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Comparing conventional and unconventional monetary policy effects in the euro area and the United States ☆

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ABSTRACT

We use a consistent framework to compare the macroeconomic effects of conventional and unconventional monetary policy in the euro area (EA) and the United States (US). We find that monetary policy has a stronger effect on prices for the conventional policy period. We interpret this result by the lower level of the natural rate of interest during the unconventional policy period. At the same time, the effects of monetary policy on the unemployment rate and financial variables are more comparable between the conventional and the unconventional policy periods. We also find that the effectiveness of unconventional monetary policy in terms of its target impact is lower in the EA than in the US, a result we attribute to differences in central bank institutional design.

1. Introduction

Monetary authorities have expanded their policy toolbox by adopting unconventional policy measures. Many central banks originally resorted to unconventional monetary policy measures in response to the global financial crisis. The evaluation of their effects has already been the focus of research. Eberly et al. (2020) and Rossi (2021) review the literature and assess the effects of these measures. However, there is a lack of a systematic comparison of conventional and unconventional monetary policy effects in the literature. Such evidence on the relative effectiveness of conventional and unconventional policy is crucial for the development of the current monetary policy framework. Accordingly, the objective and main contribution of this paper is to provide a consistent comparison of the macroeconomic effects of conventional monetary policy (CMP) and unconventional monetary policy (UMP) to assess their relative effectiveness in the cases of the euro area (EA) and the United States (US).

The objective of this paper has two sub-objectives. The first sub-objective is to compare the macroeconomic effects of CMP and UMP by considering the dynamics of the natural rate of interest. The second sub-objective is to compare UMP effects for the EA and the US by considering the differences in central bank institutional design. To achieve a consistent evaluation of the macroeconomic effects of CMP and UMP, we use analogous specification and identification methods over the periods of their implementation. In particular, we identify monetary policy shocks with sign restrictions and, alternatively, with instrumental variables. To compare UMP effects for the EA and the US, we also conduct a counterfactual analysis.

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Our estimation results show that the impact of CMP on prices is stronger both in the EA and the US. We interpret this result by the drastic decline in the natural rate of interest during the unconventional policy period. On the other hand, the effects of CMP and UMP on the unemployment rate and financial variables are comparable. Moreover, the empirical analysis shows that UMP significantly improves financial conditions in the EA and the US. We also find differences in UMP effects in the EA and the US, and we attribute them to the timing of the implementation of main unconventional policy measures by the European Central Bank (ECB) and the Federal Reserve System (Fed). In particular, the period of the implementation of main unconventional policy measures reflects the differences in the institutional design of the ECB and the Fed.

The evidence on the relative effectiveness of UMP is mixed in the literature. Debortoli et al. (2020) provide evidence that the performance of the US economy was not affected by the binding ZLB. We provide additional evidence for the EA and relate it to the evidence for the US. Weale and Wieladek (2022) provide evidence in cases of the EA, the UK, and the US that there is no significant difference between the financial effects of CMP and UMP. We complement their work by focusing on the comparison of macroeconomic effects. In the case of the EA, Burriel and Galesi (2018) evaluate UMP effects and compare them with CMP effects over the same estimation period 2007–2015. By contrast, our analysis compares CMP and UMP effects over the consecutive periods of their implementation (in line with Debortoli et al., 2020; Weale and Wieladek, 2022) for both the EA and the US. Ikeda et al. (2024) evaluate the effectiveness of UMP for Japan and the US, and find that the ZLB is an important constraint for the effectiveness of monetary policy. In our case, the focus is on the analysis of the effectiveness of UMP through the consideration of the natural policy rate and institutional factors, and the comparison of the results for the EA and the US.

According to the mandates of many central banks, the primary objective is to maintain price stability, as in the case of the ECB, but an additional objective can also be set, such as maximum employment, as in the case of the Fed. As a conventional policy approach, central banks have set the current level of the monetary policy rate to achieve their objectives. In response to the global financial crisis, monetary authorities lowered their policy rate down to the zero lower bound (ZLB). To stimulate the economy further, they also resorted to UMP measures, such as forward guidance and large-scale asset purchases, which led to a substantial increase in central bank total assets. The goal of large-scale asset purchases was to inject liquidity into the economy, directing it toward capital markets, and thereby increasing security prices and flattening the yield curve.

UMP measures helped to recover from the global financial crisis but their relative effectiveness has been an open question in the literature. We contribute to the literature by comparing the effects of CMP and UMP on the unemployment rate (or alternatively on output) and prices as well as on financial variables through the focus on the dynamics of the natural interest rate over the study period. In particular, we also include it as an additional variable in an alternative specification of our model.

As a relevant factor for the assessment of the effectiveness of monetary policy, we consider the level of the natural interest rate (also called the neutral rate), which corresponds to a monetary policy stance that is neither expansionary nor contractionary. In the case of the low level of the natural rate of interest, the ZLB constraints the policy space, reducing the effectiveness of monetary policy (Bernanke, 2020). For instance, Eberly et al. (2020) claim that while UMP helped to recover from the global financial crisis, the recovery would have been faster if the natural rate had been higher. Thus, we consider the hypothesis that the low level of the natural interest rate constrains monetary policy and reduces its effectiveness.

During the first two decades of the 21st century, the ECB and the Fed operated under different mandates and monetary policy strategies, reflecting differences in institutional design. Established to inherit the credibility of the former Bundesbank, the ECB built its strategy around the price stability mandate and considered the evolution of aggregate liquidity as a prominent analytical pillar for assessing inflation prospects. An especially restrictive Bundesbank legacy was the principle that fiscal and monetary policy should be kept institutionally separate, making taboo even temporary monetization of government debt and thus precluding the implementation of open market debt purchases. This restriction was an important handicap for the ECB because security purchases were an essential tool for the implementation of UMP. At the same time, the Fed not only had a broader mandate, including both price stability and maximum employment, but also used the open market purchases of federal debt as a monetary policy instrument. These institutional differences led to different responses to the global financial crisis, particularly curtailing the initial policy space of the ECB and potentially limiting the effectiveness of its policy actions.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the empirical methodology while Section 4 describes the data. Section 5 discusses the empirical results and Section 6 provides the concluding remarks.

2. Literature review

Our paper is related to the literature on the evaluation of the effects of CMP and UMP. Given the long history of the implementation of CMP, this literature is quite large. Some of the seminal contributions include articles by Peersman and Smets (2003) for the EA and by Christiano et al. (1999), Romer and Romer (2004), and Uhlig (2005) for the US. Coibion (2012) reviews the literature on CMP and compares its effects concluding that they are analogous across different studies if different estimation factors behind them are accounted for. The literature generally provides evidence that expansionary CMP fosters real economic activity and raises prices.

Following the implementation of UMP measures in response to the global financial crisis, new literature on their effects has emerged. Among others, this literature includes the articles by Boeckx et al. (2017), Burriel and Galesi (2018), and Dwyer et al. (2023) for the EA and the articles by Eberly et al. (2020), and Wu and Xia (2016) for the US. Gambacorta et al. (2014) evaluate the effects of UMP for a panel of countries, including the EA and the US. Rossi (2021) provides a comprehensive review of the literature and the methods on the identification of UMP shocks and their effects. In general, the literature finds that expansionary

UMP contributed to recovery from the global financial crisis. It improved economic conditions and eased financial conditions by lowering long-term yields.

There are some studies that compare the effects of CMP and UMP on specific variables. Carvelli et al. (2024) analyze their effects on innovation expenditure. Inoue and Rossi (2019) compare the effects of CMP and UMP on exchange rates. Weale and Wieladek (2022) focus on the comparative analysis of conventional and unconventional policy effects on financial variables. We focus on the comparison of the macroeconomic effects of CMP and UMP while we also analyze the impact of monetary policy on financial variables.

There are different methods to identify a monetary policy shock but the recent literature mainly uses two approaches. It is identified mainly with sign restrictions or instrumental variables. Since the seminal work by Uhlig (2005), a large body of literature has used structural vector autoregression (VAR) models with sign restrictions for the identification of monetary policy shocks (among others, Arias et al., 2019; Boeckx et al., 2017; Burriel and Galesi, 2018; Conti, 2017; Sleibi et al., 2023). The signs restrictions are sometimes supplemented by zero restrictions too. Yet, in the review of monetary policy research, Ramey (2016) questions the application of a zero restriction on output as a way to address the puzzling effect of monetary policy on output. Arias et al. (2019) discuss this issue and, without such a zero restriction, achieve the identification of a monetary policy shock, which has a theoretically coherent effect on output. Considering these discussions, we do not impose a zero restriction on output or the unemployment rate in our empirical analysis.

Conti (2017) uses a structural Bayesian VAR model with sign restrictions to study the monetary policy stance of the Fed with respect to macroeconomic conditions for the overall period of conventional and unconventional policy implementation. Sleibi et al. (2023) assess the effects of UMP on credit co-movements in the EA, using a structural Bayesian VAR model with zero and sign restrictions. In the cases of both the EA and the US, we evaluate and compare the macroeconomic effects of CMP and UMP for the periods of their implementation within a consistent framework with sign restrictions. We interpret our results by focusing on the dynamics of the natural interest rate and on the institutional differences between the ECB and the Fed.

Since the influential work by Gertler and Karadi (2015), structural VAR models with instrumental variables (monetary policy surprises) have widely been used for the identification of monetary policy shocks (among others, Caldara and Herbst, 2019; Eberly et al., 2020; Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021). Measured within a tight time interval following central bank announcements, changes in different asset prices are used as instrumental variables. Within this identification framework, monetary policy and information shocks are distinguished. Jarociński and Karadi (2020) disentangle monetary policy and central bank information shocks, and evaluate their effects on economic variables using a structural VAR model for the EA and the US. Alternatively, Miranda-Agrippino and Ricco (2021) construct an instrument purged from the Fed information effects for the identification of a monetary policy shock in the case of the US. Miranda-Agrippino and Ricco (2023) provide general conditions under which the shock of interest can be invertible in a structural VAR model with external instruments.

The literature provides various approaches to decompose monetary policy surprises (following central bank announcements) into different components. Altavilla et al. (2019) map ECB policy communication through press releases and conferences into yield curve changes. Jarociński (2024) decomposes the responses of financial variables to Fed monetary policy announcements into the components of standard monetary policy, forward guidance, large-scale asset purchases, and information effects. Swanson (2021) identifies the factors of the federal funds rate, forward guidance, and large-scale asset purchases from the changes in asset prices in response to Fed monetary policy announcements. We consider the overall measure of UMP to assess its relative effectiveness with respect to CMP, within the framework of the identification with instrumental variables. In particular, following the approach proposed by Jarociński and Karadi (2020), we identify monetary policy shocks disentangled from central bank information effects.

Existing literature emphasizes the importance of including a sufficient number of variables in VAR models. Kerssenfischer (2019) provides evidence on the importance of including sufficient information in VAR models, which can be used to identify monetary policy shocks with both recursive and instrumental variable approaches. Caldara and Herbst (2019) show that monetary policy systematically responds to financial conditions and emphasize the importance of including a financial variable such as a corporate credit spread (as a forward looking variable) into a model. Accordingly, we include a corporate credit spread (or an alternative variable for financial conditions) into the specification of our VAR model.

3. Empirical methodology

We use a structural VAR model to evaluate the effects of monetary policy, an approach commonly employed in the literature (Coibion, 2012; Rossi, 2021). For comparability, we use a consistent specification of the VAR model to evaluate the effects of both CMP and UMP. The baseline VAR model of order p is specified as follows:

$$y_t = A_0 + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \tag{1}$$

where y_t is a (5×1) vector of endogenous variables; A_0 is a (5×1) vector of intercepts, $A_j s$ (for $j = 1, \ldots, p$) are (5×5) coefficient matrices, and u_t is a (5×1) vector of error terms. The lag order p is set to be equal to 2. It is the largest lag order across all considered VAR models according to the Schwarz information criterion. We choose the lag order of the VAR model based on this criterion because our estimation samples are relatively short and the Akaike information criterion, as another popular criterion, tends to overestimate the lag order of the model (Lütkepohl and Krätzig, 2004). In any case, the estimation results are robust to the consideration of the VAR model with the lag order of 4, which is the largest lag order indicated by the Akaike information criterion for all examined models.

In our baseline specification, the vector of endogenous variables includes the monetary policy rate (the short-term interest rate as an CMP indicator or the shadow rate as an UMP indicator), the harmonized unemployment rate, the harmonized index of consumer prices, the BBB bond spread (for the EA) or the excess bond premium (for the US), and the index of stock prices: $y_t = (MPR_t/SR_t,\ HUR_t,\ HICP_t,\ BS_t/EBP_t,\ SP_t)'$. Following the convention in the literature, we consider the variables in levels in the empirical analysis. The consideration of the variables in levels allows for implicit cointegration relations among the variables (Sims et al., 1990).

Our objective is to adopt a consistent specification of the VAR model that captures the key monetary, macroeconomic, and financial interactions across policy regimes in the EA and the US. Having a consistent specification is essential for the implementation of our comparative analysis. In particular, we aim to use a model specification that is homogeneous across the conventional and the unconventional policy periods in the EA and the US, enabling a comparative analysis.

As a standard measure of CMP, we use the short-term interest rate. As a measure of UMP, we utilize the shadow rate, which is an analogous indicator that accounts for unconventional policy measures (Conti, 2017; Sleibi et al., 2023; Wu and Xia, 2016). Moreover, the short-term and the shadow rates actually coincide for the conventional policy period. As a measure of real economic activity, we employ the harmonized unemployment rate, which is available at the monthly frequency. As an indicator of prices, we use the harmonized index of consumer prices. To control for monetary policy and financial interactions, we include the BBB bond spread or the excess bond premium (Gilchrist and Zakrajšek, 2012), and the index of stock prices in the specification of the VAR model.

The main current approaches for the identification of monetary policy shocks are instrumental variable identification (proxy VAR) and the method with sign restrictions. Since the first method requires an instrumental variable for the monetary policy shock, it is more challenging to have a fully comparable identification approach in this case. The type and strength of instrumental variables might be different between the EA and the US. On the other hand, we can apply the same sign restrictions for the identification of monetary policy shocks in the cases of the EA and the US, allowing us to obtain fully comparable results. Therefore, we identify monetary policy shocks with sign restrictions in our baseline approach. At the same time, we also provide alternative results in the case of instrumental variable identification.

We estimate the VAR model with the Bayesian approach in line with Uhlig (2005), as is common in the case of the identification of monetary policy shocks with sign restrictions (Boeckx et al., 2017; Weale and Wieladek, 2022). In particular, we use an uninformative Normal-Inverse-Wishart conjugate prior. As a normalization, we consider expansionary monetary policy shocks (which are commonly considered for UMP) by imposing a negative sign restriction on the response of the policy rate, with a one percentage point reduction. Based on the algorithm proposed by Rubio-Ramirez et al. (2010), we impose sign restrictions in line with Weale and Wieladek (2022). In particular, as Weale and Wieladek (2022), we impose sign restrictions on impulse response functions (IRFs) on impact and one month thereafter.

To ensure comparability between CMP and UMP effects, we focus on expansionary monetary policy shocks, given that UMP shocks are commonly considered expansionary in the literature (Boeckx et al., 2017; Burriel and Galesi, 2018; Gambacorta et al., 2014). Sign restrictions are imposed in line with the convention in the literature about the effects of expansionary monetary policy shocks. First, we impose that the monetary policy rate decreases following an expansionary shock. We assume that the shock fosters real economic activity by lowering the unemployment rate. As an expansionary monetary policy shock, it should increase prices. We also assume that the shock eases financial conditions and increases stock prices. These effects of the expansionary monetary policy shock as sign restrictions on IRFs are summarized in Table 1.

Alternatively, we also identify monetary policy shocks using instrumental variables. We apply this identification method following the approach proposed by Gertler and Karadi (2015). When we apply this identification approach, we estimate the VAR model with the method of ordinary least squares, in line with Gertler and Karadi (2015). As instrumental variables, we use monetary policy surprises constructed by Jarociński and Karadi (2020). They propose to disentangle monetary policy and information shocks, and, based on their approach, they provide monetary policy surprises for the identification of monetary policy shocks for both the EA and the US. In particular, we use monetary policy surprises constructed by "poor man's sign restrictions" as Jarociński and Karadi (2020) refer to them.

We evaluate the effects of monetary policy through IRFs. For the comparability of the results, we make a normalization that IRFs are for an expansionary shock of a one percentage point reduction in the monetary policy rate. In the case of the baseline identification method with sign restrictions, we report median responses together with the 16th and the 84th percentiles of the posterior distribution generated with 1000 draws. In the case of the alternative identification with instrumental variables, we provide median IRFs together with 68% confidence intervals based on 1000 bootstrap replications. We report the responses of the variables for the period of two years after a monetary policy shock.

Table 1
Sign restrictions.

MPR/SR	HUR	$HICP$	BS/EBP	SP
−	−	+	−	+

Note: + or − means that the effect of the expansionary monetary policy shock is restricted to be positive or negative, respectively. The sign restrictions are imposed on IRFs on impact and one month thereafter.

4. Data description

The overall estimation period is from January 1999 to December 2019. Within this overall period, we use the estimation sample from January 1999 to September 2008 to evaluate the effects of CMP. For the unconventional policy period, we use the estimation samples January 2012–December 2019 and January 2009–December 2015 for the EA and the US, respectively. These samples are specified considering the main periods of UMP implementation in the EA and the US. Alternatively, as a robustness check for the unconventional policy period, we use the estimation samples January 2011–December 2019 and January 2008–December 2016 for the EA and the US, respectively. These alternative extended samples are also used in the case of the instrumental variable identification to ensure that the samples are sufficiently long for the instrumental variable estimation.

The start date of the overall estimation sample is based on the official establishment of the EA[1] on January 1, 1999. The end date of the estimation sample is related to the structural change caused by the Great Lockdown, which started at the beginning of 2020. The combination of CMP and UMP measures have been adopted by the ECB and the Fed since the Great Lockdown. For simplicity and sharper identification, our overall estimation period finishes in 2019, considering the periods when only CMP or UMP was implemented. The start date of the unconventional policy period is related to the beginning of the global financial crisis. As can be seen from Figs. 1(a) and 1(b), monetary policy and shadow rates began to diverge at the end of 2008, and shadow rates turned negative in 2009 for both the EA and the US. This structural change can also be seen from the dynamics of real and nominal natural interest rates[2] in Figs. 1(c) and 1(d). Given the abrupt decrease in the monetary policy rate at the end of 2008, the CMP estimation period finishes in September 2008, excluding the final quarter of the year.

Fig. 1. Monetary policy indicators.

The shadow rate (SR), which is utilized for the unconventional policy period, is the one proposed by Wu and Xia (2016). When the values of the shadow rate are positive, they coincide with the monetary policy rates (MPR), which are employed for the conventional policy period. Specifically, for the CMP analysis, we use the one-month Euribor rate and the federal funds effective rate as the policy

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1 We focus our analysis on the fixed country composition of EA-19, similarly to the work by Burriel and Galesi (2018).

2 The terms "natural" and "neutral" interest rates are used interchangeably in this work and correspond to the concept defined by Holston et al. (2017).

rates for the ECB and the Fed, respectively. As an alternative indicator of UMP, we also use central bank total assets (Fig. A.1) for robustness checks. Their data sources are the ECB and the Fed for the EA and the US, respectively.

In the extension of the empirical analysis, we use the monthly series of the real natural interest rate while we also utilize the quarterly series of the real and the nominal interest rates for a descriptive analysis (Table A.1). Since our main data are at the monthly frequency, we use the monthly estimates of the natural interest rate provided in the work by Davtyan (2025). The quarterly data on the natural rate of interest are from the New York Fed, which provides updated estimates following the approach specified by Holston et al. (2017). The data on the inflation forecast (expectation) are quarterly and come from the OECD. The nominal natural interest rate is then computed at the quarterly frequency as the sum of the natural rate of interest and the inflation forecast.

The data on the macroeconomic variables are from the OECD. The available data on the Harmonized Index of Consumer Prices (HICP) are not seasonally adjusted. Therefore, we first seasonally adjust the data on the HICP. Then, we also make the logarithmic transformation of the resulting seasonally adjusted data on the HICP. At the same time, the data on the harmonized unemployment rate (HUR) are available seasonally adjusted. Since the data on real GDP are not available at the monthly frequency, we use their estimates instead of the unemployment rate as an alternative measure of real economic activity for robustness checks. In the case of the EA, in line with Jarociński and Karadi (2020), we interpolate the quarterly series of real GDP to the monthly series using the industrial production index as a reference series, based on the method proposed by Stock and Watson (2010). In the case of the US, we incorporate the estimates of monthly real GDP data from S&P Global. We use the data on real GDP in logarithmic levels in the empirical analysis.

As an indicator of financial conditions for the US, we use the excess bond premium (EBP) proposed by Gilchrist and Zakrajšek (2012), as is common in the literature (Caldara and Herbst, 2019; Gertler and Karadi, 2015; Jarociński and Karadi, 2020). We utilize its updated series, which is from the Board of Governors of the Fed. The EBP measure is not available for the EA and thus, following Jarociński and Karadi (2020), we use the BBB bond spread (BS), which is from the database of the Fed. As an alternative indicator of financial conditions, we incorporate the new version of the Composite Indicator of Systemic Stress (CISS), which was originally developed by Holló et al. (2012) and measures financial systematic stress. Its smaller values indicate lower levels of financial stress and vice versa. The CISS (also considered by Boeckx et al., 2017; Burriel and Galesi, 2018) is available for both the EA and the US and it is from the database of the ECB. As an index of stock prices (SP), we use the EURO STOXX 50 Equity Index and the S&P 500 index for the EA and the US, respectively. Both indices are from the ECB and we use them in logarithmic levels. The statistical information for all the considered variables is provided in Appendix B.

5. Empirical analysis

We obtain theoretically coherent results. An expansionary monetary policy shock increases consumer and stock prices, and reduces the unemployment rate and the excess bond premium. At the same time, the magnitude of the response of prices is stronger for the conventional policy period[3] while the magnitudes are more comparable for the responses of the unemployment rate and the financial variables. We interpret the difference between the results for the periods of CMP and UMP by the fact that the natural rate of interest has substantially dropped since the beginning of the financial crisis in 2009 (Figs. 1(c) and 1(d)). We also compare the effects of UMP implementation in the EA and the US by considering the differences in central bank institutional design.

5.1. Comparison of CMP and UMP effects

We analyze IRFs to a one percentage point unexpected reduction in the policy rate. First, we compare IRFs for the periods of CMP and UMP in the case of the EA. Then, we compare the effects of CMP and UMP in the case of the US.

Fig. 2 displays the results for CMP effects for the EA. A CMP shock decreases the unemployment rate by approximately 1.5 percentage points and raises prices up to 3 percent. On impact, the shock reduces the bond spread by 5 percentage points and increases stock prices by 40 percent.

Fig. 3 provides the results for the unconventional policy period in the case of the EA. An UMP shock reduces the unemployment rate by approximately 0.8 percentage points. Following the shock, prices increase up to 0.7 percent. On impact, the shock decreases the bond spread by nearly 1 percentage point and raises stock prices by around 10 percent.

For the US, Fig. 4 shows that a CMP shock lowers the unemployment rate by around 1 percentage point. The shock increases prices up to 6 percent. Following the expansion, the excess bond premium decreases by approximately 1.8 percentage points. The shock raises stock prices on impact by around 20 percent.

In the case of the US, the results for the unconventional policy period are presented in Fig. 5. An UMP shock reduces the unemployment rate by approximately 1.2 percentage points. The shock raises prices by around 2.5 percent. Following the shock, on impact, the excess bond premium declines by approximately 1 percentage point and stock prices rise by around 20 percent.

In summary, the magnitudes of the IRFs for the unemployment rate and the financial variables are comparable for the shocks of CMP and UMP. The comparability of the responses of financial variables to the shocks of CMP and UMP is similar to the founding by Weale and Wieladek (2022). At the same time, in line with the results obtained by Burriel and Galesi (2018) and Gambacorta et al. (2014), the response of prices to the UMP shock is smaller than its response to the CMP shock for both the EA and the US.

[3] Burriel and Galesi (2018) find similar results when they compare CMP and UMP effects based on the same period January 2007–September 2015 for the estimation of the effects of both policy measures.

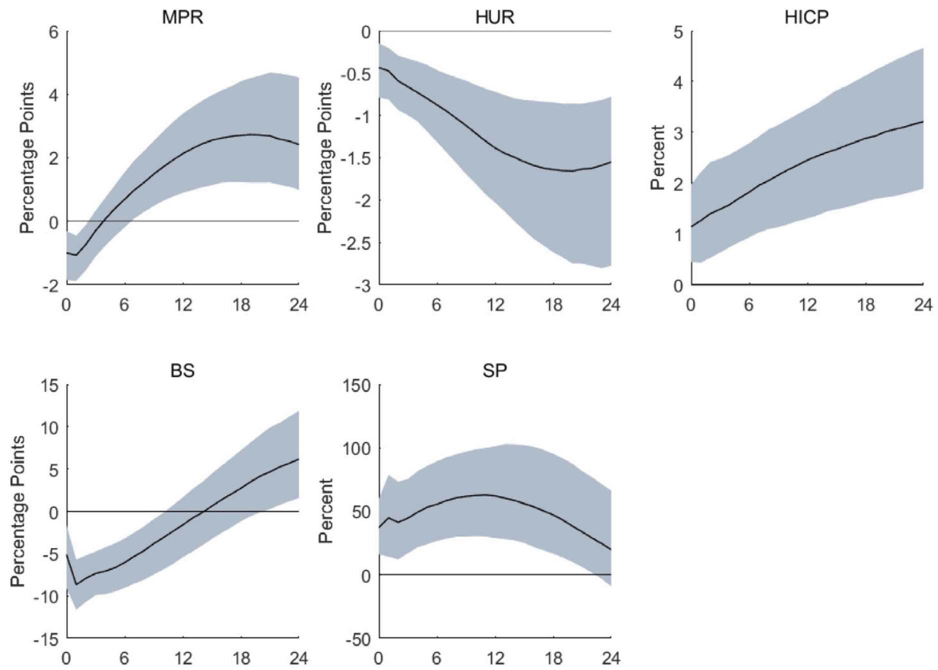

Fig. 2. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

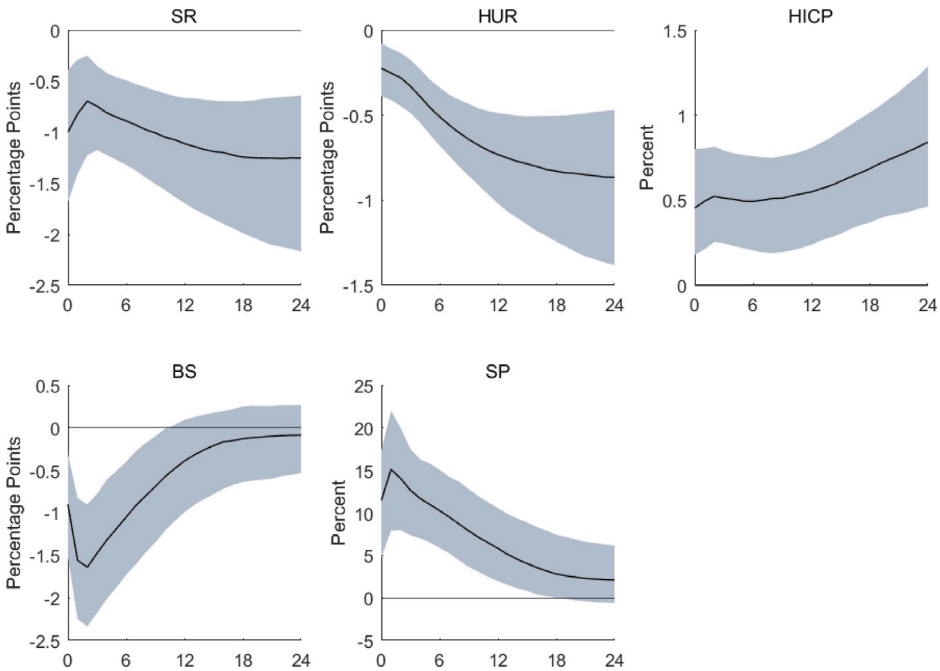

Fig. 3. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

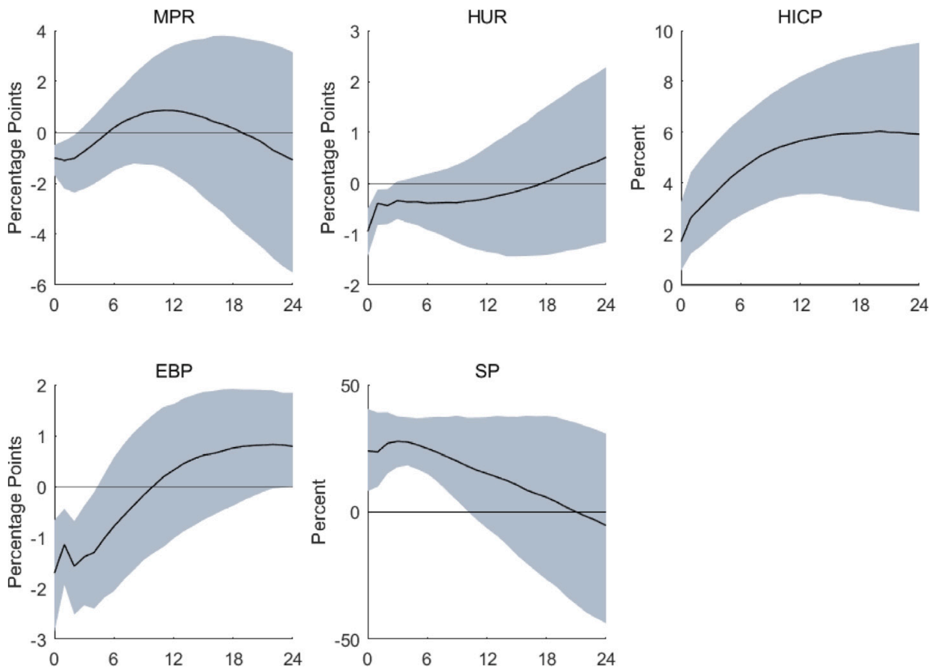

Fig. 4. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

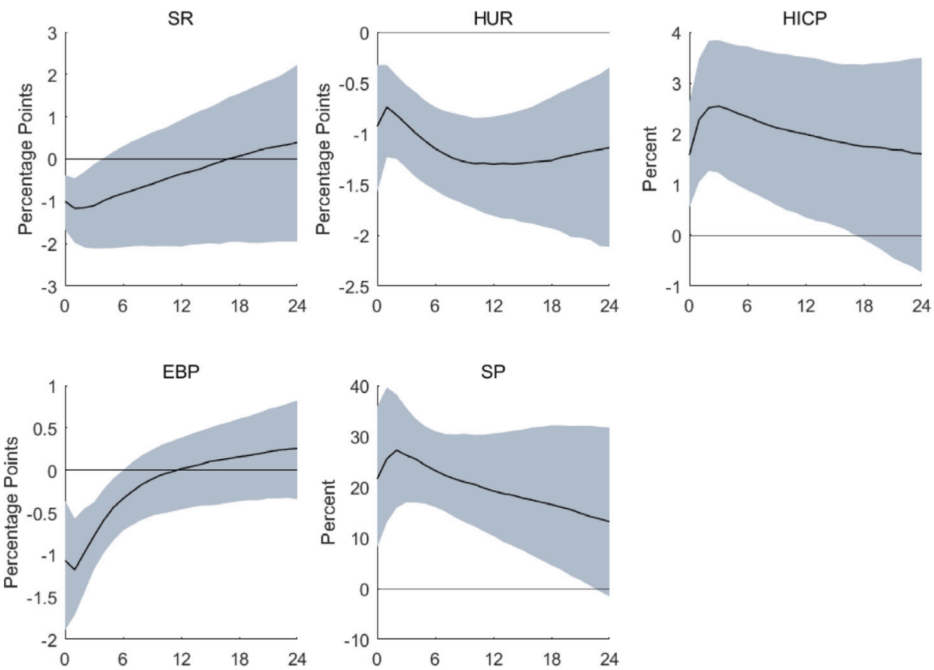

Fig. 5. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

While IRFs are normalized to be the responses of the variables to a one percentage point reduction in the policy rate, the IRFs of the policy rates have different dynamics in the remaining response periods. To account for the different dynamics of the IRFs of the policy rates and the associated IRFs of the other variables, we compute impact multipliers based on them. In particular, we compute impact multipliers as the ratio of the cumulative sum of the IRFs of a given variable to the cumulative sum of the IRFs of the policy rate. We provide the results for the first six months over which the accumulated IRFs of the policy rate are expansionary across all the considered baseline cases. The impact multipliers are reported in Appendix C. In line with the baseline results, the impact multipliers show that the effects of UMP shocks on prices are smaller while the effects of CMP and UMP shocks on the unemployment rate and the financial variables are more comparable.

We examine both the statistical significance and the signs of the differences between the effects of CMP and UMP over the response period. In line with Debortoli et al. (2020) and Weale and Wieladek (2022), we compute the differences between the median responses as well as the 16th and the 84th percentiles of the posterior distribution for the periods of CMP and UMP. The differences are graphically represented as IRFs and they are provided in Appendix D. The signs of the differences between the effects of CMP and UMP on the unemployment rate and the financial variables are mixed. Besides, the differences for the financial variables are not fully significant across the response period. Yet, the differences between the effects of CMP and UMP on prices are positive and statistically significant throughout the entire response period. In particular, the effects of CMP on prices are evidently larger in comparison with the UMP effects. We summarize the signs of the differences between the effects of CMP and UMP in Table D.1.

Various robustness checks of the results are conducted. The monetary policy shock is alternatively identified with instrumental variables (Appendix E). The lag order of the VAR models is extended to be 4, which is the largest lag order indicated by the Akaike information criterion for all considered models. (Appendix F). We extend the UMP estimation samples to January 2011–December 2019 and January 2008–December 2016 for the EA and the US, respectively (Appendix G). As an UMP indicator,[4] we use central bank total assets[5] instead of the shadow rate (Appendix H). We replace the series of the unemployment rate with the interpolated series of real GDP (Appendix I). The corporate bond spread is substituted with the CISS (Appendix J). In all these cases, the results are generally analogous to the baseline IRFs.

5.2. The natural interest rate and the effectiveness of UMP

A key determinant of the lower effectiveness of UMP relative to CMP appears to be the level of the natural (neutral) interest rate. Specifically, the low level of the natural rate reduces the space for expansionary monetary policy by making the ZLB binding and reducing the effectiveness of monetary policy (Bernanke, 2020). Moreover, as Benati (2020) shows, the dynamics of the natural interest rate also affect the velocity of money.

Figs. 1(c) and 1(d) show that both the real and the nominal natural interest rates declined significantly between the first and the second decades of the 21st century. Table A.1 provides their average values across the conventional and the unconventional policy periods. During 1999–2008, the average real natural rates were 2.1% and 2.6% while, during 2009–2019, they declined to 0.6% and 0.5% for the EA and US, respectively. For the nominal natural rate, during 1999–2008, the average rates were 4.3% and 5.5% whereas, during 2009–2019, they decreased to 1.9% and 2.1% for the EA and the US, respectively.

The policy rate cuts implemented by the ECB and the Fed to mitigate the impact of the global financial crisis resulted in the average policy rates of 0.4% and 0.7%, respectively, for the period 2009–2019. That is, the average policy rates were 1.5 and 1.4 percentage points below the nominal natural rate for the EA and the US, respectively, making the ZLB a clear binding constraint for the effectiveness of monetary policy. While the average policy rates were also below the nominal natural rate for the period 1999–2008, they were well above the ZLB, at the levels of 3.2% and 3.5% in the EA and the US, respectively.

To control for the dynamics of the real natural interest rate over the conventional and the unconventional policy periods, we include the real natural interest rate in the VAR model as an additional variable.[6] At the same time, we do not impose any identification restriction on the natural interest rate and keep our original identification framework. We extend the model with the natural interest rate for all the cases considered in the baseline analysis. The results show that the previously obtained IRFs are largely unchanged in the case of the extended model (Appendix K).

5.3. Comparison of UMP effects in the EA and the US

By comparing the relative effectiveness of monetary policy in the EA and the US during the unconventional policy period (Figs. 3 and 5), we observe that it was more effective in the US than in the EA. Our results for the EA indicate that the impact of UMP on prices is smaller. This difference in the results cannot be explained by the dynamics of the natural interest rates in the EA and the US as they were virtually identical during the unconventional policy period.

4 Because of limited data availability, we use the actual series of central bank total assets (as for example, Boeckx et al., 2017; Sleibi et al., 2023). Nevertheless, some papers Hesse et al. (2018), Weale and Wieladek (2022) claim that asset purchases are announced in advance before their actual implementation and thus the change in totals assets might already be anticipated. Therefore, it is suggested using the series of the announcements of asset purchases instead of total assets or actual asset purchases to capture their effects better.

5 The IRF of the total assets is normalized to increase by 1% on impact, given that we consider an expansionary monetary policy shock.

6 To control for the declining equilibrium real interest rate in Japan, Hayashi and Koeda (2019) augment their VAR model with the trend growth rate, which is closely related to the natural interest rate.

One factor behind the difference in the results is probably the fact the Fed was legally fit to adopt aggressive UMP actions from the start of the global financial crisis, implementing three large-scale asset purchase (quantitative easing) programs between 2008 and 2015. This policy implementation by the Fed led to a fourfold increase in its balance sheet (Fig. A.1) and to a reduction in the financial stress. By contrast, the ECB was legally constrained to buy the government debt of member states. So, its market operations consisted of regular weekly main refinancing operations and newly introduced longer-term refinancing operations. The latter were offered from March 2008 to February 2012, with a 6-month initial term, which was progressively increased to 12 months in the offer of June 2009 and to 36 months in the offers of December 2011 and February 2012, as the European debt crisis aggravated. As a result, the ECB balance sheet peaked in 2012, representing a twofold increase relative to its level in 2008. Yet, as longer-term refinancing instruments matured, the ECB balance sheet shrank, and, by early 2015, its size was only 35% higher than in 2008. (Fig. A.1).

The ECB created a new policy tool in 2012 to bypass the legal prohibition on buying the government debt of member states. It was called Outright Monetary Transactions. This tool was introduced after tough negotiations and was approved despite the final opposition from the German representative of the ECB Governing Council. The deployment of this tool was subject to conditionality. The ECB could purchase the government debt of member states if some conditions were satisfied. Yet, the conditions were so demanding that no member state ended up qualifying and the tool was not deployed. In any case, the mere fact that the creation of Outright Monetary Transactions signaled the credible intention of the ECB to act as a lender of last resort if needed was enough to calm market turmoil. Italian and Spanish 2-year government bond yields declined by 2% while the yields of the same maturity remained unchanged in France and Germany (Altavilla et al., 2016). The policy tool helped to bring the risk of a self-fulfilling downward spiral under control in the sovereign debt market of the EA.

The ECB again resorted to longer-term refinancing operations in September 2014. This time, they were referred to as targeted. Nevertheless, it was not until 2015 that the ECB received the green light to implement genuine asset purchase programs involving systematic purchases of the government debt of all member states. The argument that made this possible was that the large dispersion of government debt yields was impairing the transmission of monetary policy actions, and thus the ability of the ECB to fulfill its mandate of price stability. In March 2015, the ECB began injecting liquidity by buying the government debt of member states and, by 2019, its balance sheet was three times larger than in 2008. Yet, this policy implementation led to a smaller relative expansion than the one undertaken by the Fed. Besides, it was the result of an erratic trajectory driven by the institutional design that was not fully fit for the agile and effective policy response required in the aftermath of the global financial crisis. This fact appears to be reflected in lower policy effectiveness during the unconventional policy period.

In summary, in response to the global financial crisis, the Fed reacted fast and had completed its main UMP measures by 2015. By contrast, the adoption of UMP measures by the ECB came with a delay because of institutional constraints. The timelines of UMP measures implemented by the ECB and the Fed are presented in Tables L.1 and L.2, respectively. To evaluate the differences in the timing of policy responses by the ECB and the Fed during the unconventional policy period, we conduct an additional analysis.

For the unconventional policy period, we first study the cumulative effect of monetary policy shocks on the evolution of the variables in the EA.[7] As can be seen from Fig. 6, the cumulative contribution of monetary policy shocks was relatively more expansionary during the period from 2012 to 2016. In particular, mainly during this period, the unemployment rate decreased, prices went up, the bond spread declined, and stock prices increased.

Fig. 7 shows that, for the unconventional policy period in the US, the cumulative effect of monetary policy shocks on the variable was already relatively expansionary in 2009, with the peak impact occurring in 2014. This policy expansion generally led to a decline in the unemployment rate, an increase in prices, a decrease in the bond spread, and a rise in stock prices. Thus, the comparison of Figs. 6 and 7 shows that the main period of UMP expansion occurred later in the EA than in the US.

We also estimate a series of counterfactual monetary policy shocks that allows the path of the EA shadow rate to replicate the trajectory of the US shadow rate for the period from 2009 to 2015. Using this counterfactual series, we also simulate the paths of the other variables for the EA. We then compute the difference between the counterfactual and the actual values of the variables. That is, we explore how the dynamics of the EA variables would have changed, all else equal, if the EA shadow rate had followed the same path as that of the US shadow rate. According to the results presented in Fig. 8, the dynamics of the changes in the variables would generally have been better in the EA. In particular, at the end of 2013, the unemployment rate would have been lower by around 2 percentage points and prices would have been higher by approximately 1 percentage point. Thus, if the ECB had acted as promptly as the Fed, the economic recovery from the global financial crisis might have occurred earlier in the EA.

[7] The variables are in their original units in the current empirical analysis.

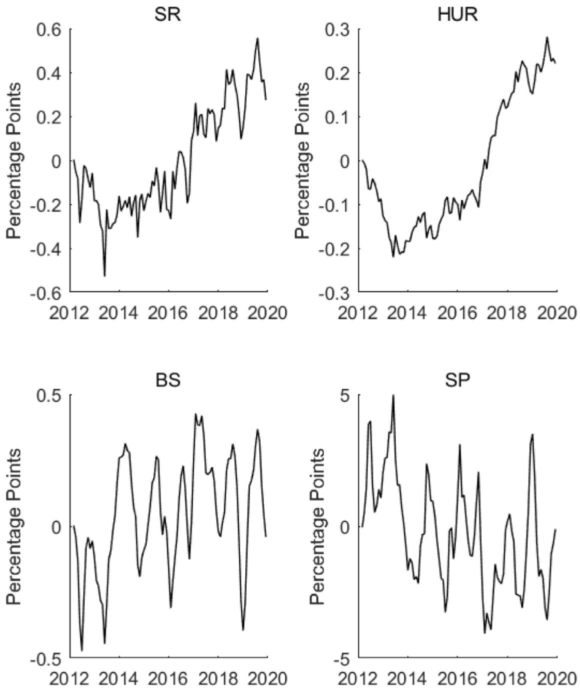

Fig. 6. Cumulative effect of UMP shocks (the EA).
Note: The figure depicts the cumulative effect of UMP shocks on the evolution of the variables. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

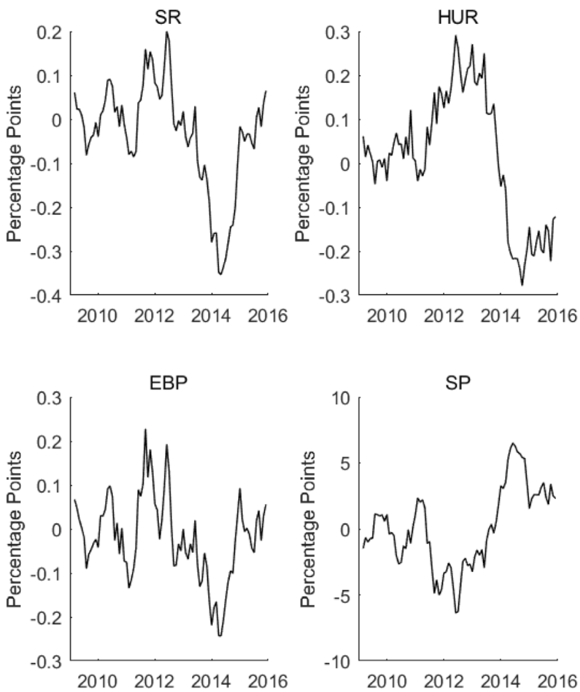

Fig. 7. Cumulative effect of UMP shocks (the US).
Note: The figure depicts the cumulative effect of UMP shocks on the evolution of the variables. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

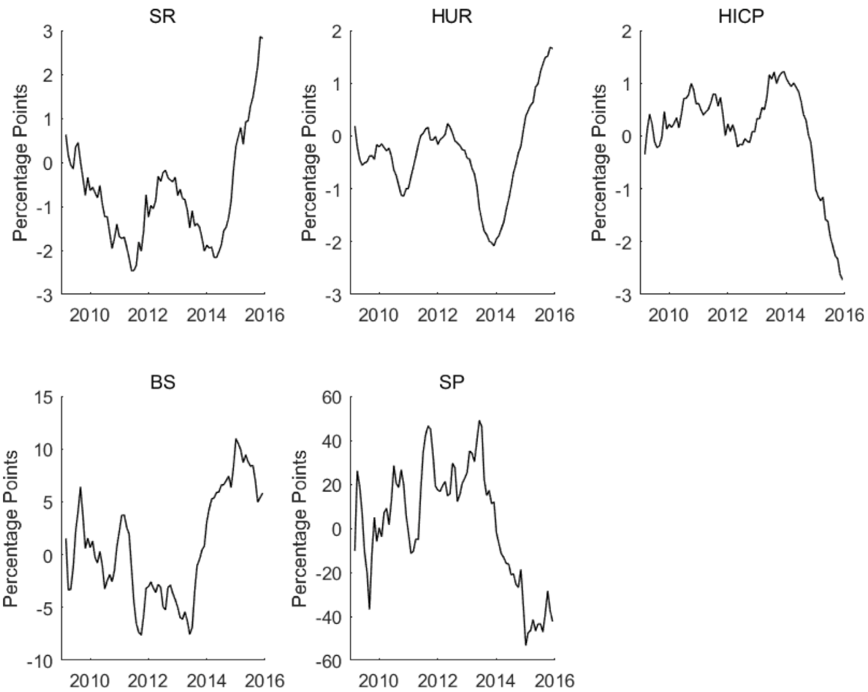

Fig. 8. Difference between the counterfactual and actual values of the variables (the EA).
Note: The figure depicts the difference between the counterfactual and the actual values of the variables. The counterfactual values are constructed under the scenario in which the EA shadow rate followed the same trajectory as the US shadow rate. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

6. Conclusion

We provide a consistent comparison of the effects of monetary policy in the EA and the US between the conventional and the unconventional policy periods. We examine monetary policy effects over these periods through the lens of the dynamics of the natural interest rate. We also explore the institutional factors underlying central bank responses to the global financial crisis by examining the timing of UMP effects in the EA and the US.

The results show that the impact of monetary policy on prices is weaker for the unconventional policy period in both the EA and the US. We attribute this result to the lower level of the natural rate of interest during the unconventional policy period. At the same time, the responses of the unemployment rate and the financial variables are more comparable between the conventional and the unconventional policy periods.

For the unconventional policy period, the effect of monetary policy on prices is relatively smaller in the EA than in the US. We interpret these differences in the results by the institutional factors that characterized central banking in the EA and the US during the unconventional policy period. In particular, UMP measures implemented by the ECB were more effective in the second half of the 2010s whereas the Fed undertook effective UMP measures from the onset of the global financial crisis.

On the policy side, our empirical results highlight the significant constraints faced by policymakers because of the too low natural interest rate and rigid central bank institutional design. Efforts to ease these constraints appear essential for increasing the space and the effectiveness of monetary policy.

CRediT authorship contribution statement

Fernando Ballabriga: Writing – review & editing, Writing – original draft, Visualization, Validation, Funding acquisition, Conceptualization. **Karen Davtyan:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Monetary policy indicators

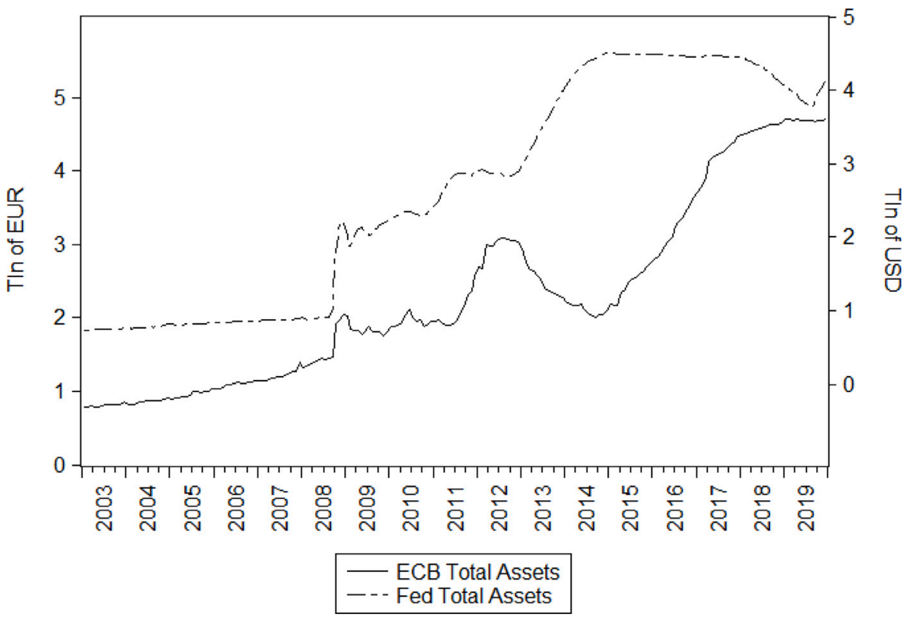

Fig. A.1. Central Bank total assets (the ECB and the Fed).
Note: The figure displays the ECB and the Fed total assets. The data sources are the ECB and the Fed, respectively.

Table A.1
Average real and nominal natural interest rates (the EA and the US).

Policy periods	R. Natural rate (EA)	R. Natural rate (US)	N. Natural rate (EA)	N. Natural rate (US)
1999–2008	2.08	2.63	4.30	5.45
2009–2019	0.63	0.54	1.89	2.13
2008–2015	0.85	0.74	2.40	2.44
2012–2019	0.49	0.46	1.64	2.07

Note: The table provides the average real and nominal natural interest rates in the EA and the US across the conventional and the unconventional policy periods.

Appendix B. Statistical characteristics of the variables

Table B.1
Statistical characteristics of the variables (the EA).

	CMP period (Jan. 1999–Sept. 2008)				UMP period (Jan. 2012–Dec. 2019)			
Variables	Mean	SD	Max	Min	Mean	SD	Max	Min
MPR	3.24	0.94	4.95	2.04	−0.12	0.29	0.84	−0.46
SR	3.08	0.83	4.28	1.98	−3.36	2.42	0.52	−7.82
HUR	8.74	0.70	10.10	7.30	10.15	1.59	12.20	7.40
HICP	81.95	5.21	91.97	73.66	100.95	2.17	105.41	97.07
BS	6.36	3.51	15.37	1.91	4.40	1.46	9.50	2.46
SP	3609.71	799.46	5317.08	2086.46	3139.01	385.19	3733.80	2152.75
TA	0.93	0.20	1.47	0.69	3.33	0.97	4.70	2.01
RGDP	2.24	0.13	2.47	2.00	2.52	0.10	2.69	2.38
CISS	0.14	0.12	0.53	0.00	0.12	0.11	0.43	0.00

Notes: The table shows statistical information on the following variables: the monetary policy rate (MPR), the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), the index of stock prices (SP), total assets (TA), real GDP (RGDP), and the Composite Indicator of Systemic Stress (CISS). The variables are in their original units. The data on total assets and real GDP are in trillion of EUR.

Table B.2
Statistical characteristics of the variables (the US).

Variables	CMP Period (Jan. 1999–Sept. 2008)				UMP Period (Jan. 2009–Dec. 2015)			
	Mean	SD	Max	Min	Mean	SD	Max	Min
MPR	3.51	1.81	6.54	0.98	0.13	0.04	0.24	0.07
SR	3.36	1.89	6.65	0.67	−1.23	0.89	0.88	−2.99
HUR	4.99	0.69	6.30	3.80	7.81	1.57	10.00	5.00
HICP	79.39	6.27	92.53	69.58	96.07	3.53	100.47	89.53
EBP	0.16	0.70	1.81	−1.05	0.11	0.68	3.23	−0.50
SP	1233.25	175.18	1539.66	837.48	1481.27	391.46	2111.94	757.13
TA	0.82	0.06	1.01	0.72	3.19	0.89	4.51	1.88
RGDP	15.23	1.14	17.09	13.22	17.50	0.81	18.92	16.25
CISS	0.09	0.10	0.47	0.00	0.15	0.17	0.70	0.00

Notes: The table shows statistical information on the following variables: the monetary policy rate (MPR), the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), the index of stock prices (SP), total assets (TA), real GDP (RGDP), and the Composite Indicator of Systemic Stress (CISS). The variables are in their original units. The data on total assets and real GDP are in trillion of USD.

Appendix C. Impact multipliers computed based on IRFs

Table C.1
Impact multipliers (the EA).

Variables	Months					
	1	2	3	4	5	6
			CMP Period			
HUR	0.43	0.44	0.54	0.70	0.96	1.41
HICP	−1.14	−1.16	−1.36	−1.71	−2.27	−3.27
BS	5.12	6.66	7.74	9.38	11.93	16.30
SP	−37.28	−39.68	−44.08	−54.27	−71.81	−103.15
			UMP Period			
HUR	0.22	0.26	0.30	0.33	0.36	0.39
HICP	−0.45	−0.52	−0.59	−0.61	−0.61	−0.61
BS	0.90	1.35	1.63	1.71	1.69	1.64
SP	−11.47	−14.61	−16.15	−16.34	−15.96	−15.43

Note: The impact multipliers are computed as the ratio of the accumulated IRFs of a given variable to the accumulated IRFs of the policy rate. The VAR models include the following variables: the monetary policy rate/the shadow rate (MPR/SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP).

Table C.2
Impact multipliers (the US).

Variables	Months					
	1	2	3	4	5	6
			CMP Period			
HUR	0.95	0.64	0.57	0.55	0.58	0.64
HICP	−1.71	−2.08	−2.38	−2.81	−3.41	−4.27
EBP	1.70	1.35	1.41	1.50	1.64	1.82
SP	−23.99	−22.68	−23.94	−26.51	−30.16	−35.25
			UMP Period			
HUR	0.93	0.77	0.75	0.77	0.81	0.87
HICP	−1.58	−1.78	−1.92	−2.02	−2.11	−2.19
EBP	1.07	1.04	0.97	0.91	0.85	0.80
SP	−21.61	−21.82	−22.47	−22.82	−23.39	−23.95

Note: The impact multipliers are computed as the ratio of the accumulated IRFs of a given variable to the accumulated IRFs of the policy rate. The VAR models include the following variables: the monetary policy rate/the shadow rate (MPR/SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP).

Appendix D. Differences between CMP and UMP effects

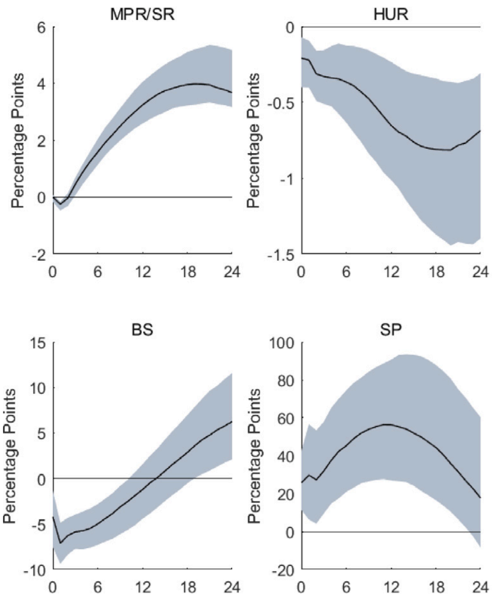

Fig. D.1. Differences between IRFs for CMP and UMP (the EA).
Note: The solid lines report the differences between the median responses of the posterior distribution for the periods of CMP (January 1999–September 2008) and UMP (January 2012–December 2019) while the gray areas represent the 68% credible intervals. The VAR models include the following variables: the monetary policy rate/the shadow rate (MPR/SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP).

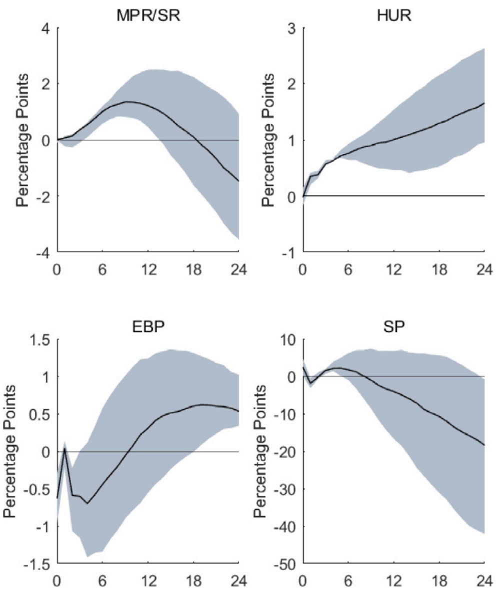

Fig. D.2. Differences between IRFs for CMP and UMP (the US).
Note: The solid lines report the differences between the median responses of the posterior distribution for the periods of CMP (January 1999–September 2008) and UMP (January 2009–December 2015) while the gray areas represent the 68% credible intervals. The VAR models include the following variables: the monetary policy rate/the shadow rate (MPR/SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP).

Table D.1
Signs of the differences between IRFs for CMP and UMP (the EA and the US).

	CMP vs UMP				
	MPR/SR	HUR	$HICP$	BS/EBP	SP
EA	+	−	+	?	+
US	+	+	+	?	?

Note: +, −, or ? means that the sign of the difference between IRFs for the periods of CMP (January 1999–September 2008) and UMP (January 2012–December 2019/January 2009–December 2015) is predominantly positive, negative, or inconclusive, respectively. The VAR models include the following variables: the monetary policy rate/the shadow rate (MPR/SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread/the excess bond premium (BS/EBP), and the index of stock prices (SP).

Appendix E. Results based on instrumental variable identification

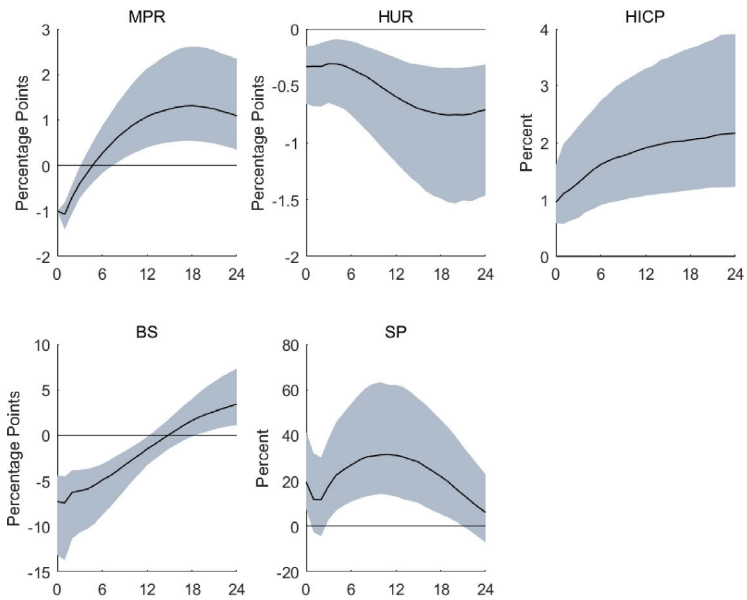

Fig. E.1. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% confidence intervals. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

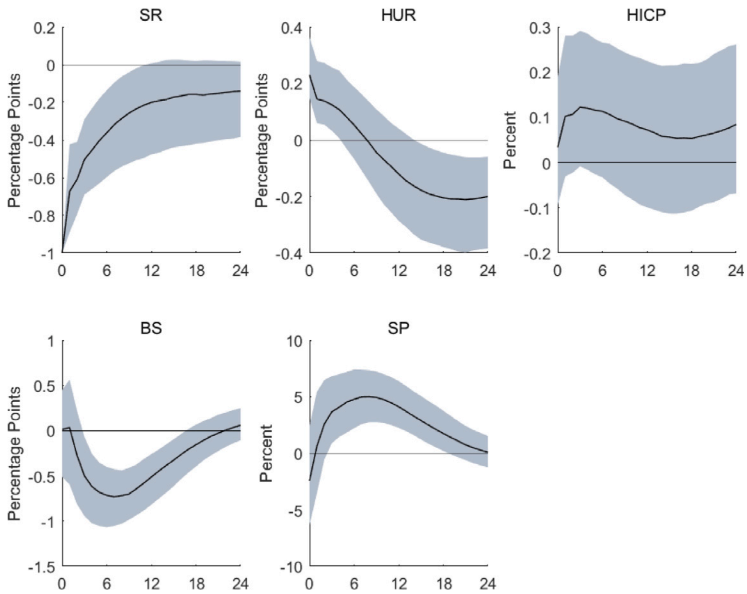

Fig. E.2. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% confidence intervals. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2011–December 2019.

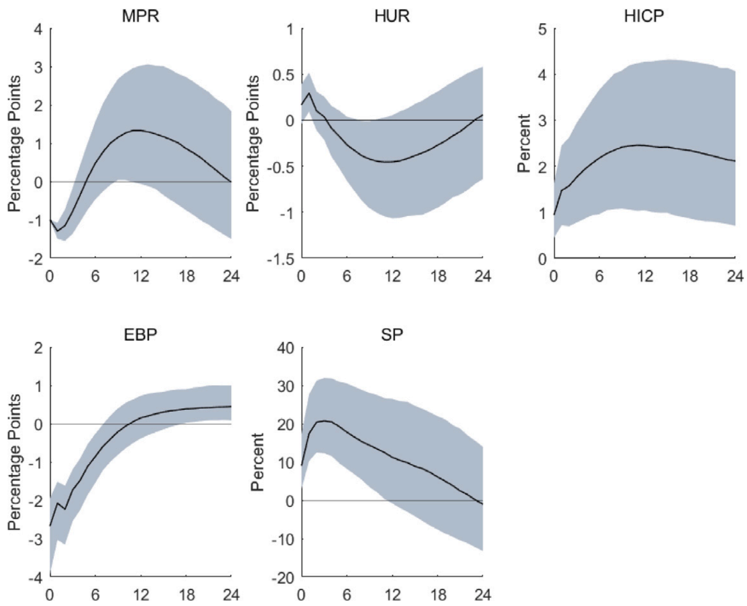

Fig. E.3. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% confidence intervals. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

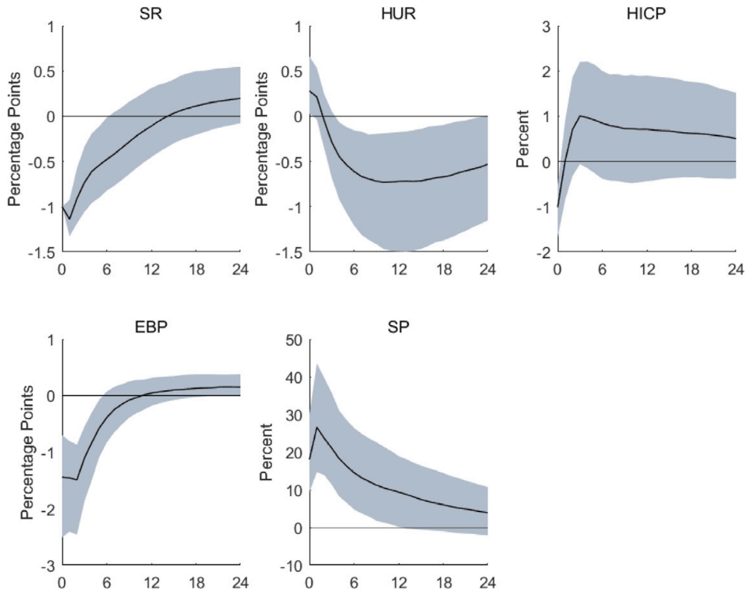

Fig. E.4. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% confidence intervals. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2008–December 2016.

Appendix F. Results for the VAR model with the lag order of 4

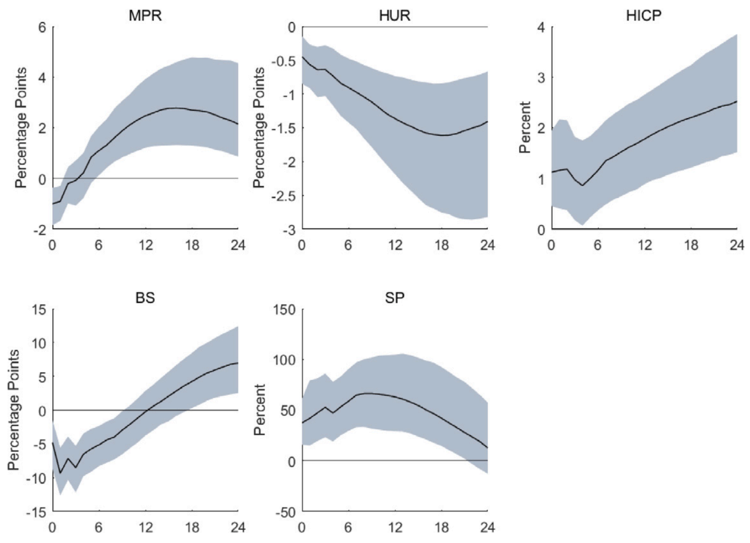

Fig. F.1. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

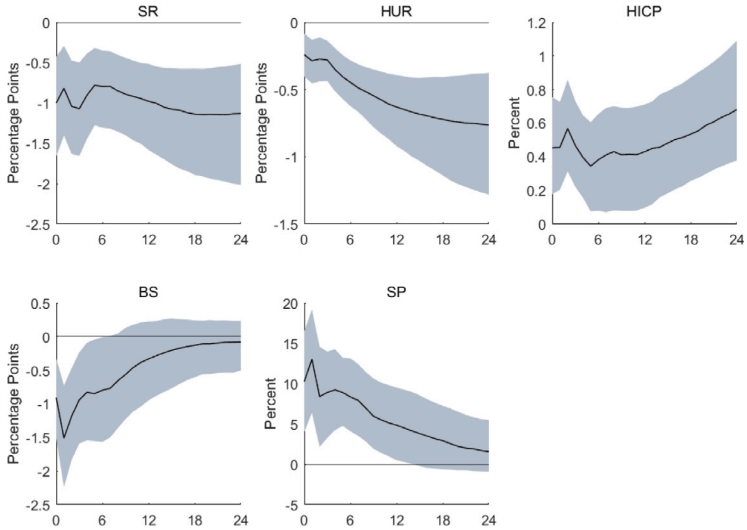

Fig. F.2. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

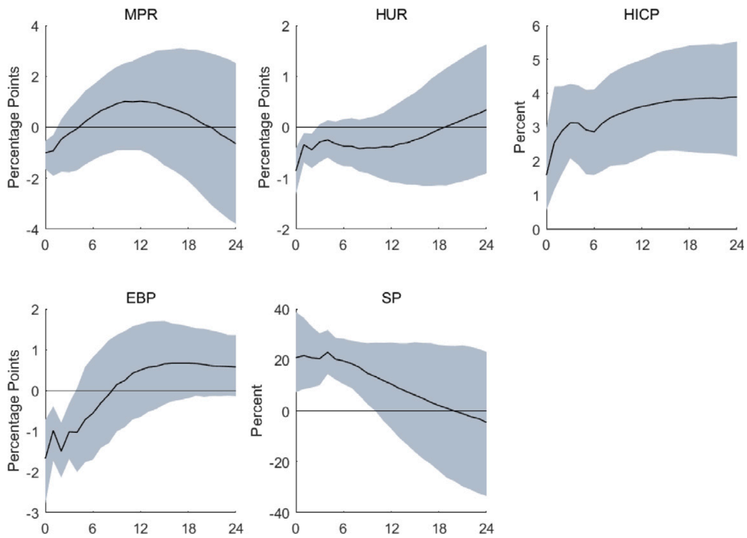

Fig. F.3. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

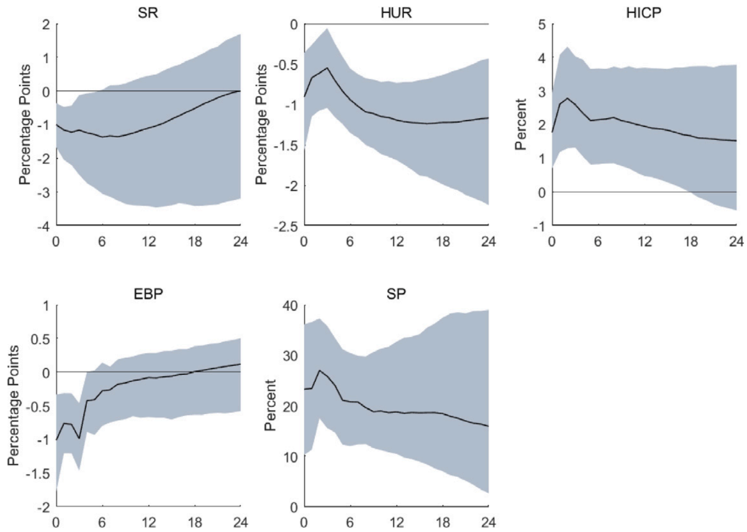

Fig. F.4. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

Appendix G. Results for different UMP estimation samples

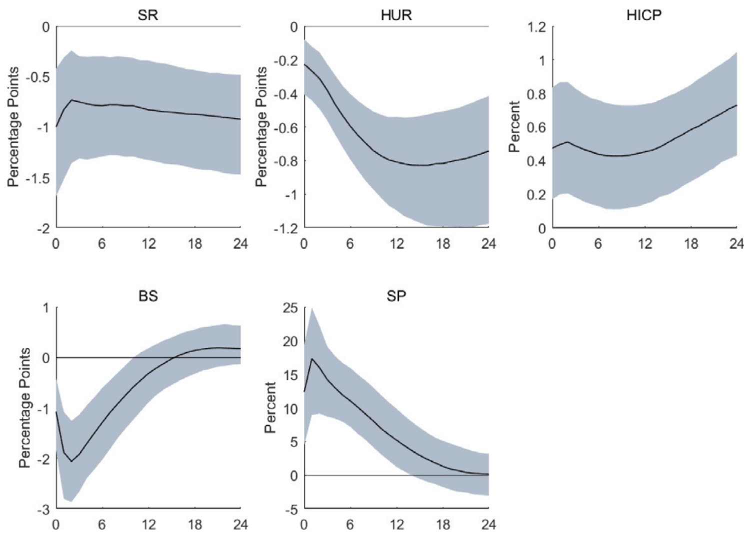

Fig. G.1. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2011–December 2019.

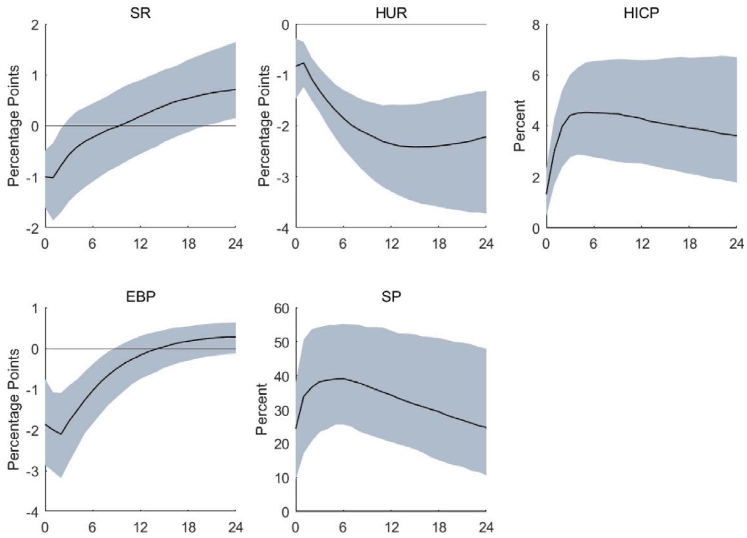

Fig. G.2. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2008–December 2016.

Appendix H. Results for the model with central bank total assets

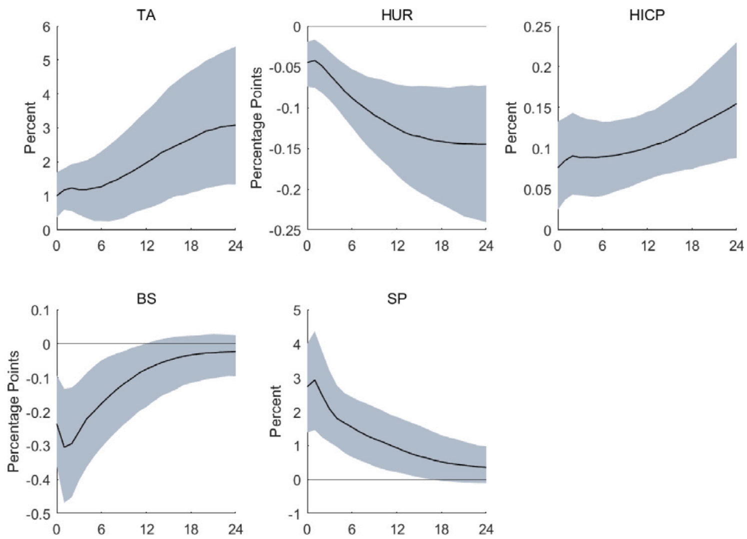

Fig. H.1. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: central bank total assets (TA), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

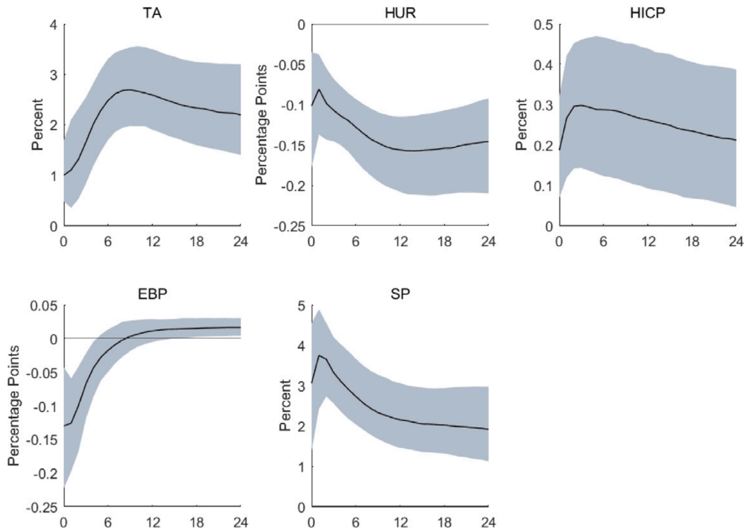

Fig. H.2. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: central bank total assets (TA), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

Appendix I. Results for the model with real GDP

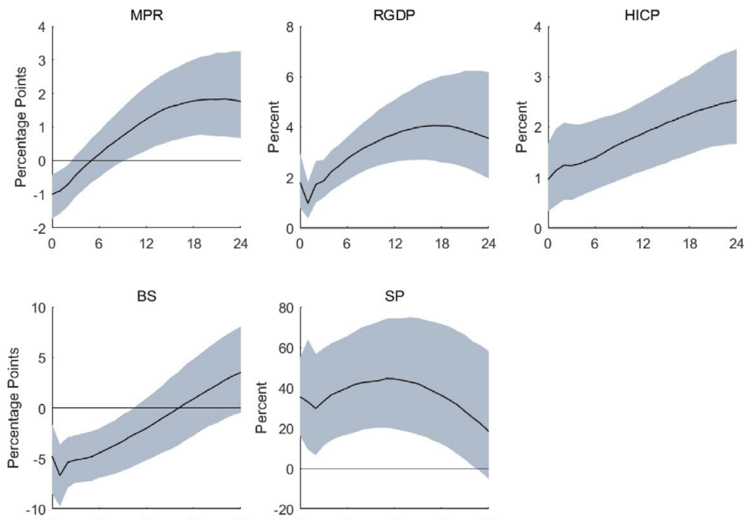

Fig. I.1. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% confidence intervals. The VAR model includes the following variables: the monetary policy rate (MPR), real GDP (RGDP), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

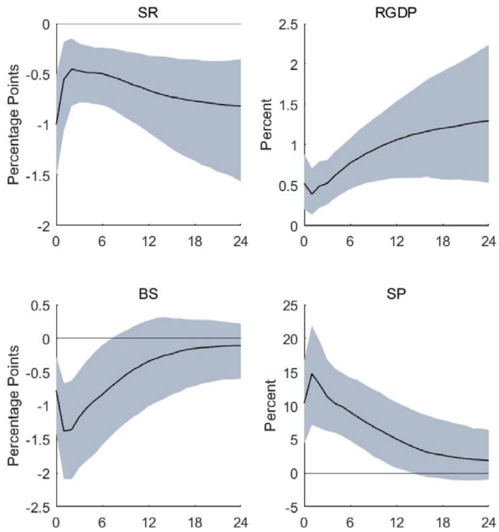

Fig. I.2. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), real GDP (RGDP), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

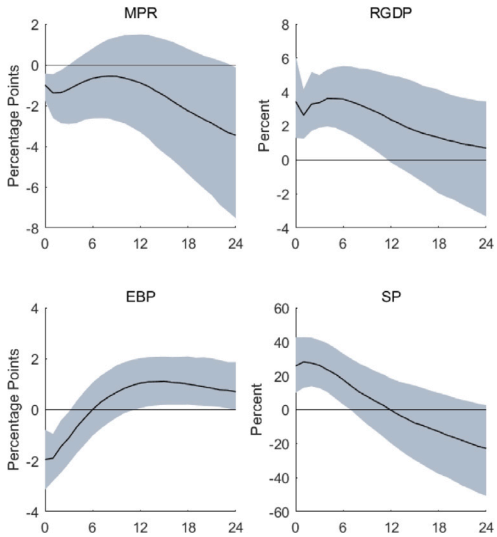

Fig. I.3. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), real GDP (RGDP), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

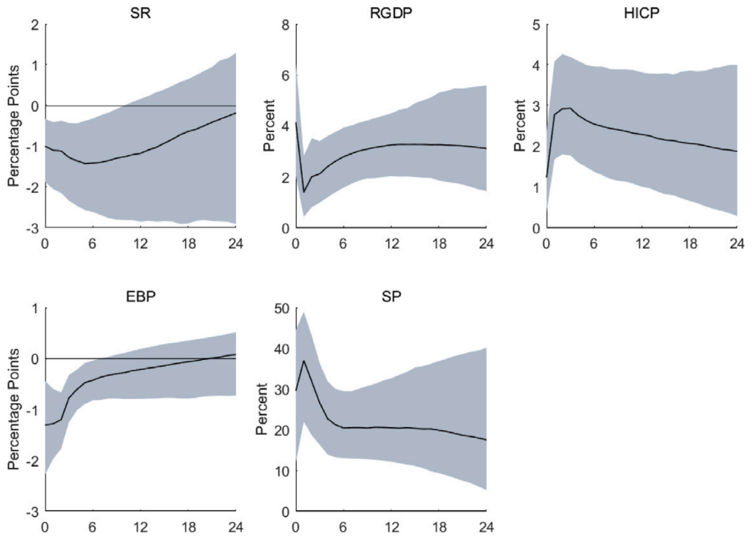

Fig. I.4. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), real GDP (RGDP), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

Appendix J. Results for the model with the CISS

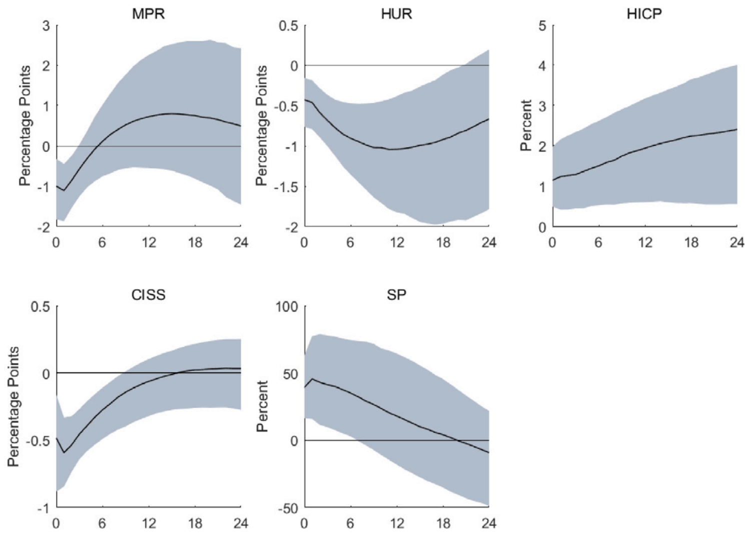

Fig. J.1. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the Composite Indicator of Systemic Stress (CISS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

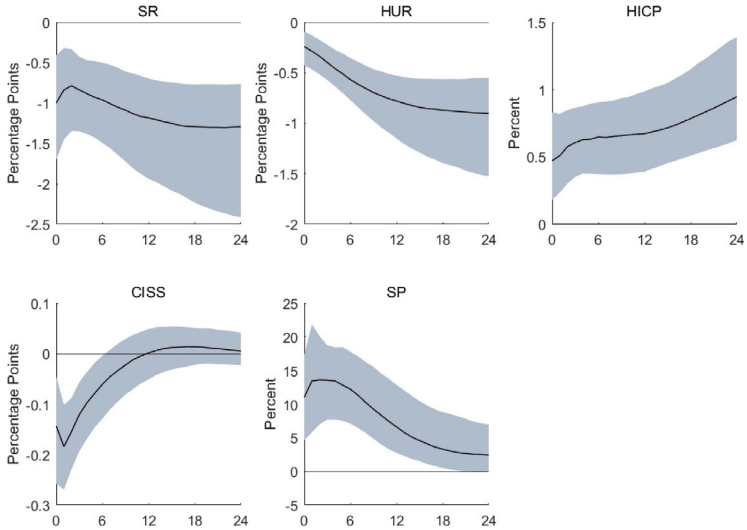

Fig. J.2. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the Composite Indicator of Systemic Stress (CISS), and the index of stock prices (SP). The model is estimated over the period January 2012–December 2019.

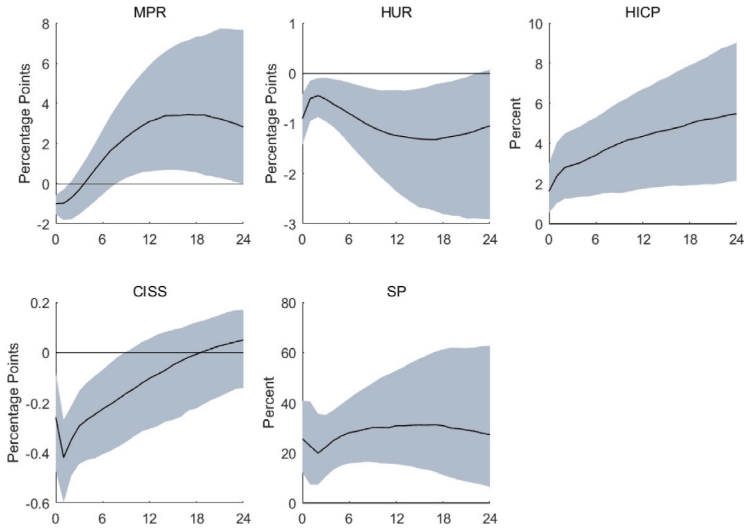

Fig. J.3. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the Composite Indicator of Systemic Stress (CISS), and the index of stock prices (SP). The model is estimated over the period January 1999–September 2008.

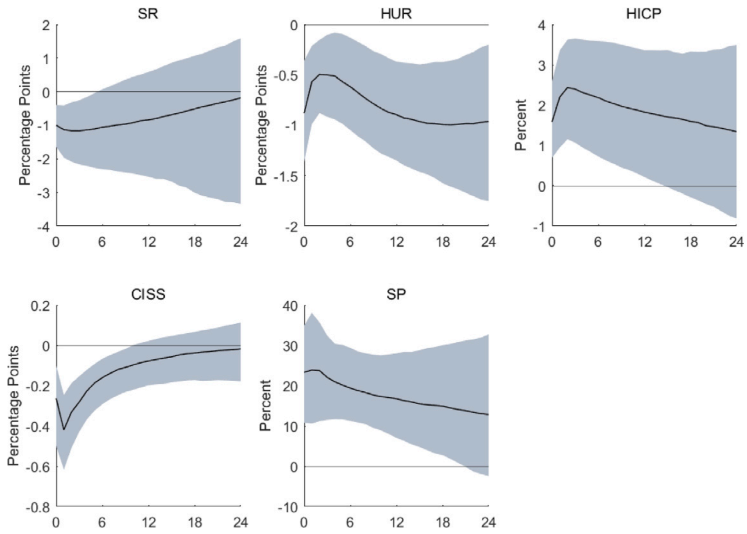

Fig. J.4. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the Composite Indicator of Systemic Stress (CISS), and the index of stock prices (SP). The model is estimated over the period January 2009–December 2015.

Appendix K. Results for the extended model with the natural rate

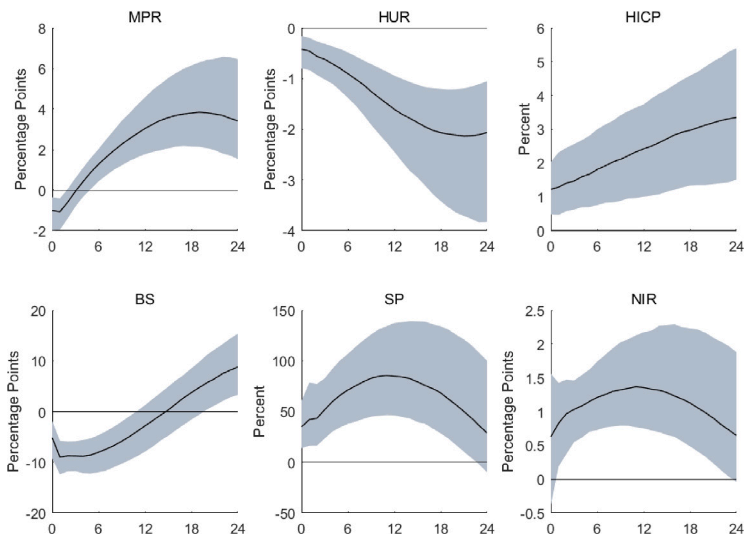

Fig. K.1. IRFs to a CMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), the index of stock prices (SP), and the natural interest rate (NIR). The model is estimated over the period January 1999–September 2008.

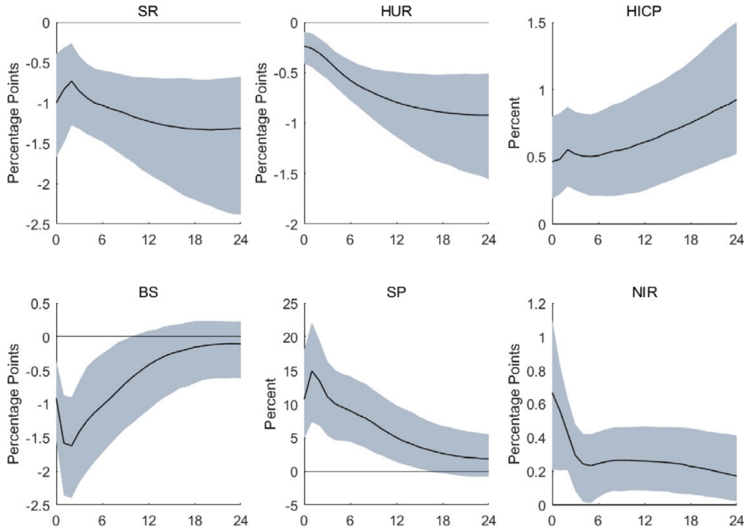

Fig. K.2. IRFs to an UMP shock (the EA).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the BBB bond spread (BS), the index of stock prices (SP), and the natural interest rate (NIR). The model is estimated over the period January 2012–December 2019.

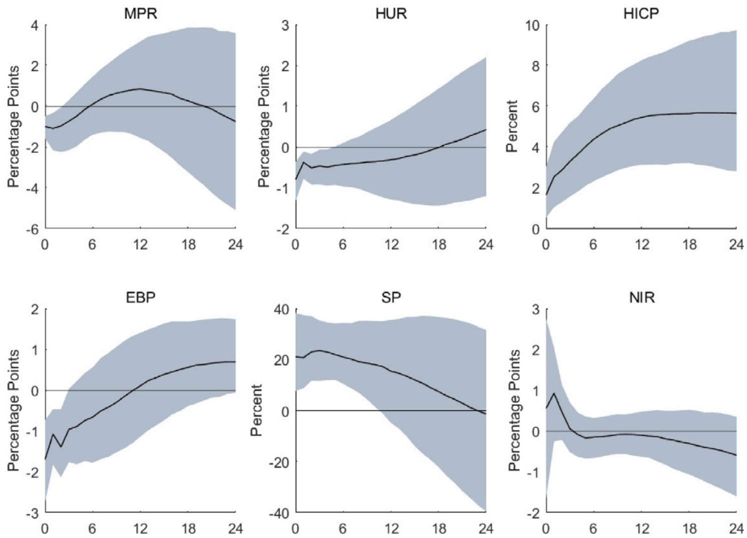

Fig. K.3. IRFs to a CMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the monetary policy rate (MPR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), the index of stock prices (SP), and the natural interest rate (NIR). The model is estimated over the period January 1999–September 2008.

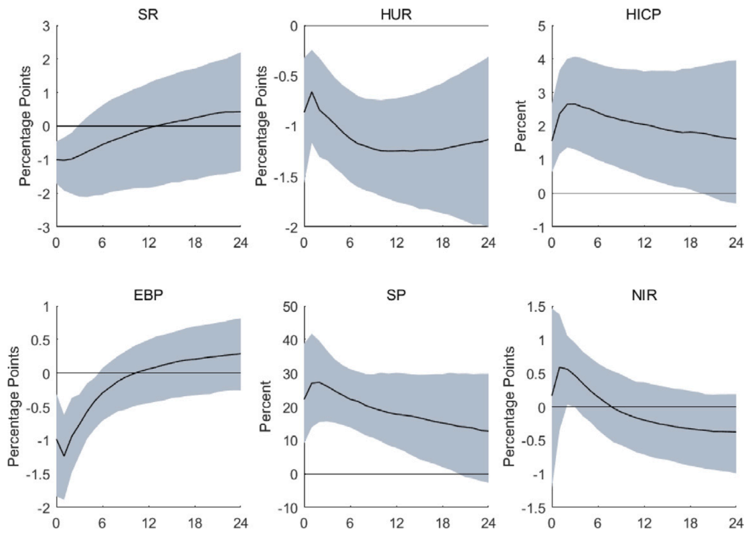

Fig. K.4. IRFs to an UMP shock (the US).
Note: The solid lines report the median responses while the gray areas represent the 68% credible intervals of the posterior distribution. The VAR model includes the following variables: the shadow rate (SR), the harmonized unemployment rate (HUR), the harmonized index of consumer prices (HICP), the excess bond premium (EBP), the index of stock prices (SP), and the natural interest rate (NIR). The model is estimated over the period January 2009–December 2015.

Appendix L. Timelines of main UMP measures

Table L.1
Timeline of asset purchase programs implemented by the ECB.

Program	Size (Monthly, Bn of EUR)	Period
APP1	60	Mar. 2015–Mar. 2016
APP2	80	Apr. 2016–Mar. 2017
APP3	60	Apr.–Dec. 2017
APP4	30	Jan.–Sept. 2018
APP5	15	Oct.–Dec. 2018
APP6	20	Nov.–Dec. 2019

Note: The table provides the timeline of asset purchase programs (APP) implemented by the ECB over the period from 2015 to 2019. The data source is the ECB.

Table L.2
Timeline of quantitative easing programs implemented by the Fed.

Program	Size (Total, Bn of USD)	Period
QE1	1725	Nov. 2008–Mar. 2010
QE2	600	Nov. 2010–June 2011
QE3	1613	Sept. 2012–Oct. 2014

Note: The table provides the timeline of quantitative easing (QE) programs implemented by the Fed over the period from 2008 to 2014. The data source is the Fed.

Data availability

Data will be made available on request.

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