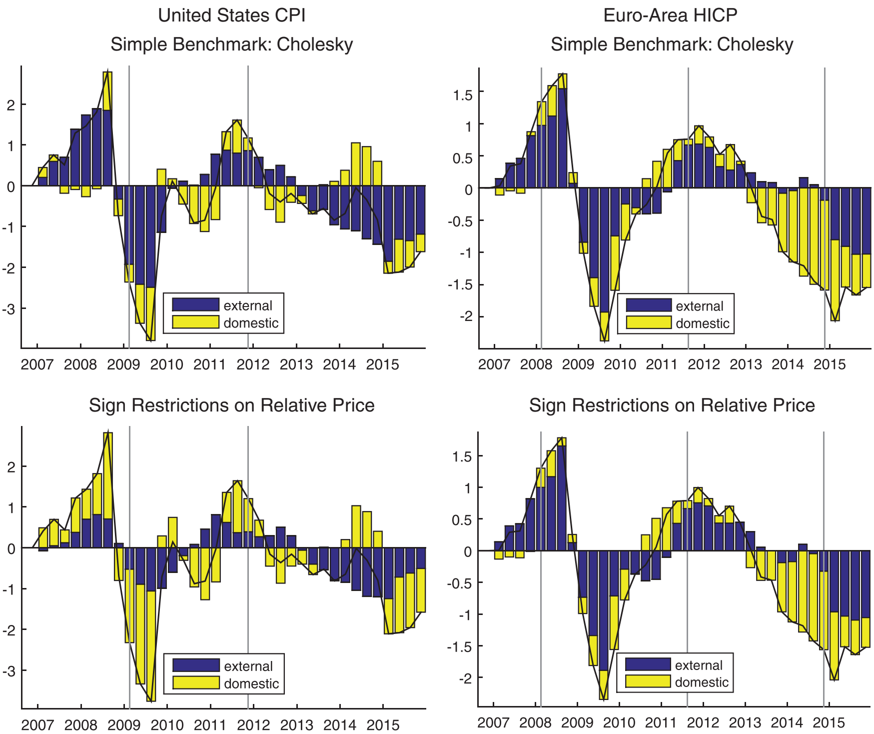
Table 2. Sign and Zero Restrictions Used to Identify Shocks in the Two VARs

A. Restrictions on the Relative Price Movements							
	Shocks						
Variables	**External**	**External**	**External**	**Domestic**	**Domestic**	**Domestic**	**Domestic**
Relative Consumer Prices ($\log(p/p^*)$)	+	+	+	+	+	+	+
Rest-of-the-World Real GDP	•	•	•	•	•	•	•
Real GDP	•	•	•	•	•	•	•
Uenmployment Rate	•	•	•	•	•	•	•
Consumer Prices ($\log(p)$)	−	−	−	+	+	+	+
Short-Term Interest Rate	•	•	•	•	•	•	•
Excess Bond Premium	•	•	•	•	•	•	•

B. Corsetti, Dedola, and Leduc (2014) and Baumeister and Benati (2013)							
	Shocks						
Variables	**Oil Supply**	**Global Demand**	**Domestic Demand**	**Domestic Supply**	**Monetary Policy**	**Spread**	**Residual**
Price of Oil	+	+	•	• (≈0)	•	•	0
Real GDP Share in World Real GDP	•	−	+	+	−	•	0
Real GDP	−	+	+	+	−	−	0
Consumer Prices	+	+	+	−	−	−	0
Short-Term Interest Rate	0	•	+	•	+	0	0
Ten-Year Bond Spread	•	•	•	•	−	+	0
Exchange Rate	+ (•)	•	•	+	+	+	+

Notes: • = unconstrained, + = positive sign, − = negative sign, 0 = zero restriction, ≈0 = magnitude restriction that centers the error band of the responses at zero. All restrictions are imposed on impact. The exchange rate is defined so that a + means an appreciation. In parentheses we show the restrictions used for the U.S. VAR whenever they differ from the euro-area VAR.

Figure 5. Historical Decompositions of Inflation in the Euro Area and in the United States—the First Structural VAR



Note: The black line is the deviation of year-on-year inflation from the unconditional forecast as of 2006:Q4; the bars show the contributions of different types of shocks to this deviation.

plot.[12] While there is no obvious way to statistically discriminate between the two identification schemes, we think that the second interpretation is more plausible.

In light of these results, we can rationalize the conditional forecasting results from the previous section as follows. Inflation in the Great Recession was driven predominantly by U.S. shocks.

[12]The contribution of domestic shocks dominates even though in the sign-restriction identification we isolate three external shocks instead of only two in the Cholesky identification. Of course, domestic shocks also dominate when we isolate only two external shocks; the resulting picture is very similar.

Euro-area prices improve the conditional forecasts of the U.S. inflation so much because the euro-area prices reflected the U.S. shocks very quickly in the Great Recession.[13]

Unlike in the United States, in the euro area the Cholesky and sign-restrictions identifications produce very similar pictures (compare the top-right plot and the bottom-right plot in figure 5). Under either of these identifications the first disinflation was more externally driven, while the second was more domestically driven.

First, both identifications agree on the large role of external shocks in the first disinflation. The Cholesky identification implies a large role of external shocks, because the U.S. and euro-area inflation rates fell simultaneously in the Great Recession. The sign-restriction identification agrees, because the U.S. inflation fell by more, hence the large contributions of external shocks in this identification too.

Second, both identifications agree also on the large role of domestic shocks in the second disinflation, especially during its later part. The second disinflation was specific to the euro area, so we see large contributions of the euro-area shocks whether we relax the zeros in the Cholesky identification or not. This picture changes again around the end of 2014: once more, the negative contributions of external shocks become important.

We confirm the above lessons in the second VAR, where we identify and label each individual shock. The second VAR includes the price of oil, real GDP's share in the world real GDP, real GDP, consumer prices, short-term interest rate, ten-year bond spread, and the nominal effective exchange rate. In this VAR we distinguish between global demand shocks and domestic demand shocks based on the co-movement of domestic real GDP and its world share. This approach follows Corsetti, Dedola, and Leduc (2014) and is akin to the sign restrictions on prices in the first structural VAR above. We distinguish between supply and demand shocks based on the co-movement of prices and quantities, in a standard way: we interpret

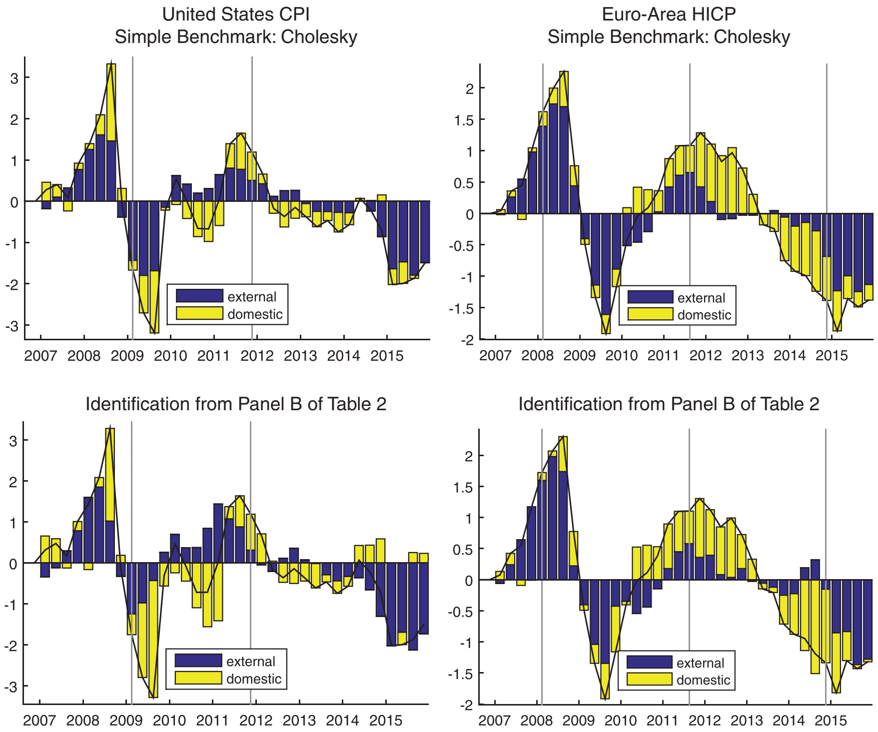
[13]The precise mechanism of such inflation spillovers deserves further study. Henriksen, Kydland, and Sustek (2013) propose an explanation of the cross-country spillovers in inflation rates based on an interaction of TFP spillovers and similar monetary policy rules, but whether a similar mechanism was at work during the Great Recession remains an open question.

a positive co-movement of quantities and prices as a manifestation of a demand shock and a negative co-movement as a manifestation of a supply shock. We identify an *oil supply shock* that increases the price of oil, has a negative impact on real activity, and has a positive impact on inflation. These restrictions reflect the lessons from the literature that identifies various types of oil-related shocks by modeling the global crude oil market and then investigates the impact of these shocks on the key macroeconomic variables (see, for example, Kilian 2009 and Baumeister and Peersman 2013 for the case of the United States). The monetary policy shock and the spread shock are taken from Baumeister and Benati (2013). A contractionary *monetary policy shock* is an increase of the short-term interest rate that has an immediate negative effect on output, prices, and bond spread. A Baumeister-Benati *spread shock* increases the bond spread and reduces output and prices, while leaving the short-term interest rate unchanged. This shock is useful to reflect either non-standard monetary policies or financial tensions when the short-term interest rates are at their effective lower bound. Finally, a residual shock accounts for the fluctuations of the exchange rate not explained by the previous shocks. This shock matters very little for inflation. We add further restrictions based on standard economic reasoning until there are no two shocks with similar impulse responses. Sign restrictions on the exchange rate are often useful for achieving identification. Table 2 presents all the restrictions in panel B and we discuss them in more detail in online appendix B. Of course, there are many ways to define a set of seven shocks that drive the economy (remember that we have seven variables and in a VAR the number of structural shocks is equal to the number of variables), and we think of this specific structural VAR as an example. For a similar structural VAR-based analysis of the recent euro-area inflation that focuses on the role of monetary policy, see also Conti, Neri, and Nobili (2017).

As before, we compare the identification of external and domestic shocks by means of sign restriction with the one using the Cholesky identification.[14] We can see in figure 6 that the lessons from the second structural VAR are very similar to those from the first

[14]When using the Cholesky identification we include the rest-of-the-world real GDP, a purely external variable, instead of the share of domestic GDP in the world.

Figure 6. Historical Decompositions of Inflation in the Euro Area and in the United States—the Second Structural VAR



Note: The black line is the deviation of year-on-year inflation from the unconditional forecast as of 2006:Q4; the bars show the contributions of different types of shocks to this deviation.

structural VAR. In the United States, external shocks only appear important when we identify them with the Cholesky identification, but domestic shocks gain importance when we use the relative amplitude of domestic and global real GDP movements for identification. In the euro area the Cholesky identification implies that external shocks were more important in the first disinflation and less important in the second disinflation. This conclusion is reinforced when we use sign restrictions instead: external shocks gain even more importance in the first disinflation and domestic shocks gain even more importance in the second disinflation.

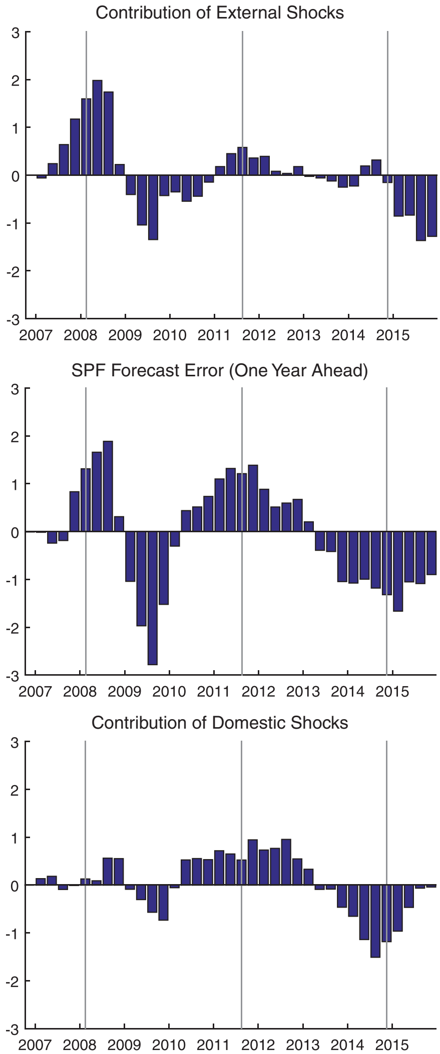
To sum up, according to these results, both external and domestic shocks have driven euro-area inflation in the crisis. In the missing disinflation period external shocks played a larger role, while in the missing inflation period domestic shocks were relatively more important. These findings reinforce the lessons from the conditional forecasts reported in the previous section. Taken together, these findings put some perspective on the literature arguing in favor of inflation in advanced countries being largely a global phenomenon. Ciccarelli and Mojon (2010), using data up to the international financial crisis, find that global inflation explains more than two-thirds of the variance of national inflation rates and that it also acts as an attractor for national inflation. Ferroni and Mojon (2015) revisit the relevance of global factors in the aftermath of the crisis and find that they still explain a dominant part of national inflation. We confirm that global factors account for much of inflation dynamics, but we find that the missing inflation episode in the euro area is mainly driven by domestic shocks.

Figure 7 compares, for the euro area, the errors made by professional forecasters and the contributions of selected types of shocks. The middle panel shows the errors of one-year-ahead inflation forecasts reported in the Survey of Professional Forecasters (SPF), defined as the outcome minus the forecast. Forecasts tend to be clustered around similar values, and the errors of the official European Central Bank forecasts, Eurozone Barometer, and Consensus Economics are very similar. In the top and bottom panels we plot the contributions of, respectively, external and domestic shocks (including monetary policy), from the second structural VAR identified as in panel B of table 2.

One-year-ahead forecast errors and shock contributions are, of course, different objects, but they do have some similarities. The contributions contain the effects of new shocks, which by definition could not have been anticipated a year earlier, and the propagation of all the past shocks. Forecast errors contain the effect of the same new shocks and the part of the propagation of all the past shocks that is misspecified in the forecaster's model.

With this interpretation in mind, the comparison of the middle and the bottom panel is striking: in the missing inflation period the forecast errors are very similar to the contributions of domestic shocks. This suggests a particular interpretation of the persistent

Figure 7. Errors of the SPF Forecasts and the Contributions of Shocks Identified as in Panel B of Table 2



forecast errors in the missing inflation episode, namely that economists, attuned to the global nature of inflation (which was indeed crucial in the preceding period), missed the effect of domestic shocks during this episode.

4. Conclusions

We specify a medium-sized VAR estimated on the data preceding the Great Recession, in which conditional forecasts of inflation in and after the Great Recession match actual realizations well. In light of this VAR, inflation appears to be puzzling neither during the missing disinflation in the United States and the euro area, nor during the euro-area missing inflation episode.

Given that the VAR can account for the inflation dynamics during the "puzzling" episodes, we use it to shed light on their nature. We find strong spillovers from U.S. to euro-area inflation in the Great Recession. However, weak domestic real activity and deflationary domestic shocks are crucial in the second euro-area disinflation. This implies that economists and models that excessively focused on the global nature of inflation were liable to overpredict it during the missing inflation episode. Future research will clarify whether the large role that domestic factors played in this episode simply reflected the regional nature of the euro-area sovereign debt crisis or was a harbinger of the new normal resulting from the slowdown or even reversal of globalization trends.

Our results have practical implications for economic modeling. First, an empirically successful model of inflation needs to account well for both external factors and domestic real activity. Financial and uncertainty indicators may also carry additional information on top of domestic real activity. Second, the link between inflation and real activity has been relevant and remained unchanged during the studied period, which alleviates concerns about the time variation in the slope of the Phillips curve in the aftermath of the Great Recession. By contrast, our results suggest that the composition of the shocks driving the economy was changing over time. Hence, it may be promising to model the volatility of the shock processes as time varying.

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