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January 2016

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International housing markets, unconventional monetary policy and the zero lower bound

Florian Huber*[1] and Maria Teresa Punzi[1]

[1]Vienna University of Economics and Business

Abstract

In this paper we propose a time-varying parameter VAR model for the housing market in the United States, the United Kingdom, Japan and the Euro Area. For these four economies, we answer the following research questions: (i) How can we evaluate the stance of monetary policy when the policy rate hits the zero lower bound? (ii) Can developments in the housing market still be explained by policy measures adopted by central banks? (iii) Did central banks succeed in mitigating the detrimental impact of the financial crisis on selected housing variables? We analyze the relationship between unconventional monetary policy and the housing markets by using the shadow interest rate estimated by Krippner (2013b). Our findings suggest that the monetary policy transmission mechanism to the housing market has not changed with the implementation of quantitative easing or forward guidance, and central banks can affect the composition of an investors portfolio through investment in housing. A counterfactual exercise provides some evidence that unconventional monetary policy has been particularly successful in dampening the consequences of the financial crisis on housing markets in the United States, while the effects are more muted in the other countries considered in this study.

Keywords: Zero Lower Bound, Shadow interest rate, Housing Market, Time-varying parameter VAR.

JEL Codes: C32 E23, E32.

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*Corresponding author: Florian Huber, Vienna University of Economics and Business, Phone: +43-1-31336-4534. E-mail: fhuber@wu.ac.at. The work on this paper is part of FinMaP (Financial Distortions and Macroeconomic Performance, contract no. SSH.2013.1.3-2), funded by the EU Commission under its 7th Framework Programme for Research and Technological Development. We would like to thank Hans Genberg and Philipp Piribauer for helpful comments and suggestions.

1 Introduction

The evolution of housing prices and household leverage, for instance measured by the debt-to-income ratio, have played an important role in the recent financial crisis that pushed many advanced economies into a deep recession. Low interest rates and loose lending standards in the run-up to the financial crisis contributed to a sharp build-up in household debt. The sudden collapse of housing prices translated into a significant deleveraging process, which has been a major obstacle for the economic recovery that followed the worst recession since the great depression. During tranquil time periods, increasing house prices amplify the net worth of households, boosting household consumption and private investments. On the other hand, house price declines lift the level of indebtedness, yielding a situation where outstanding household debt suddenly exceeds property values. Within the recent financial crisis, many households experienced a sudden drop of their wealth relative to their debt, facing severe difficulties to fulfill their mortgage payments and other financial obligations, despite being in an environment of extraordinary low interest rates.[1] The first two rows of Fig. 1 depict real house prices and mortgage indebtedness for the United States (US), the United Kingdom (UK), Japan (JP) and the Euro Area (EA). Apparently, both quantities display negative growth rates since 2007, providing some evidence for the poor conditions housing markets reached in that period. Declining house prices, a sharp deleveraging process and the following recession forced all major central banks to reduce short-term interest rates to historically low levels. Japan provides a different view. Japanese real estate values experienced a massive boom during the '80s, peaking in 1990, followed by a sharp decline in housing and property prices.[2] Since then, housing prices have been declining continuously. Mortgage indebtedness increased markedly during the housing boom, but remained stable after the burst of the housing bubble. The third row of Fig. 1 presents the policy rate in the four countries/regions, where it can be seen that across the globe, interest rates reached the zero-lower bound (ZLB) in the beginning of 2009.[3]

[Fig. 1 about here.]

As a reaction to the ongoing economic slump, central banks noted that a re-balancing procedure for households' balance sheets is important to promote a quick recovery. However, with nominal interest rates close to zero, conventional monetary policy tools that aim to promote economic growth became ineffective.[4] Thus several central banks adopted so-called unconventional monetary policy tools to steer the economy back towards a balanced growth path. Such unconventional monetary policy tools span a wide

[1] The huge decline in housing prices and housing net worth are one of the shocks that pulled the economy into recession (Guerrieri and Iacoviello, 2014).

[2] For Japan, land price and house price are used interchangeably.

[3] The first quantitative easing experiment for Japan finds its roots in 2001.

[4] Ngo (2015) finds that in the presence of the zero lower bound amplifies the house price decline when the economy is hit by adverse credit shocks.

variety of methods such as credit and quantitative easing or signalling.[5] Several central banks have been very active since the beginning of the crisis and their actions helped the financial sector to avoid a complete collapse. The US Federal Reserve (Fed), the Bank of England (BoE) and the Bank of Japan (BoJ) have implemented quantitative easing programs with large-scale asset purchases to exert a positive impact on financial variables as well as on output and inflation. By contrast, the European Central Bank (ECB) has introduced measures to ensure provision of liquidity needed by the banking sector in order to repair the bank-lending channel. Table B.1 summarizes the main actions taken by the Fed, the BoE, the BoJ and the ECB in terms on unconventional monetary policy. Each action translates into an expansion of the central banks' balance sheet, providing several stimuli to dampen the global economic slowdown.

Since the policy rate is typically stuck at zero or near zero, such unconventional monetary policy measures are not reflected in short-term interest rates. This proves to be one of the main challenges for understanding and describing the stance of monetary policy.

In this paper we investigate the relationship between the stance of monetary policy and the housing markets during periods of the ZLB for the US, the UK, JP and the EA. The motivation to review the role of the housing market and monetary policy during the ZLB is threefold.

First, we want to evaluate if developments in the housing market, i.e. changes in housing prices and mortgage lending, can still be explained by policy measures adopted by central banks. As a central research objective we evaluate whether unconventional monetary policy succeeded in mitigating the collapse of house prices and lending activities. For this purpose we propose a time-varying vector autoregressive model coupled with stochastic volatility (TVP-VAR-SV) for the housing market. Our model closely resembles the specifications proposed by Cogley and Sargent (2005) and Primiceri (2005) with some minor differences. With respect to the choice of the covariates, we include information on prices, consumption, interest rates that constitute a standard macroeconomic model commonly employed to investigate monetary policy. In addition, we include quantities related to housing markets to analyze the dynamic properties of housing markets with respect to unconventional monetary policy. To investigate the relationship between unconventional policy actions and the dynamic responses of several key macroeconomic quantities we include a measure of the monetary policy stance. More specifically, we follow Krippner (2012; 2013a;b) and include the shadow rate, which is constructed by adding an explicit function of maturity to the shadow rate forward curve.[6] The final row of Fig. 1 depicts the shadow rate for all countries under scrutiny. Note that the shadow rates reflect accommodative monetary policy due to unconventional policy measures adopted by various central banks since the 2008 financial crisis. However, while the shadow rate in the US, the UK and Japan has been

[5] Signalling can be used to steer market expectations towards lower interest rates in the future. For example, during the credit crisis of 2008, the US Federal Reserve indicated interest rates would be low for an "extended period".

[6] Alternative measures are offered by Wu and Xia (2015) and Lombardi and Zhu (2014).

decreasing since 2008, shadow rates in the EA indicated expansionary monetary policy actions only since 2011.

Second, we quantify the likely impact of unconventional monetary policy by performing several simple counterfactual experiments. To this end we "zero-out" the structural coefficients of the monetary policy rule and investigate what would have happened if the central bank was indeed constrained by the ZLB. Our findings suggest that for all economies under consideration, unconventional monetary policy actions helped to mitigate the detrimental impact of the financial crisis on several macroeconomic quantities. More specifically, unconventional monetary policy increased inflation, consumption growth, housing prices and residential investment. Moreover, it also provided at least some liquidity to the private sector.

Finally, we assess the quality of the shadow rate proposed by Krippner (2012), Krippner (2013a) and Krippner (2013b) as a trustable measure to investigate unconventional monetary policy. Using an identification scheme based on Baumeister and Benati (2013), which assumes that the central bank is effectively trying to reduce long-term yields while operating at the ZLB, we find that our results are qualitatively in-line with other procedures typically adopted in the literature. This results holds true for all countries under consideration.

The paper is organized as follows. Section 2 describes the related literature. Section 3 presents the time-varying parameter VAR model and the corresponding prior setup. Section 4 provides a brief information on the dataset employed, the identification of the structural model and presents the main results of the paper. Section 5 describes the counterfactual experiments while Section 6 documents additional information concerning the robustness of our findings. Finally, the last Section concludes.

2 Related Literature

Our work is related to the recent contributions of Krippner (2013a), Wu and Xia (2015) and Baumeister and Benati (2013) that aim to evaluate monetary policy when the ZLB is reached. Since recessions that occurred as a reaction to large drops in housing and property prices tended to be deeper in countries and regions where house price declines have been comparatively larger (Mian and Sufi, 2011), we put a particular focus on housing markets and assess whether unconventional monetary policy has helped to re-balance households' balance sheets and avoid a even stronger housing burst.

Krippner (2013b) proposed an approximation for the instantaneous forward rate in continuous-time, using the implied shadow overnight rate as a metric for the actual stance of monetary policy. Wu and Xia (2015) estimate a factor-augmented VAR (FAVAR) model where the shadow rate is constructed as a linear function of three latent variables called factors and find that the effects of the shadow rate on macroeconomic variables are similar to those of federal funds rate. Moreover, Wu and Xia (2015) find that the unconventional monetary policy adopted by the Federal Reserve was successful in reducing the unemployment rate in December 2013 by 0.13% compared to a situation where monetary policy exclusively utilized conventional tools.[7] We extend Krippner (2013a) and Wu and Xia (2015) by studying the case of the housing market and analyze the impact of unconventional monetary policy on the four countries/regional aggregates mentioned above. Moreover, we assess the quality of their approach by evaluating whether the impulse responses obtained are qualitatively similar to responses obtained by using the approach put forward in Baumeister and Benati (2013). In that contribution, they estimate a time-varying parameter structural VAR model for the US and the UK and identify a pure spread shock to investigate the responses of macroeconomic aggregates to declining long-term yield spreads induced by central banks bond purchase programs during the ZLB. They find that measures of unconventional monetary policy in both the US and the UK have helped avoiding a strong deflation and have boosted employment.

Finally, the present paper is also related to Walentin (2014) who estimates a structural VAR model incorporating important quantities related to housing markets and shows that mortgage spread shocks are quantitatively important for the real economy. Moreover, Walentin (2014) shows that central banks' asset purchases in mortgage markets have been very successful in affecting the mortgage spread, and led to a sizeable effect on aggregate quantities and property prices.

Different approaches have been studied to quantitatively evaluate the impact of unconventional monetary policy. Meaning and Zhu (2011; 2012) study the size and maturity of Treasury securities holdings and actual asset purchases to evaluate the effects of unconventional monetary policy and find that quantitative easing has lowered the 10-year Treasury yield by approximately 180 basis points. Chung, Laforte, Reifschneider, and Williams (2012) developed a large-scale macroeconomic model showing that the expansion in the Federal Reserve's balance sheet has helped to avoid a rise in the unemployment rate that would have occurred in the absence of unconventional monetary policy. Del Negro, Eggertsson, Ferrero, and Kiyotaki (2011) and Chen, Cúrdia, and Ferrero (2012) developed medium-sized dynamic stochastic general equilibrium (DSGE) models with a ZLB on nominal interest rates[8] and obtained similar results as in Chung, Laforte, Reifschneider, and Williams (2012). For the EA, Lenza, Pill, and Reichlin (2010) gauge the effectiveness of an unconventional monetary policy intervention with a decline in spread rates, but found that the economic stimulus occur only with a considerable delay. Gambacorta, Hofmann, and Peersman (2014) estimate a panel VAR for eight advanced economies to analyze the impact of an increase in central banks' balance sheets at the zero lower bound on economic activity and consumer prices. They find that output and prices increase in the US, the UK and the EA due to unconventional monetary policy during crisis periods.

[7] Lombardi and Zhu (2014) also construct a shadow interest rate for the US by estimating a dynamic factor model where term structure, monetary aggregates and balance sheet variables are taken into account. They also find that the Federal Reserve generated sizable stimulus to the economy during the zero lower bound.

[8] Chen, Cúrdia, and Ferrero (2012) use the US term and corporate spreads to proxy the Federal Reserves policy measures and analyse the global impact of quantitative easing.

Our paper is also related to the growing literature on the role of housing prices for business cycle fluctuations and the effect of monetary policy on asset prices. Iacoviello (2005) estimates a small-scale VAR model and simulates the effects of monetary policy shocks on several macroeconomic quantities. He finds that nominal prices, real housing prices and output tend to decrease with respect to a restrictive monetary policy shock. Similarly, Musso, Neri, and Stracca (2011) estimate a structural VAR model incorporating the housing market for the US and the EA.[9] They find that monetary policy shocks in the US tend to have a deeper impact on housing markets, relative to the reactions observed for the EA. Goodhart and Hofmann (2008) estimate a fixed-effects panel VAR for 17 industrialized countries and show that there exist a significant link between house prices, monetary variables and the macroeconomy. Den Haan and Sterk (2011) estimate a structural VAR including residential investment and mortgages loans, but they exclude housing prices. However, they find that macroeconomic variables tend to exhibit co-movement with respect to monetary policy shocks. All aforementioned studies relied on identification based on a simple Cholesky decomposition of the variance-covariance matrix.

By contrast, Jarociński and Smets (2008) use a mixture of zero and sign restrictions to identify monetary policy shocks and find that a persistent 25 basis point tightening of the policy rate yields a negative effect not only on real GDP and the GDP deflator, but also on housing investments and house prices.[10] Vargas-Silva (2008) and Sá and Wieladek (2015) estimate a VAR model by restricting output and the price level to be non-negative for an expansionary monetary shock, while leaving the housing variables unrestricted.[11] They find that house prices and residential investments increase as a result of an expansionary monetary policy shock.[12]

3 The econometric framework

In the following section we briefly outline the econometric methodology employed and discuss the prior specification and the corresponding Markov chain Monte Carlo (MCMC) algorithm.

3.1 The time-varying parameter VAR with stochastic volatility

Assume that the dynamics of a N-dimensional vector of macroeconomic quantities y_t may be well described by the following dynamic model

$$y_t = A_{1t} y_{t-1} + \cdots + A_{pt} y_{t-p} + u_t, \tag{3.1}$$

[9] For a similar setup of VAR estimation with the housing market, see Lambertini, Mendicino, and Punzi (2013) and Punzi and Kauko (2015).

[10] Uhlig (2005) offers a wide-ranging discussion on VAR identification with sign restrictions.

[11] For similar results on restricting output and prices to identify monetary policy shocks, see Canova and De Nicolo (2002).

[12] Sá and Wieladek (2015) use sign restrictions in an open economy framework.

where, for the sake of simplicity, we omit any deterministic terms. The $N \times N$-dimensional matrices of autoregressive coefficients are denoted by A_{jt} $(j = 1, \ldots, p)$ and $u_t \sim \mathcal{N}(0, \Sigma_t)$ is a normally distributed vector white noise error term with time-varying variance-covariance matrix Σ_t.

We can rewrite Eq. (3.1) more compactly as

$$y_t = (I_N \otimes x_t')\alpha_t + u_t, \tag{3.2}$$

with $x_t = (y_{t-1}', \ldots, y_{t-p}')'$ and $\alpha_t = \text{vec}\{(A_{1t}, \ldots, A_{pt})\}$ where vec denotes the vectorization operator. Consistent with the literature on TVP-SV-VARs (Cogley and Sargent, 2005; Primiceri, 2005; Baumeister and Benati, 2013) we assume that α_t evolves according to

$$\alpha_t = \alpha_{t-1} + v_t, \tag{3.3}$$

where $v_t \sim \mathcal{N}(0, V)$ is a vector of white noise innovations and V is a $K \times K$-dimensional variance-covariance matrix with $K = N \times (Np)$. Equation (3.3) is called a state equation that describes the law of motion for the latent states α_t while Eq. (3.1) is called a observation equation that relates the states to the observed quantities.

We can factorize the variance-covariance matrix of u_t as

$$\Sigma_t = Q_t H_t Q_t'. \tag{3.4}$$

Let Q_t be a $N \times N$-dimensional lower triangular matrix with $\text{diag}(Q_t) = \iota_N$ and $\iota_N = (1, \ldots, 1)'$ is a N-dimensional vector of ones. Furthermore, $H_t = \text{diag}(\exp\{h_{1t}\}, \ldots, \exp\{h_{Nt}\})$ is a matrix of volatilities.

After collecting the free elements of Q_t in a $M = \frac{N \times (N-1)}{2}$-dimensional vector q_t we assume that q_t evolves according to

$$q_t = q_{t-1} + e_t. \tag{3.5}$$

Here we let $e_t \sim \mathcal{N}(0, S)$ with S being a $M \times M$-dimensional variance-covariance matrix.

To complete the model we assume that the vector of log-volatilities $h_t = (h_{1t}, \ldots, h_{Nt})'$ follows an autoregressive process of order one,

$$h_t = \mu + \Xi(h_{t-1} - \mu) + \eta_t, \tag{3.6}$$

where $\mu = (\mu_1, \ldots, \mu_N)'$ is a vector of intercepts, $\Xi = \text{diag}(\xi_1, \ldots, \xi_N)$ is a $N \times N$ matrix of autoregressive coefficients and $\eta_t \sim \mathcal{N}(0, \Omega)$ is a white noise error with $\Omega = \text{diag}(\omega_1, \ldots, \omega_N)$. Equation (3.6) implies that the log-volatilities are described by a stationary stochastic process, as opposed to all other coefficients in the model. This choice is predicated by the fact that assuming random walk behaviour for the log-volatility would translate into an excessively explosive behaviour of the volatilities when time approaches infinity.

Equations (3.1) to (3.6) describe a state-space system that provides a great deal of flexibility when it comes to describing the dynamic relationship between monetary policy and housing markets. Since all parameters are allowed to change over time, our model captures any potential time variation along two important dimensions. First, since linear VARs assume that the data-generating process remained stable over the estimation period it is effectively ruled out that transmission mechanisms changed over time. Our specification accounts for this by assuming that the autoregressive parameters change dynamically, thus capturing possible structural breaks (Koop, Leon-Gonzalez, and Strachan, 2009). Second, several studies provide ample evidence that the volatility of macroeconomic shocks changed over time (Sims and Zha, 2006; Primiceri, 2005). Our specification of the variance-covariance matrix thus incorporates this evidence by assuming that the volatilities evolve smoothly over time.

3.2 Prior setup and posterior simulation

We estimate the model described by Eqs. (3.1) to (3.6) using Bayesian methods. Our prior setup is a modified variant of the specification adopted by Primiceri (2005). More specifically, we impose the following set of priors on the coefficients of our model.

- Autoregressive coefficients: $p(\beta_0) \sim \mathcal{N}(\hat{\beta}, \hat{\Theta}_\beta)$ and $V \sim \mathcal{IW}(\underline{v}_0, \underline{V}_0)$
- Simultaneous relationships: $p(q_0) \sim \mathcal{N}(\hat{q}, \hat{\Theta}_q)$ and $S \sim \mathcal{IW}(\underline{s}_0, \underline{S}_q)$
- Stochastic volatilities: $p(h_0) \sim \mathcal{N}(0, 10 \times I_N)$, $p(\mu_j) \sim \mathcal{N}(0, 10^2)$ and $p(\xi_j + 1/2) \sim \mathcal{B}(25, 5)$ for $j = 1, \ldots, N$

where we follow Primiceri (2005) and set $\hat{\beta}$ and $\hat{q}$ equal to the maximum likelihood estimate over the first 30 observations and $\hat{\Theta}_\beta$ and $\hat{\Theta}_q$ equal to four times the variance of the maximum likelihood estimator. The priors for V and S are calibrated by setting $V = k_V^2 \times \hat{\Theta}_\beta$, $S = k_S^2 \times \hat{\Theta}_q$ and $\underline{v}_0 = \underline{s}_0 = 30$ with $k_V^2 = k_S^2 = 0.01$ thus being fairly conservative on the degree of time-variation.[13] Finally, our prior setup for the coefficients of the state equation of the log-volatilities closely follows Kastner and Frühwirth-Schnatter (2014).

We estimate the model using the algorithm put forth in Primiceri (2005) with one important exception. Due to superior convergence characteristics we simulate the full-history of log-volatilities through the algorithm put forward in Kastner and Frühwirth-Schnatter (2014) and subsequently applied in a global VAR model by Huber (2016).[14] For the final results we use 30,000 iterations of our MCMC algorithm and thin the corresponding chain such that inference is effectively based on 5,000 draws from the joint posterior of the parameters of the model.

[13] Since the priors on V and S are typically quite influential, we have performed a battery of robustness checks with respect to the hyperparameters of the priors, yielding results that are qualitatively similar across countries and variables.

[14] This step is implemented by means of the excellent R package stochvol, which is available on CRAN (Kastner, 2014)

4 Data and Results

In this Section we first provide a brief description of the data and the identification strategy adopted. The second subsection presents the impulse response functions (IRFs) to a 25 basis points (bps) increase in the shadow interest rate for the US, the UK, JP and the EA, respectively. Finally, we present the findings of our robustness analysis where unconventional monetary policy is analyzed by means of the identification scheme outlined in Baumeister and Benati (2013).

4.1 Data and Identification

We include the following variables in our model: the quarterly growth rates of real consumption (RCC), the consumer price index (P), real residential investments (RIH), the real house price index (HPI), and the level of the shadow federal interest rate (Shadow rate). For the spread shock we also include the short-term interest rate for the US (SR). Thus all variables except shadow rates and term spreads are included in first (log) differences.[15] All data are taken at quarterly frequency from 1980 until 2014. Note that since the shadow rate is typically not observed and is estimated from the data, we completely ignore any estimation uncertainty surrounding the point estimate of the shadow interest rate. However, this proves to be only a minor shortcoming since a broad body of literature on the estimation of factor-augmented VAR models (Bernanke, Boivin, and Eliasz, 2005; Korobilis, 2013) reports only minor differences between impulse responses obtained when the factors are treated as latent variables or as observed quantities (approximated through principal components). We identify the monetary policy shock by imposing the set of sign restrictions shown in Table 1.

[Table 1 about here.]

The identifying restrictions imposed for the aggregate demand (AD) and supply (AS) shock are standard in the literature. We assume that a (negative) AD shock lowers consumption growth, inflation and the shadow rate. By contrast, a positive AS also decreases consumption growth but increases inflation and the shadow rate on impact. For the unconventional monetary policy shock we follow Musso, Neri, and Stracca (2011), who identify a conventional monetary policy shock based on a similar collection of sign restrictions. More specifically, we assume that consumption growth and inflation falls while the shadow rate increases. Moreover we also assume that house prices, residential investment and real household debt declines.

In the robustness section we will exchange the shadow rate with the short-term interest rate and, in addition, include the term spread. We calculate the term spread as the difference between 10-year long-term government bond yields and the short-term interest rate and use it to identify unconventional monetary policy, following Baumeister and Benati (2013) and Walentin (2014). The sign restrictions imposed closely mirror the ones presented in Table 1. However, we also identify a spread shock, where we

[15] Details can be found in Appendix A.1.

assume that the same restrictions hold as in the case of the UMP shock. Moreover, we also identify a conventional monetary policy shock that introduces the restriction that the term spread increases on impact.

4.2 The dynamic effects of unconventional monetary policy

Figure 2 depicts the posterior median of the impulse responses for the US to a 25 bp unconventional monetary policy shock. An increase of the shadow rate generates a decrease in housing prices, residential investment, consumption, CPI and mortgage lending. This occurs because a contractionary monetary policy shock will most likely increase the shadow value of borrowing by increasing the future service cost of debt, which in turn has a negative impact on the level of mortgage lending. Such an increase in the shadow value of borrowing will negatively affect consumption via the wealth/collateral channel.

Looking at the time profile of the IRFs reveals that the magnitude of the impact is sensitive to the selection of the horizon for which the restrictions hold. The responses to a monetary policy shock display significant time variation on impact, and the impact is especially pronounced during the period covering the recent financial crisis. This is simply due to the fact that the stochastic volatility specification is flexible enough to account for the changing volatility and this directly influences the impact magnitudes of the impulse responses.

Inspection of variables related to housing markets reveals pronounced effects of unconventional monetary policy on all housing market quantities under consideration, particularly residential investments and housing prices.[16] This occurs because house price fluctuations directly affect residential investment, as the change in house prices shifts Tobin's q for residential investment, i.e. the value of housing relative to construction costs. If, for instance, house prices increase and exceed the construction costs, then residential investment increases as well. Moreover, the value of land and dwellings can be used as collateral and this affects the ability of firms to borrow, boosting their investment opportunity and leading to stronger economic growth. Fluctuations in the net worth of firms due to changes in house values will amplify the impact of macroeconomic shocks and give rise to a well-known financial accelerator mechanism.[17]

[Fig. 2 about here.]

To provide some evidence on the statistical significance of our results we also report information on the shape of the posterior distribution of impulse responses in Fig. 3. The figure presents responses that have been averaged across three selected time periods: 1990Q4 to 2007Q4, representing the period prior to the recent global financial crisis, 2008Q1 to 2009Q2 marking the period of the financial crisis and 2009Q3 to 2013Q1

[16] Similar results are found in Erceg and Levin (2006), Vargas-Silva (2008) and Goodhart and Hofmann (2008).

[17] For details see Bernanke, Gertler, and Gilchrist (1999) and Kiyotaki, Moore, et al. (1997).

serving as a post-crisis period. All figures report median responses along with the 16th (25th) and 84th (75th) credible sets in light (dark) orange across time, starting from 1990Q1, and for a 14 quarter horizon.

The residential investment response is quite large, with a maximum mean negative effect of about 12 percent deviation from baseline on impact in 1990 and of about seven percent around in 2009 and 2014. The impact on house price shows a maximum response after the third quarter in 1990, but a slightly smaller response in 2009 and 2014. Mortgage lending also exhibits a certain amount of time variation from 1990 to 2009 and 2014. In addition, the responses of mortgage lending appear to be rather persistent.

The effects of monetary policy shocks on house prices, mortgage lending and consumption also increased over time. The sensitivity of house prices and mortgage lending to tightening monetary policy depends on the overall increase in households indebtedness in the US. Carroll and Dunn (1997) have studied the relationship between the growth rate of household debt and consumption in durable goods and find a positive and significant relationship between these variables. Such relationship arises from precautionary motives where highly leveraged households are more sensitive to uncertainty about current and future income and they are more likely to decrease consumption on durable goods when adverse shocks hit the economy. It is worth noting that the responses of house prices to monetary policy shocks depicts two important sharp changes, which coincide with three US recessions: 1990/1991, 2000/2001 and 2007 to 2009. Between the first two recessions, housing price responses have been quite stable, but steadily increased after the burst of the dot-com bubble in 2000.

Our findings for the US are generally in concordance with the literature. Similar results are provided in Jarociński and Smets (2008), Goodhart and Hofmann (2008), Bernanke and Gertler (1995), Erceg and Levin (2006), McCarthy, Peach, et al. (2002), Vargas-Silva (2008) and Musso, Neri, and Stracca (2011). The exception is the behaviour of prices. The specification of our model helps to avoid the well-known "price puzzle" (Sims, 1992), and the CPI declines on impact in response to a monetary policy tightening.

[Fig. 3 about here.]

Figure 4 reports responses to a 25 basis points increase in the shadow interest rate for the UK. The results tend to be similar to the ones obtained for the US, but less persistent. While the general pattern that responses are stronger within the recent financial crisis holds for some variables under scrutiny, this finding is less pronounced as compared to our findings for the US. The impact on housing market variables is particularly pronounced during the late 1990s and 2004, periods where house prices increased at their fastest pace because of extraordinary low policy and mortgage rates, boosting mortgage lending of new borrowers. In addition, responses of inflation suggest that prices decrease on impact but tend to increase after two quarters, thus producing a price puzzle. The impact on housing variables is lower in 2009 and 2014. Figure 5 shows that all responses are rather short-lived, becoming insignificant after one to two quarters.

[Fig. 4 about here.]

[Fig. 5 about here.]

Figures 6 and 7 depict the responses of several macroeconomic quantities for Japan. All variables display negative reactions with respect to a 25 basis points increase in the Japanese shadow rate. Figure 7clearly shows that house prices have been more responsive to monetary policy until 1990, the year that marked the peak of the housing bubble, turning less responsive afterwards. After the collapse of the Japanse real estate market in the early 1990s, the BOJ did not react to worsening conditions by becoming increasingly expansionary, implementing standard and non-standard monetary policy more aggressively. Residential investment and inflation show more variability in their response, relative to other variables. Residential investments are typically identified as important drivers of the Japanese current account surplus. In order to reduce the large trade surplus and the risk of protectionism abroad, the Japanese authorities have implemented several housing subsidies, housing regulations and land use policies to promote residential investments, improving the existing stock of houses and avoid an excess current account surplus (see, for instance, Matsuyama, 1990). Therefore, the response of residential investments has been more volatile relative to other housing variables, reflecting several policies implemented by the Japanese Government, besides various QE actions.

[Fig. 6 about here.]

[Fig. 7 about here.]

Finally, Figs. 8 and 9 report responses for the EA. Residential investments are omitted because the data is available only since 1995, and inclusion of this time series would thus seriously shorten the available sample. Similar to the UK and the US, an increase in the shadow interest rate by 25 basis points generates a decrease in housing prices, consumption, CPI and mortgage lending. Responses of housing prices and mortgage lending exhibit significant time variation, in particular during the late 1990s and in the midst of the 2000s. Mortgage rates in the EA have been declining considerably since the 1990s. Changes in EU regulations, financial innovations and competition in financial markets can be traced back to be among the main determinants of declining mortgage rates. However, changes in other market rates, including the policy rate, are generally perceived to be the main reason for the pronounced decline in mortgage rates. Moreover, the intensified convergence process also led to declining interest rates. In addition, the responses of housing variables, consumption and prices are strongest within these two time periods.

Differently from the US and the UK, the impact on housing variables tends to be stronger towards the end of the sample. This reflects the fact the the ECB has implemented forward guidance policies with different time periods relative to the US and the UK. The overall magnitudes of the responses are, however, much lower as compared to the US or the UK. This somewhat weaker response could be due to the fact that the individual member states of the EA tend to be less integrated. Since the sovereign debt crisis engulfed the EA in 2010, financial fragmentation has become a major obstacle to a successful implementation of the ECB's unconventional monetary policy actions. Altavilla, Giannone, and Lenza (2014) report that the ECB's unconventional monetary policy actions have lowered government bond yields by around 200 basis points, significantly impacting credit and GDP growth in Italy and Spain, whereas for France and Germany the effects are rather muted.

[Fig. 8 about here.]

[Fig. 9 about here.]

To sum up, the overall results are consistent with Musso, Neri, and Stracca (2011) who find that the impact of a contractionary monetary policy shock on housing variables is significantly larger in the US than in the UK and the EA. Moreover, the transmission mechanism of monetary policy to the housing market has not changed with the implementation of unconventional monetary policy.

4.3 Robustness Check

The previous analysis reports the IRFs with respect to an unconventional monetary policy shock when the Krippner (2013b) index is used. This implies that we focus on a broader measure of unconventional monetary policy, which can not be interpreted in classical terms as a monetary policy reaction function.

To assess whether shadow rates prove to be a good alternative to other identification procedures based on the term spread, we contrast the findings of Subsection 4.2 with the responses obtained by simulating a 25 basis points spread shock. This implies that we identify a "pure term spread" shock, similar to Baumeister and Benati (2013) and Walentin (2014). Monetary policy shocks at the ZLB are broadly defined as shocks to the long-term yield or to the long-term yield spread.[18] However, this approach can be criticized because more emphasis should be put on the effect of the spread of other asset yields like the mortgage spread or the risk spread.[19]

To recover the structural form of our model we use the identification scheme described in the lower part of Table 1. We identify a pure spread shock by assuming that

[18] See also Lenza, Pill, and Reichlin (2010) and Kapetanios, Mumtaz, Stevens, and Theodoridis (2012).

[19] Walentin (2014) uses the 30-year Conventional Mortgage Rate relative to the average of the 5-year and the 10-year Treasury bond rate, in order to isolate the term premia given the longer maturity of mortgage loans. His estimate finds that 100 basis-points increase in mortgage spread leads to a decline in consumption, residential investment and house prices.

the short-term interest rate reacts sluggishly with respect to a monetary policy shock and the term spread falls on impact. The remaining restrictions on the housing market variables mirror the ones presented for the UMP shock. Since we are interested in how monetary policy operates at the ZLB, we closely follow Baumeister and Benati (2013) and "zero-out" the structural coefficients of the monetary policy rule to capture the notion that the central bank is unable to lower nominal interest rates below zero. This is imposed for the first eight quarters after the UMP shock hit the economy.

Figure 10 presents the responses for the US. We find that a pure term spread shock leads to a decrease in housing prices, residential investment, consumption, CPI and mortgage lending. Results are qualitatively similar to the ones presented in Fig. 2 and Fig. 3. Looking at the time profile of the impulses reveals that apart from being of comparable magnitudes, the shape also looks remarkably similar between these two measures of unconventional monetary policy. For the EA and the UK the results also tend to be very similar to the ones based on the Krippner index. Thus, for the sake of brevity we do not include them in the paper.[20]

The striking similarity between the results obtained by estimating a TVP-VAR coupled with the shadow rate and the approach put forward by Baumeister and Benati (2013) and Walentin (2014) provides some evidence that the shadow interest rate proposed by Krippner (2013b) is a trustable measure to investigate unconventional monetary policy.

[Fig. 10 about here.]

5 Counterfactual Analysis

In this section, we evaluate the stance of monetary policy by performing a simple counterfactual exercise. We simulate a counterfactual path for all variables in the VAR system based on the notion that central banks remained inactive in the wake of the financial crisis, i.e. had not implemented unconventional monetary policy measures like quantitative easing or forward guidance and simply kept the policy rate at the ZLB.

To this end we "zero-out" the structural coefficients of the equation associated with the shadow rate and investigate what would have happened if the central bank was indeed constrained by the ZLB. It is worth noting that manipulating the structural coefficients of the model is generally vulnerable to the Lucas critique. Within a Bayesian framework, policy is treated as being random and since we assume that the volatility of the unconventional monetary policy shock follows a random walk, this argument proves to be even stronger (Primiceri, 2005). However, to assess whether our findings are indeed robust with respect to the Lucas critique, we also performed the same counterfactual exercise by manipulating the historical structural shocks such that the shadow rate is kept at the ZLB. Consistent with Baumeister and Benati (2013), the

[20]The corresponding figures can be obtained from the authors.

results stay relatively robust, with only minor quantitative alterations across countries and variables.[21]

Figure 11 reports the posterior distribution of the difference between the counterfactual path and the actual realization of a given variable. The dark blue line corresponds to the median difference and the light (dark) orange areas correspond to the 16th (25th) and 84th (75th) credible sets.

The first column on the left side of Fig. 11 reports the case of the US. On average, unconventional monetary policy actions reflect a long lasting expansionary monetary policy. If the Fed would have kept the interest rate at the zero lower bound without implementing any quantitative easing, then, on average, the growth rate in house prices, residential investments, mortgage lending and consumption would have been sharply lower as compared to the actual realization. In addition, inflation would have also been lower, indicating that QE introduced additional upward pressure on prices.

The central and rightmost columns of Fig. 11 presents the results for the UK, JP and the EA. The findings described for the US carry over to all economies under consideration, suggesting that unconventional monetary policy actions helped to mitigate the detrimental impact of the financial crisis on several macroeconomic quantities. More specifically, unconventional monetary policy increased inflation, consumption growth, housing prices and residential investment across all countries considered. Moreover, it also provided at least some liquidity to the private sector. However, the impact seems to be most pronounced in the US as compared to the other economies.

The final row of Fig. 11 depicts the difference between the estimated shadow rate and the short-term policy rate. The difference has been negative until the beginning of 2008, turning positive already in the beginning of 2009, meaning that the estimated shadow rate reached negative values after the announcements of QE, reflecting the pronounced shift towards accommodative monetary policy. The only exception is the EA, where the shadow rate has been positive well into 2011, turning negative after the QE announcements in 2011.

To sum up, our counterfactual exercise shows that during periods of monetary policy tightening, housing variables have reached higher values relative to levels obtained if the BoE, BoJ and ECB had done nothing in terms of quantitative easing and forward guidance. The impact of QE on housing variables has been slightly higher with the QE2 implementation in 2011. Probably this reflects the fact that economic agents respond to QE with some lag and that they perceive less policy uncertainty in the market. Residential investments have been stimulated more in the UK, where the BoE's policy measures have been successful in increasing it by about 10%, while the BoJ managed to increase residential investment by only 0.8%. On the other hand, the BoJ has been more successful in stimulating household indebtedness, leading to increases of around 3%, while the BoE and ECB managed to increase this variable at an average rate of 0.2%. Also consumption and inflation display higher growth rates due to the different implementations of QE, showing no discernible differences across

[21] The specific results are available on request.

countries. We conclude this section by noting that between 2007 and 2014, all four Central Banks have been quite successful in mitigating the consequences of the crisis on the housing market by successfully implementing unconventional monetary policy, but less success can be attributed to the impact of UMP on housing markets in the other economies.

[Fig. 11 about here.]

6 Closing Remarks

We estimate a time-varying vector autoregressive model coupled with stochastic volatility for the housing market during periods of the ZLB for the US, the UK, JP and the EA. In our estimation, we include the shadow interest rate estimated by Krippner (2013b), because these estimated rates tend to provide a broader measure of monetary policy adopted by various central banks.

Our findings suggest that an increase in the shadow interest rate by 25 basis points generates a decrease in housing prices, residential investment, consumption, CPI and mortgage lending. The monetary policy shock displays a significant amount of time variation, providing some evidence in favour of our time-varying parameter model in order to capture changes in the transmission mechanisms and the volatility of policy shocks. The results show that tightening monetary policy shocks are significantly larger in the US than in the other countries under consideration. Moreover, we find limited evidence that the transmission mechanism of monetary policy to the housing market has changed with the implementation of unconventional monetary policies.

Furthermore, we evaluate the stance of monetary policy by performing a counterfactual exercise. We ask if the values of housing variables would have been different if the central banks had been inactive since the financial crisis, i.e. had not implemented policies of quantitative easing or forward guidance and left the policy rate at the ZLB. To this end we "zero-out" the structural coefficients of the monetary policy rule and investigate what would have happened if the central bank was indeed constrained by the ZLB. We find that for all countries under scrutiny, unconventional monetary policy actions succeeded in mitigating the detrimental effect of the financial crisis on all macroeconomic quantities considered. Unconventional monetary policy effectively averted deflationary tendencies, increased consumption and several housing variables significantly.

Finally, we perform a robustness exercise where we compare the results from our benchmark model coupled with the shadow interest rate proposed by Krippner (2013b) with an identification strategy akin to the simulation exercise performed in Baumeister and Benati (2013) and Walentin (2014). Our results display a striking similarity between both approaches and we therefore conclude that the shadow interest rate proposed by Krippner (2013b) proves to be a trustable measure to investigate unconventional monetary policy.

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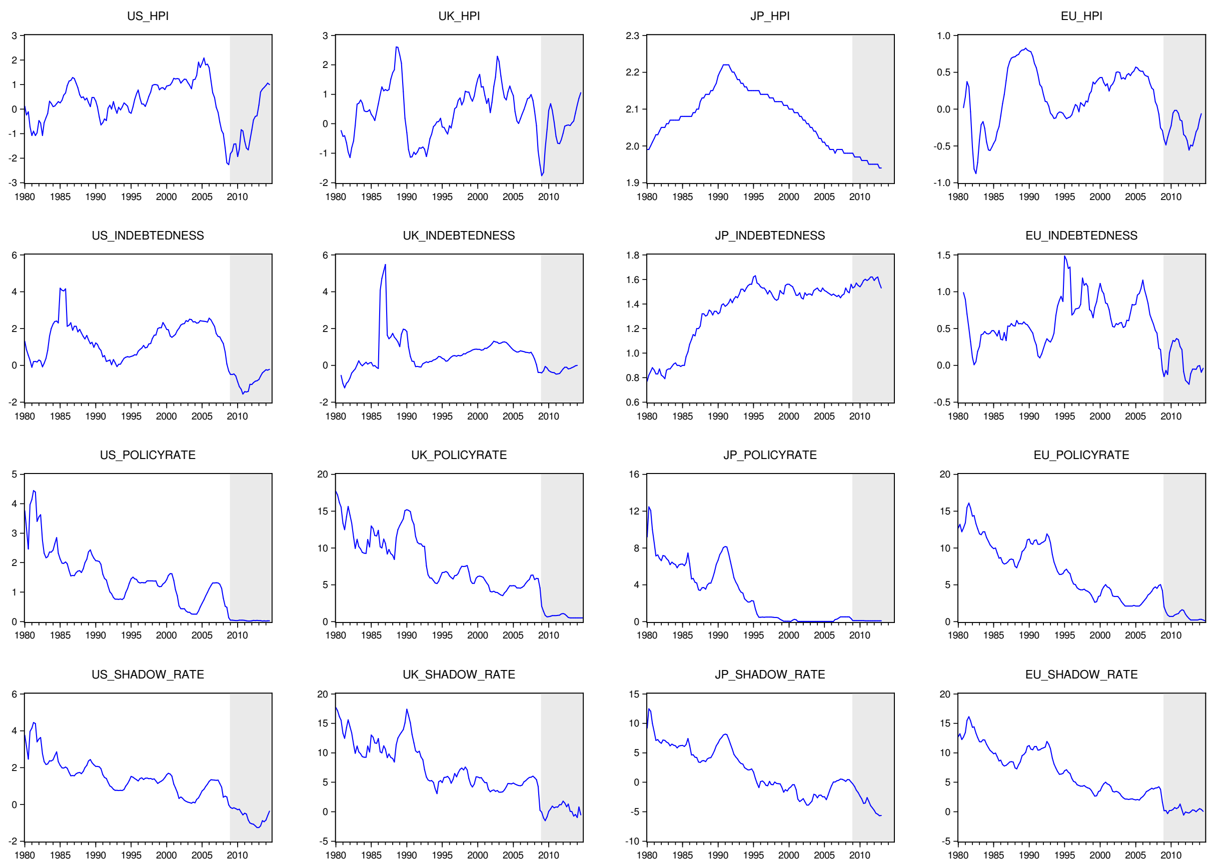
Table 1: Identification restrictions

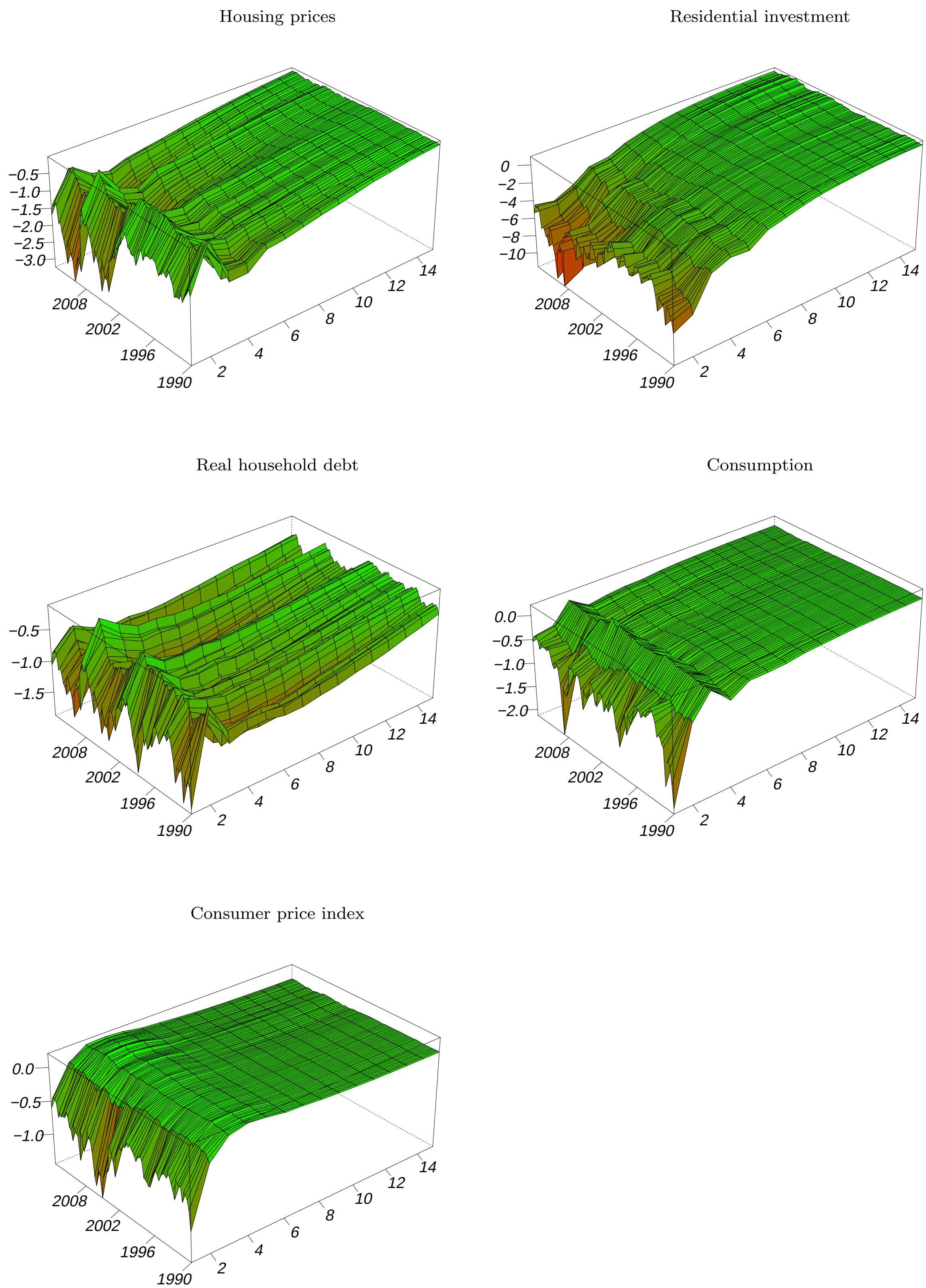
	Unconventional monetary policy shock						
	RCC	P	Shadow Rate	HPI	RB	RIH	Spread
AD	−	−	−	∗	∗	∗	X
AS	−	+	+	∗	∗	∗	X
UMP	−	−	+	−	−	−	X
	Spread shock						
	RCC	P	SR	HPI	RB	RIH	Spread
AD	−	−	−	∗	∗	∗	∗
AS	−	+	+	∗	∗	∗	∗
MP	−	−	+	−	−	−	+
Spread	−	−	0	−	−	−	−

Notes: The table presents the sign restrictions imposed for an aggregate demand (AD), aggregate supply (AS), monetary policy (MP) and unconventional monetary policy shock (UMP). All restrictions are imposed on impact only. Responses marked with ∗ are left unrestricted. An X marks the exclusion of a given variable from the model.



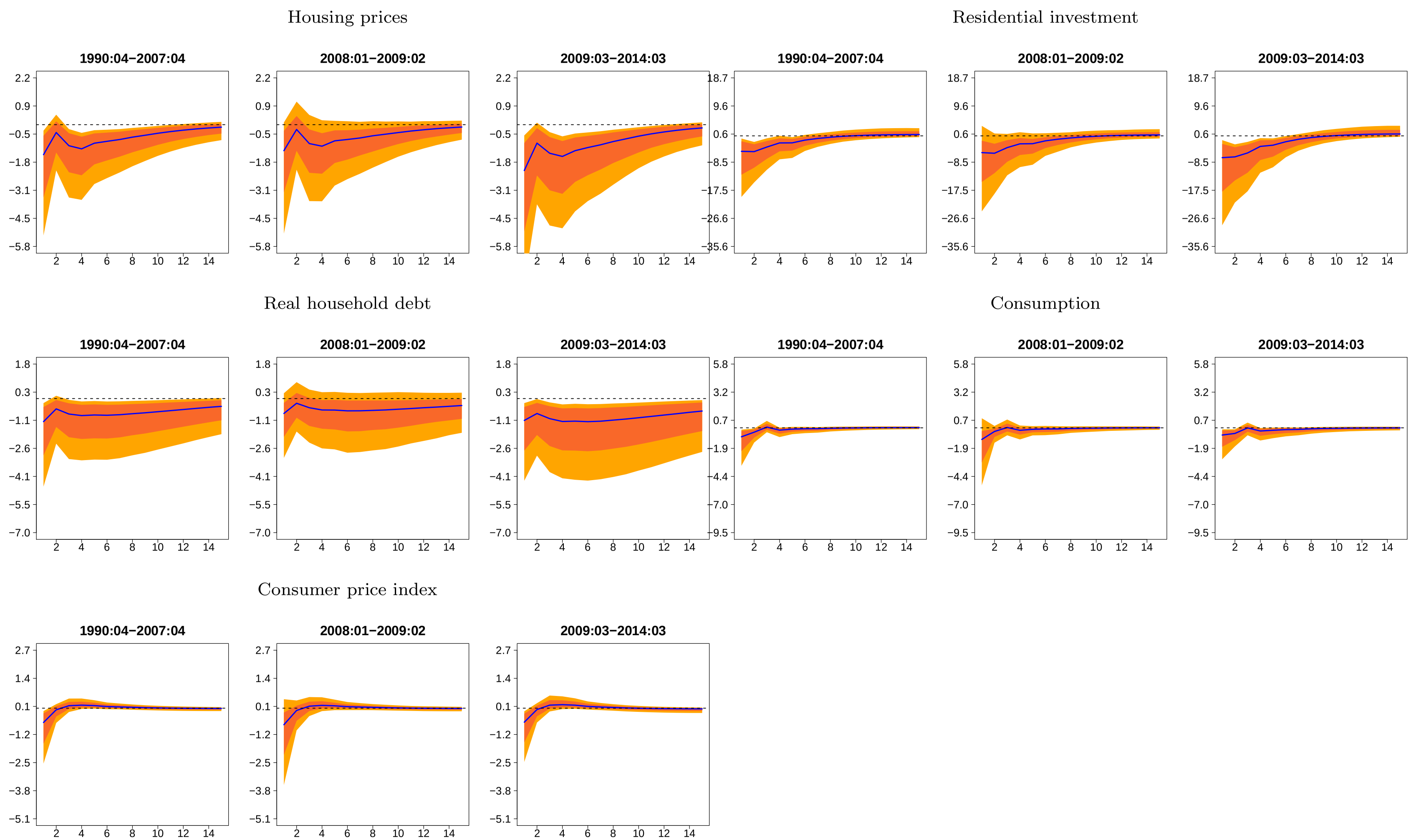
Notes: The figure shows the house price index, the growth rate of household indebtedness (in year on year terms), policy rates and shadow interest rates for all economies under consideration.

Fig. 1: Data overview



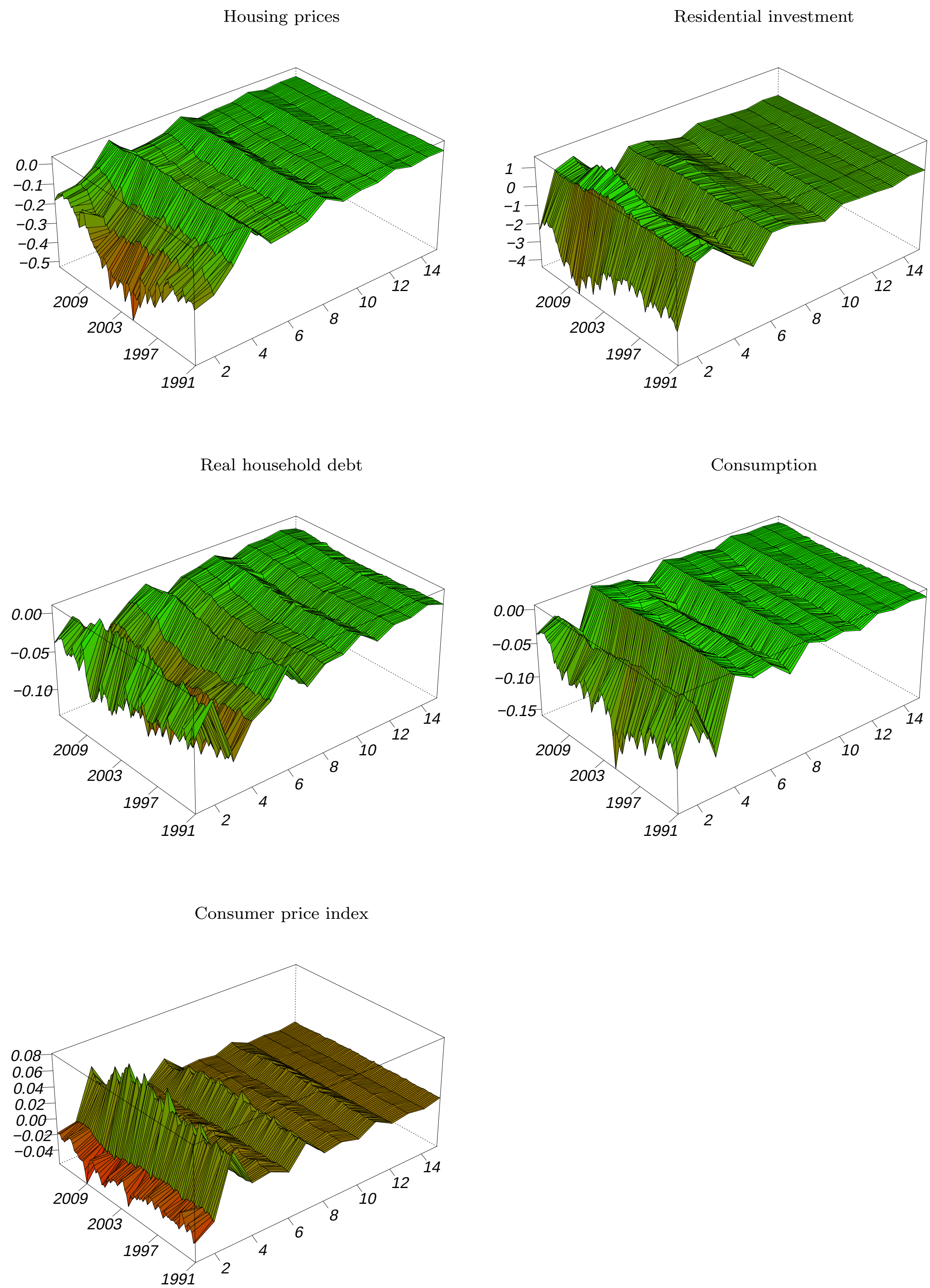
Notes: Posterior median of impulse responses. Results based on 5,000 draws from a total chain of 15,000 iterations from the posterior distribution of impulse responses.

Fig. 2: Dynamic responses of US macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock



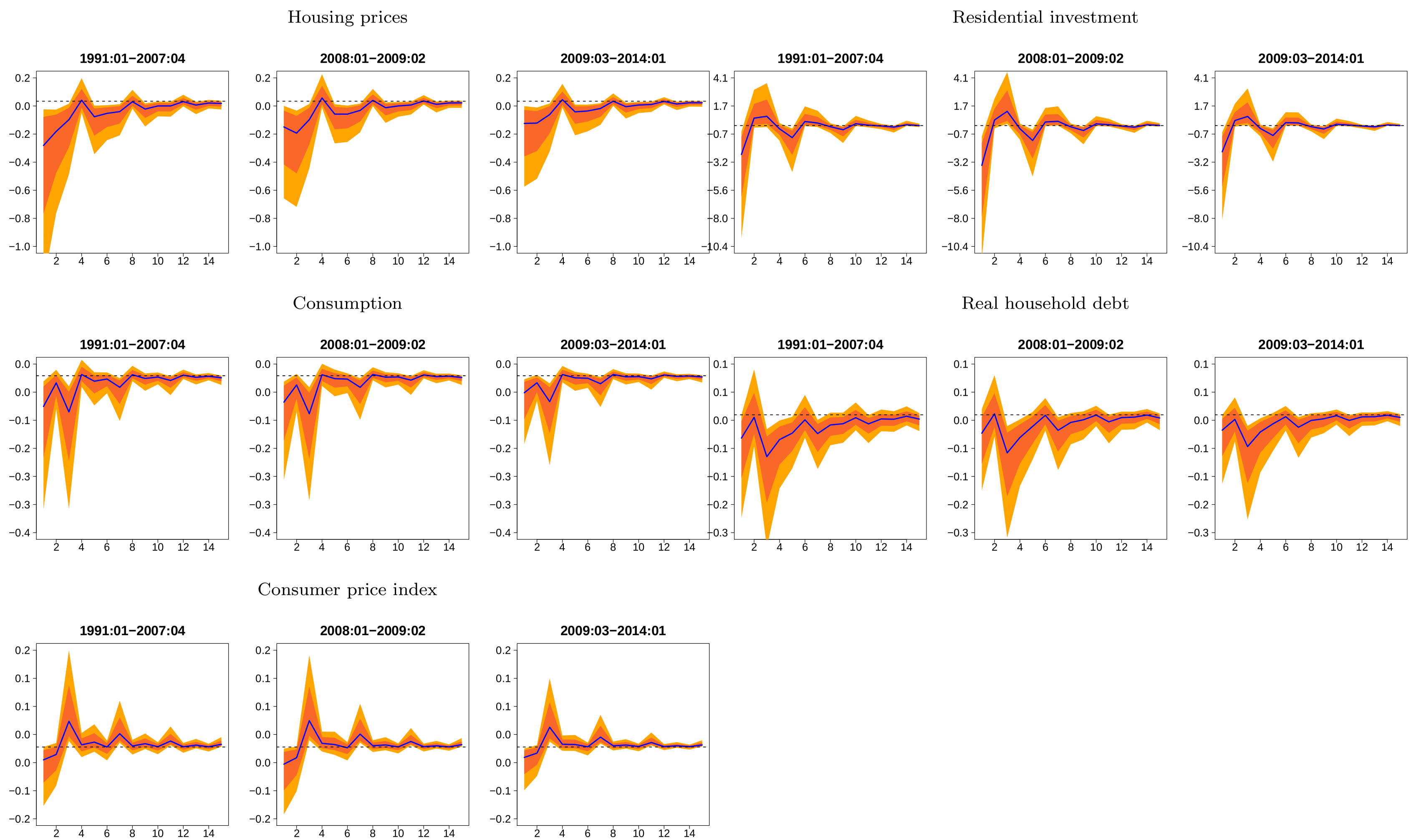
Notes: Posterior distribution of impulse responses averaged across three selected time periods for the US. All figures report median responses (in dark blue) along with the 16th (25th) and 84th (75th) credible sets in light (dark) orange across time. The responses are based on 5,000 draws from a total chain of 15,000 draws.

Fig. 3: Selected dynamic responses of US macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock.



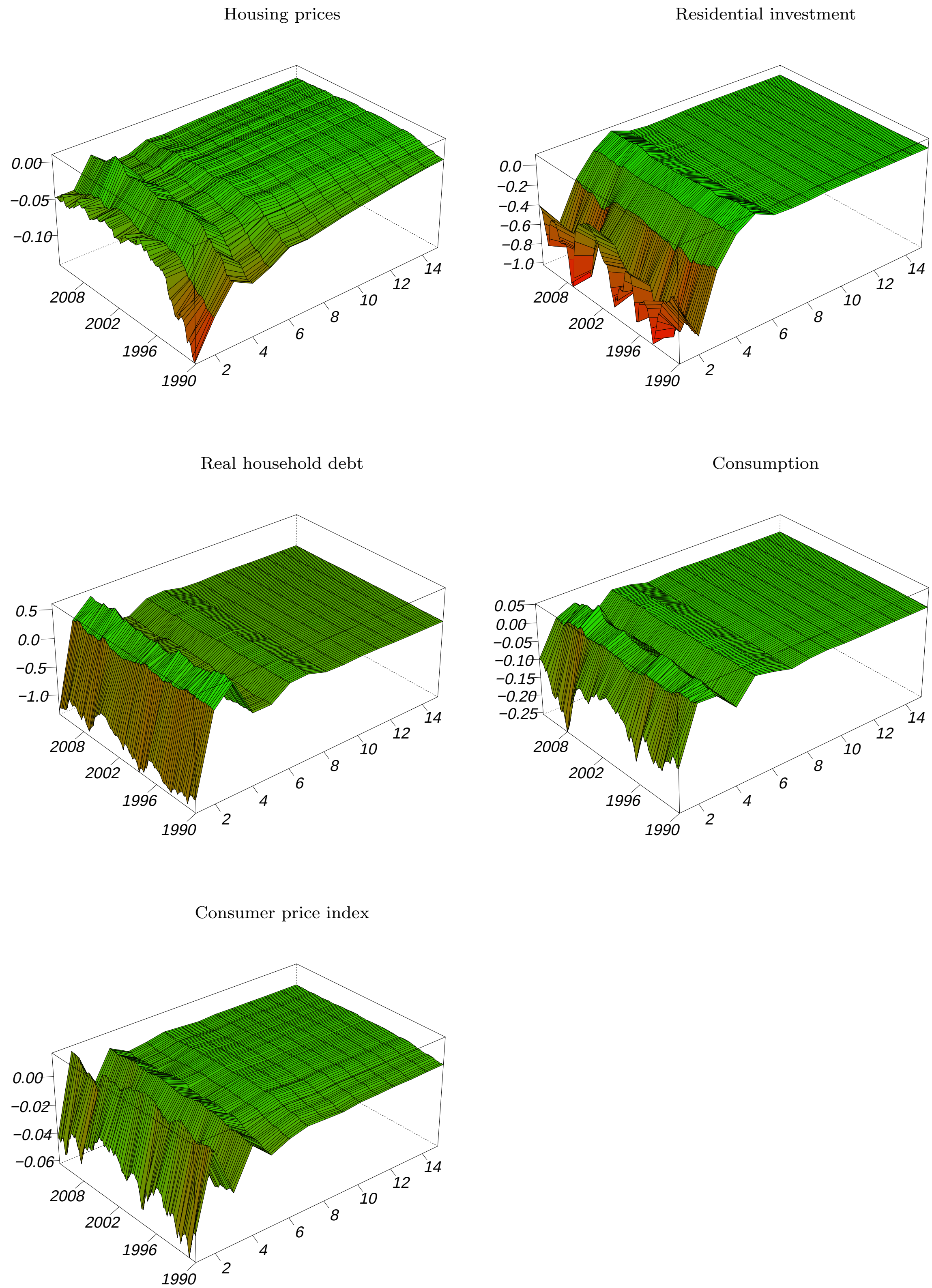
Notes: Posterior median of impulse responses. Results based on 5,000 draws from a total chain of 15,000 iterations from the posterior distribution of impulse responses.

Fig. 4: Dynamic responses of UK macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock



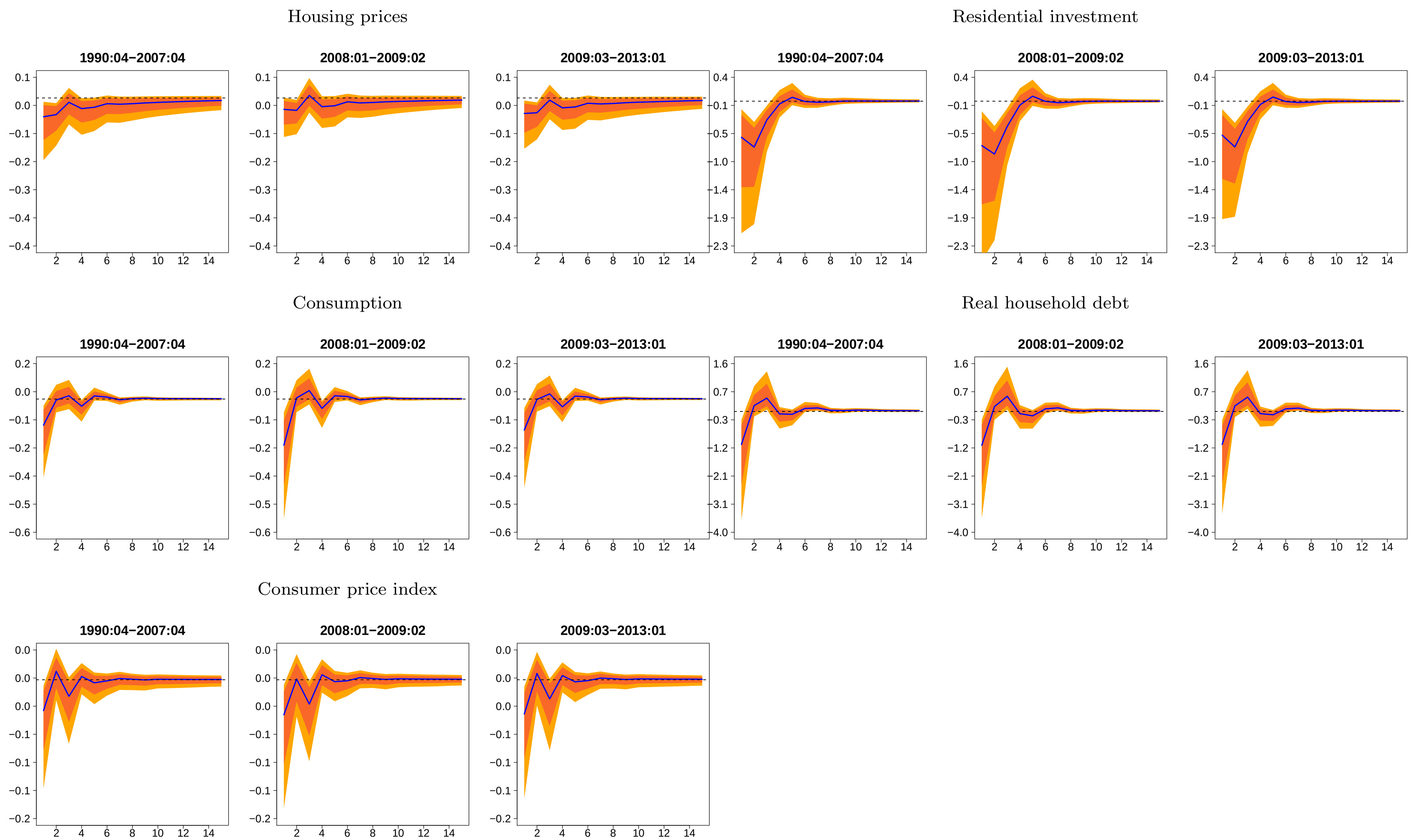
Notes:Posterior distribution of impulse responses averaged across three selected time periods for the UK. All figures report median responses (in dark blue) along with the 16th (25th) and 84th (75th) credible sets in light (dark) orange across time. The responses are based on 5,000 draws from a total chain of 15,000 draws.

Fig. 5: Selected dynamic responses of UK macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock.



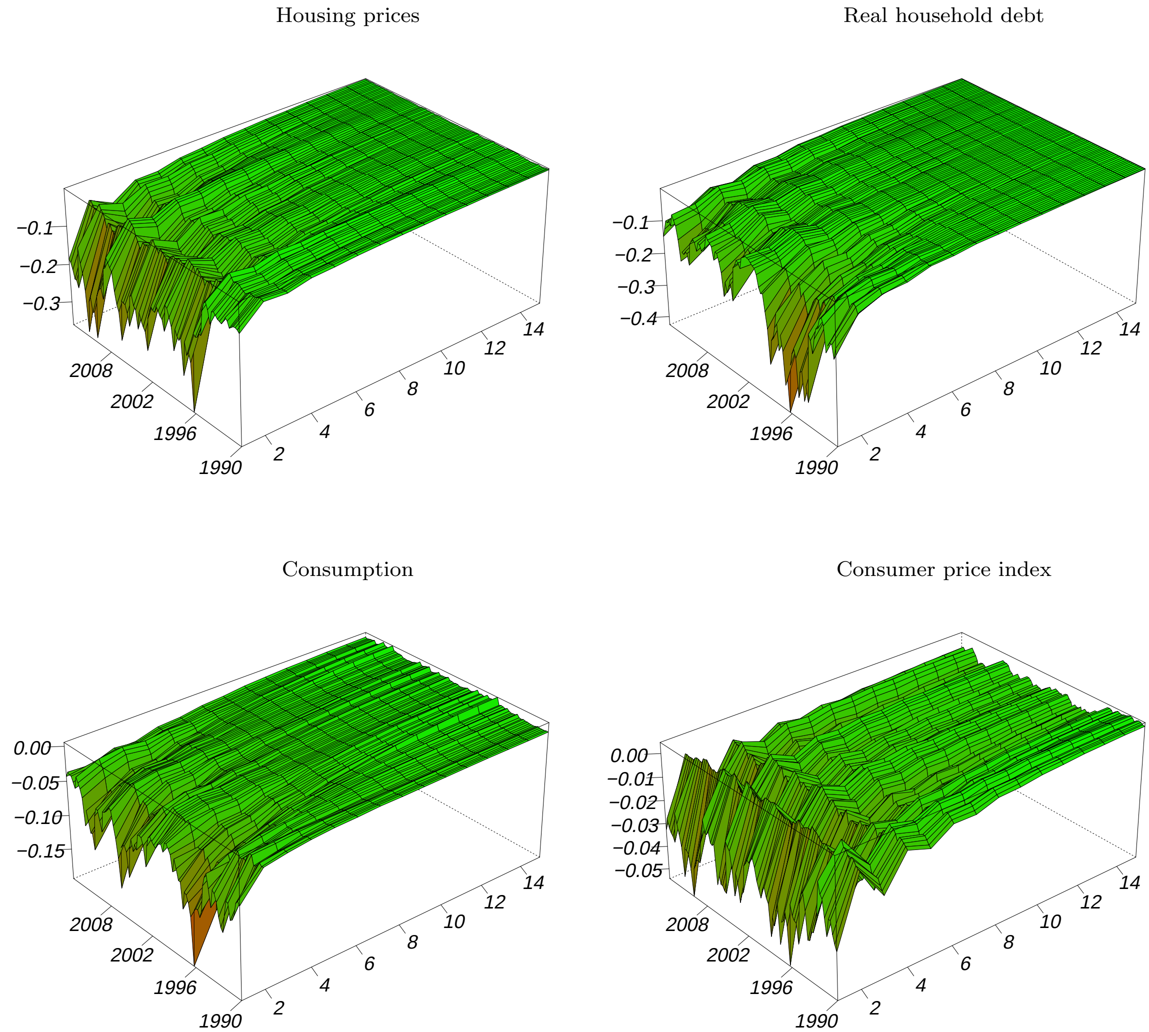
Notes: Posterior median of impulse responses. Results based on 5,000 draws from a total chain of 15,000 iterations from the posterior distribution of impulse responses.

Fig. 6: Dynamic responses of Japanese macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock



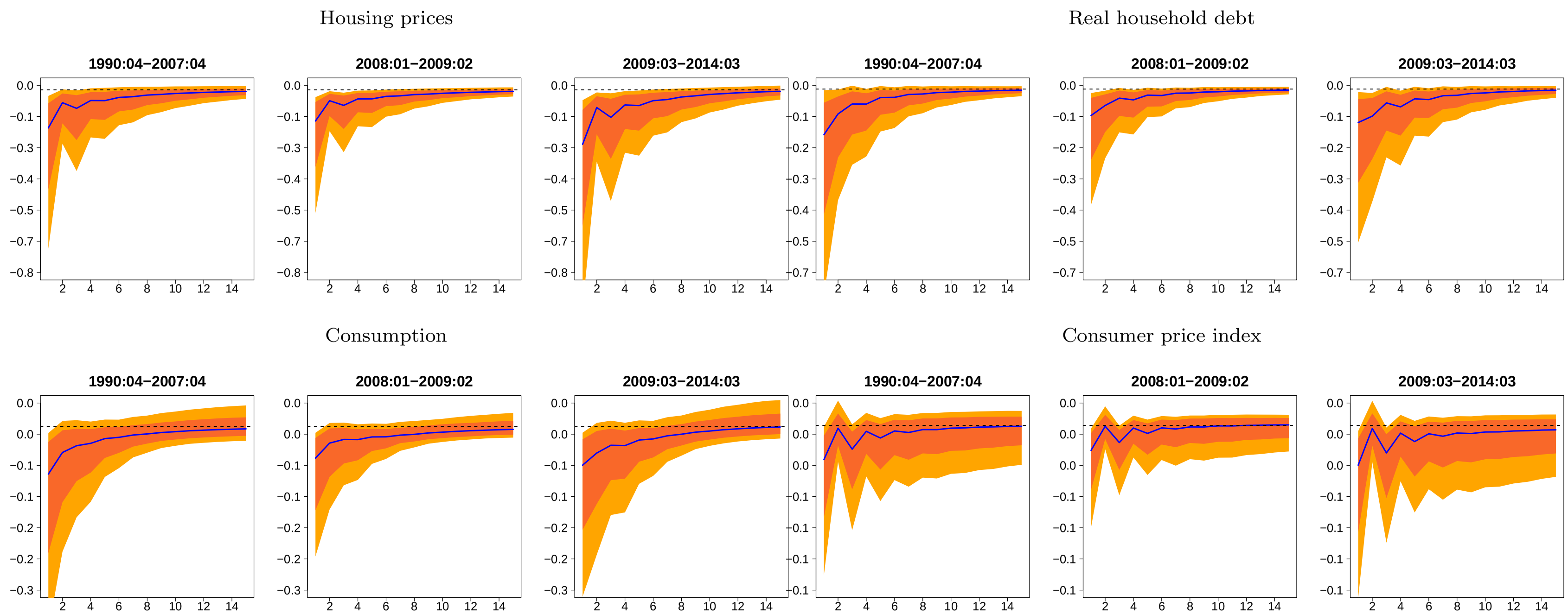
Notes: Posterior distribution of impulse responses averaged across three selected time periods for JP. All figures report median responses (in dark blue) along with the 16th (25th) and 84th (75th) credible sets in light (dark) orange across time. The responses are based on 5,000 draws from a total chain of 15,000 draws.

Fig. 7: Selected dynamic responses of Japanese macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock.



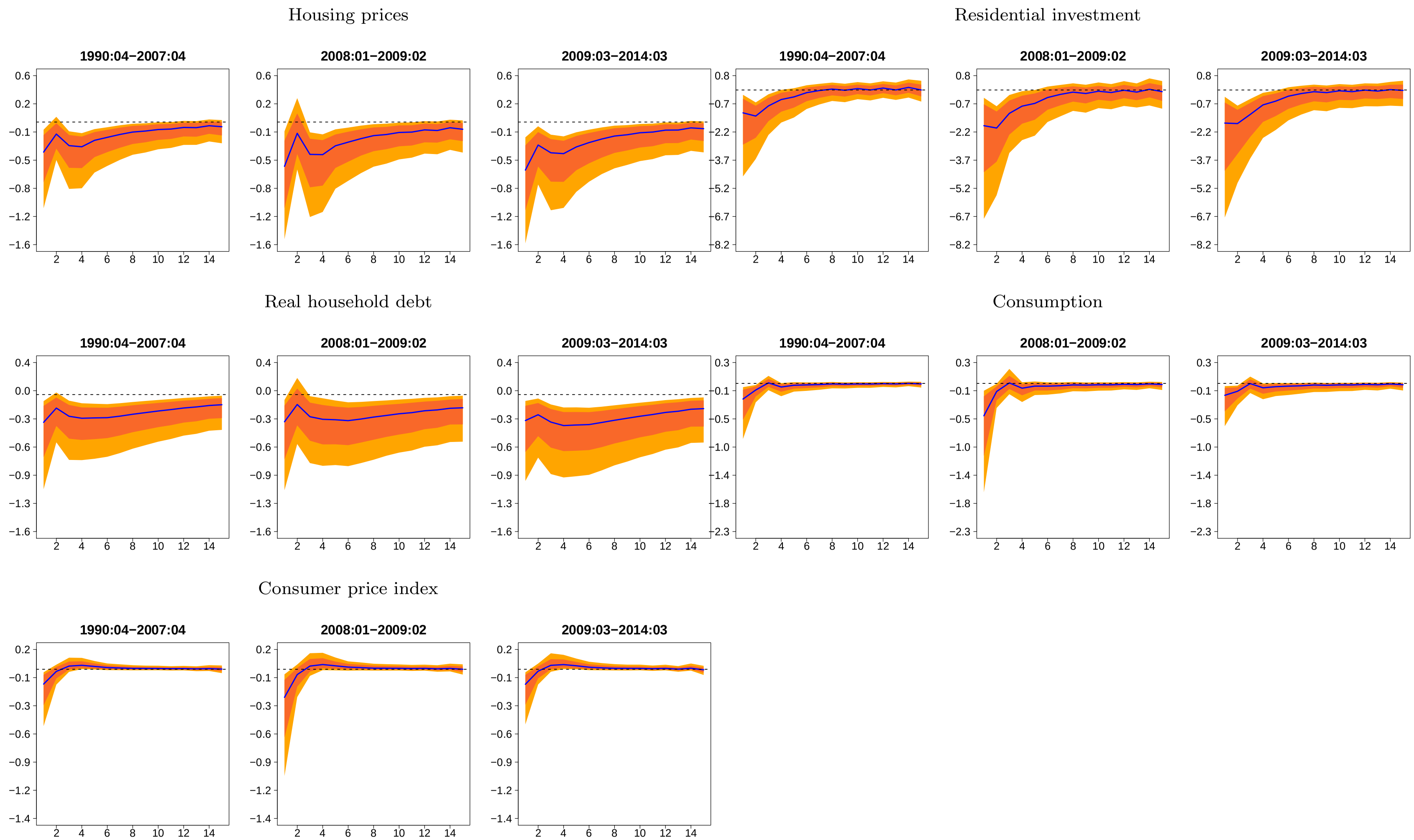
Notes: Posterior median of impulse responses. Results based on 5,000 draws from a total chain of 15,000 iterations from the posterior distribution of impulse responses.

Fig. 8: Dynamic responses of EA macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock



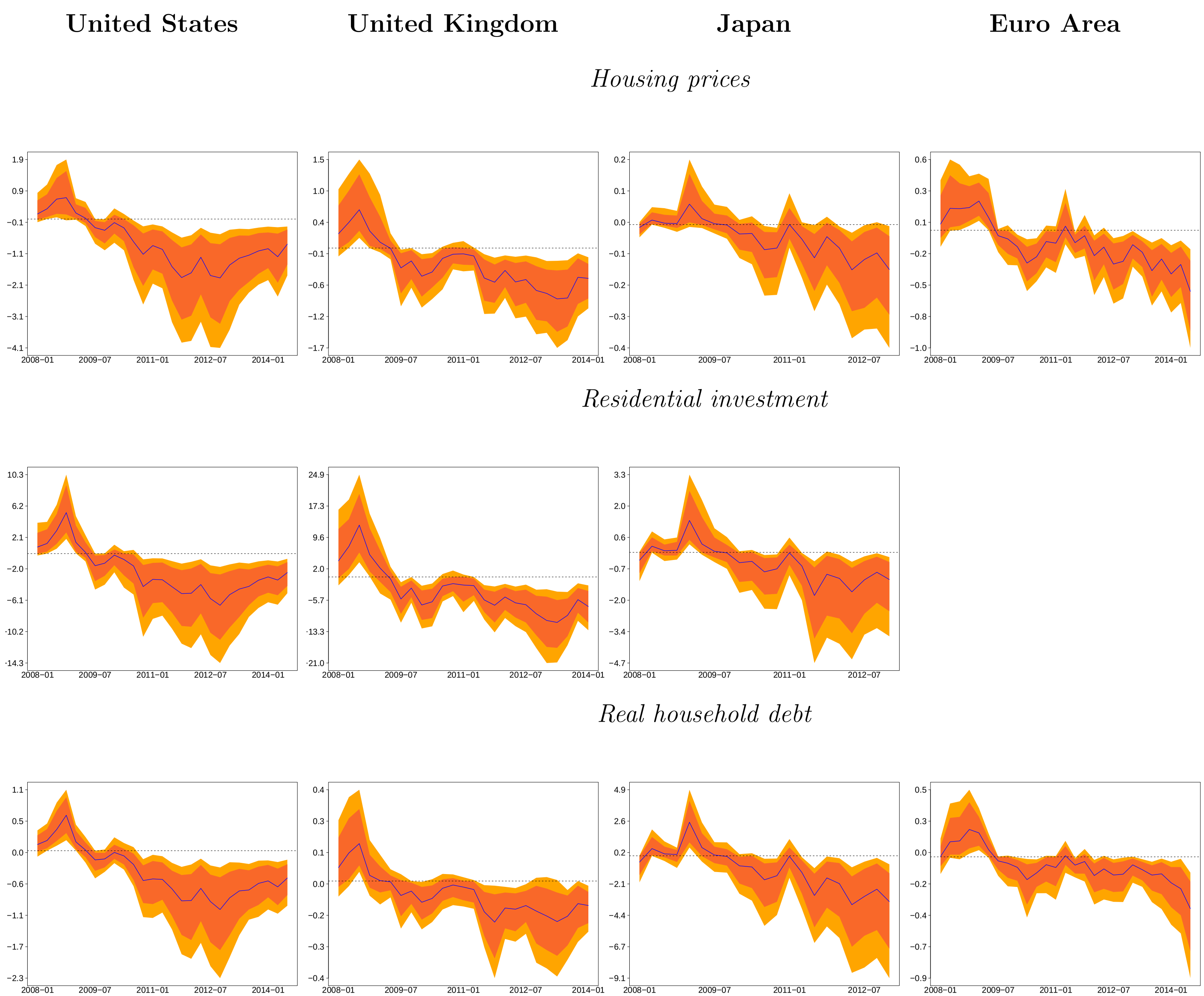
Notes: Posterior distribution of impulse responses averaged across three selected time periods for the EA. All figures report median responses (in dark blue) along with the 16th (25th) and 84th (75th) credible sets in light (dark) orange across time. The responses are based on 5,000 draws from a total chain of 15,000 draws.

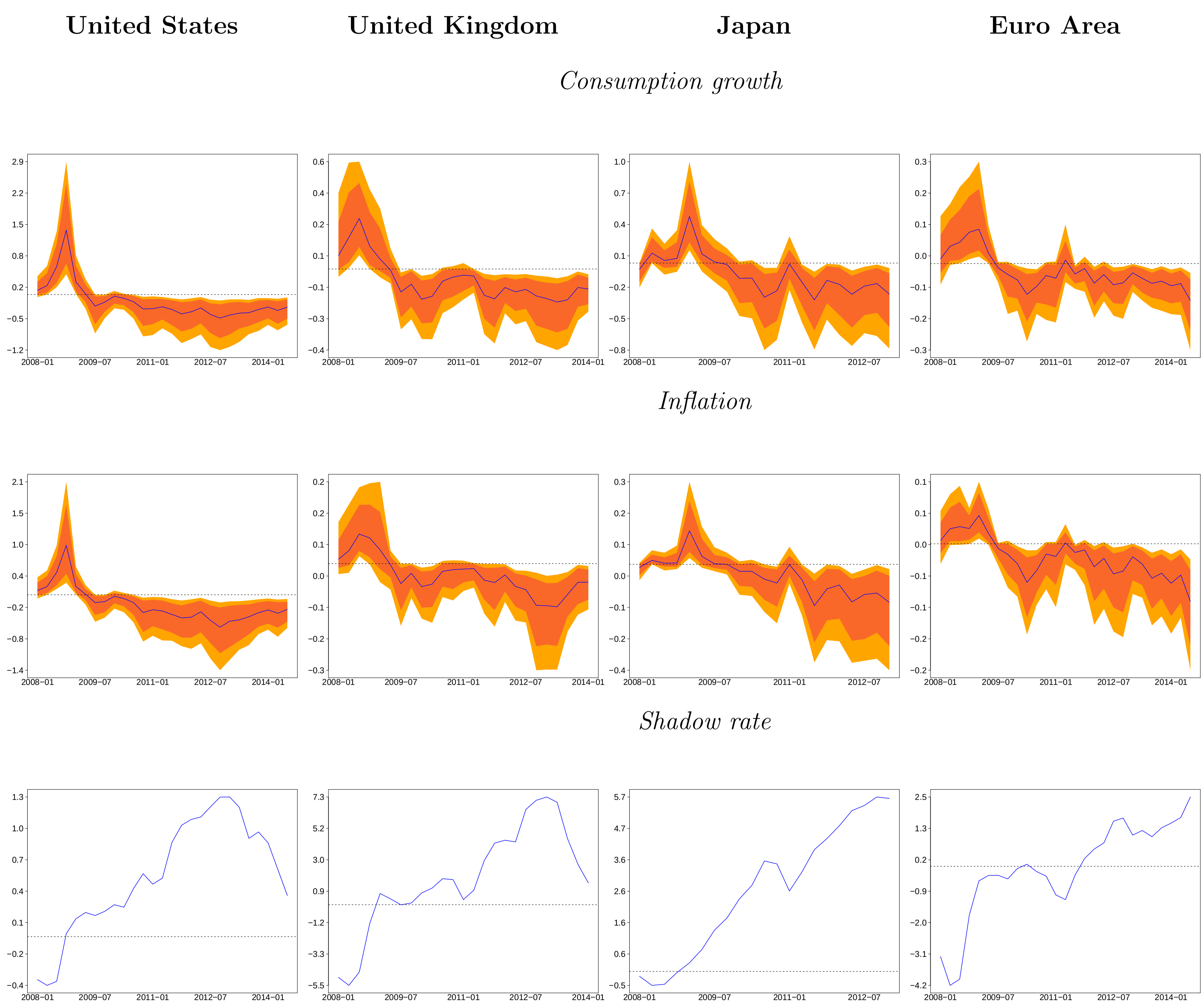
Fig. 9: Selected dynamic responses of EA macroeconomic quantities to a 25 basis point (bp) unconventional monetary policy shock.



Notes: Posterior distribution of impulse responses averaged across three selected time periods for the US. The moments of the responses are based on 5,000 draws out of a total chain of 15,000 draws from the posterior distribution of impulse responses.

Fig. 10: Selected dynamic responses of US macroeconomic quantities to a 25 basis point (bp) shock to the term spread


United States
United Kingdom
Japan
Euro Area
Housing prices
Residential investment
Real household debt



Notes: Posterior distribution of the difference of time series based on a counterfactual where it is assumed that the shadow rate is set equal to zero and the actual realization of a given time series. Results are based on 5,000 draws from the posterior distribution of impulse responses.

Fig. 11: Counterfactual historical simulation for selected macroeconomic quantities

Appendix A   Data appendix

Table A.1: Definitions and Sources of Data

Data	Country	Definition	Source
Real Consumption	US	Real Personal Consumption Expenditures	Bureau of Economic Analysis
	UK	Real Private Consumption Expenditures	Bank of England
	Japan	Real Private Consumption Expenditures	Bank of Japan
	EA	Real Private Consumption Expenditures	ECB
Consumer Price Index	US	Consumer Price Index	Bureau of Economic Analysis
	UK	Harmonized Index of Consumer Price	Eurostat
	Japan	Consumer Price Index	Bank of Japan
	EA	Harmonized Index of Consumer Price	ECB
GDP Deflator	US	GDP Deflator	Bureau of Economic Analysis
	UK	GDP Deflator	Bank of England
	Japan	GDP Deflator	Bank of Japan
	EA	GDP Deflator	ECB
Real Residential Investment	US	Real Private Residential Fixed Investment	Bureau of Economic Analysis
	UK	House Building: Permanent Dwellings Started and Completed	Bank of England
	Japan	Real Private Residential Fixed Investment	Bank of Japan
Real House Price Index	US	Real Residential Property Prices, Existing Dwellings	Bank of International Settlement
	UK	Real Residential Property Prices, Existing Dwellings	Bank of International Settlement
	Japan	Real Residential Property Prices, New and Existing Dwellings	Bank of International Settlement
	EA	Real Residential Property Prices, New and Existing Dwellings	Bank of International Settlement
Real Home Mortgage Loans	US	Real Home Mortgages Liabilities of Households and Nonprofit Organizations	Flow of Funds, Federal Reserve
	UK	Real Loans Secured on Dwellings	Bank of England
	Japan	Real Loans to Households for House Purchases	Bank of Japan
	EA	Real Loans to Households for House Purchases	ECB
Shadow Interest Rate	US	Shadow Interest Rate	Krippner index
	UK	Shadow Interest Rate	Krippner index
	Japan	Shadow Interest Rate	Krippner index
	EA	Shadow Interest Rate	Krippner index
Long Term Interest Rate	US	10-Year Treasury Constant Maturity Rate	Federal Reserve System
	UK	Long-Term Government Bond Yields: 10-year	OECD
	Japan	Long-Term Government Bond Yields: 10-year	OECD
	EA	Harmonized Long-Term Interest Rate	ECB

Appendix B A taxonomy of unconventional monetary policy

Table B.1: Implementation of Unconventional Monetary Policy

US	Date	Actions
QE1	November 2008	Purchased \$ 1.75 trillion in long-term Treasuries as well as debt issued by Fannie Mae and Freddie Mac and fixed-rate mortgage backed securities (MBS) guaranteed by those agencies.
QE2	November 2010	Purchases of \$ 600 billion in long-term Treasuries, ended in June 2011.
QE3	September 2012	Purchase \$40 billion in agency-backed MBS per month until economic conditions improved substantially.
UK	**Date**	**Actions**
QE1	March 2009	Initial purchase of GBP 75 billion of assets over 3 months financed by issuance of central bank reserves. Purchases increased over subsequent months to GBP 200 billion, completed in January 2010.
QE2	October 2011	Purchases of further GBP125 billion, completed in May 2012.
QE3	July 2012	Additional GBP50 billion to be completed in November 2012.
ECB	**Date**	**Actions**
CBPP 1	July 2009	Purchases of EUR60 billion of euro-denominated covered bonds (through the Covered Bond Purchase Program (CBPP)).
CBPP 2	November 2011	A second CBPP was launched and was supposed to buy 40 billion of covered bonds. However when the program was interrupted in October 2012, only EUR16,4 billion had been purchased.
SMP 1	May 2010	Securities Markets Program (SMP): purchases of Portuguese, Irish and Greek government bonds.
SMP 2	August 2011	Securities Markets Program (SMP): purchases of Spanish and Italian government bonds.
OMT 1	September 2012	Outright Monetary Transactions (OMT) program: purchases of sovereign bonds with a maturity of up to 3 years in the secondary markets.
Forward Guidance	July 2013	Promise to keep low interest rates for an extended period of time.
Japan	**Date**	**Actions**
QE1	March 2001	Bank reserve target increased from 5 trillion yen to 3235 trillion yen, with purchase of government bonds amounting to 18 trillion.
Credit Easing	March 2001	Purchase of ABS (Asset-Backed Securities), ABCP (Asset-Backed Commercial Paper) and equities from financial institutions
Comprehensive easing policy	October 2010	Asset-purchase fund of 35 trillion.
Comprehensive easing policy	October 2011	Previous Asset-purchase fund up to 55 trillion.