

## **The Folk Theorem of Decreasing Effectiveness of Monetary Policy:**

### **What Do the Data Say? \***

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October 17, 2016

#### Summary:

It is increasingly claimed that unconventional monetary policies are subject to decreasing effectiveness in supporting growth and raising the inflation rate. There are good reasons to believe that the effects of further asset purchases by central banks and of moving the interest rate deeper in negative territory progressively decline. But has it been happening? This paper attempts to provide an answer. Looking at the Eurozone, the UK, the US and Japan, it uses different approaches (linear projection and Bayesian VAR) on different sub-samples. The evidence is mixed: interest rates seem to be subject to the decreasing effectiveness hypothesis, QE less so.

(\*) Paper to be presented at the Annual Research Conference of the IMF on November 3, 2016. We are most grateful to Tomasz Wieladek for having generously shared data and for help with coding. We also wish to thank the National Institute of Economic and Social Research and Kiyohiko Nishimura for providing data. We acknowledge useful comments by two anonymous reviewers.

## 1. Introduction

After several years of experimentation, a growing number of observers are convinced that unconventional monetary policies are becoming increasingly less efficient (see, e.g., Goodhart and Ashworth 2012; Krishnamurthy and Vissing-Jorgensen, 2013; Roubini, 2014; Blanchard 2016a; Oakley, 2016). Central bankers, on the other hand, generally consider that these policies work well and eventually deliver what they are designed for (Draghi, 2016; Gagnon et al., 2016), although the lags may be much longer than with traditional monetary policy (Engen et al., 2015). Former central bankers are less sanguine, though, for example Bernanke (2016) and Ueda (2012).<sup>1</sup> A poll of British-based economists (Armstrong et al., 2015) shows that opinions on the issue are about equally split. This paper attempts to determine which view is backed by (admittedly short) data.

This is an important issue at this juncture. Nearly ten years after the Global Financial Crisis, in most advanced economies growth remains subdued and inflation is generally significantly below target. It may be that this state of affairs is unrelated to monetary policies. Slow growth is sometimes justified by the secular stagnation hypothesis while low inflation is related to a possibly flatter Phillips curve. Responses to these possibilities do not belong to central banks. Yet, the central banks of the US, Japan, the UK and the Eurozone, and others as well, are actively engaged in trying to support growth and raise inflation with unconventional policies. In their views, therefore, there is a role for monetary policy. It matters greatly whether they have the tools to achieve their aims. It means that, in the presence of decreasing effectiveness, they will have to act increasingly aggressively (Orphanides and Wieland, 2000). Ominously, however, if the general view is that unconventional policies do not work, inflation expectations will decrease, as they have in Japan. In that case, the task of central banks could be hopeless.

Skeptics argue that unconventional policies have drawbacks. They fear the mispricing of risk, the scarcity of safe assets and, more generally, distortions created by interest rates too low for too long. While central banks seem to believe that the risks are small and the effects large, skeptics take the view that the balance between costs and benefits – or between risk and returns – is increasingly tilting against unconventional policies. This view implies that fiscal policies should take over. Given the high indebtedness of many governments in advanced countries, this means shifting from one series of drawbacks to another one. An often mentioned way-out is helicopter money, fiscal expansions financed by money creation.

This is one important reason to explore the decreasing effectiveness hypothesis. Obviously, the sample size is limited, a few years in a few countries. Ideally, we should wait until more evidence accumulates. Yet, there are good reasons to attempt an early evaluation. This is a live issue, including the potential role to be played by fiscal policies. In addition, unconventional policies are not meant to be pursued for years onward. They have already stopped in the US, where the issue is when and how to exit. This means that the sample size is unlikely to increase much further.

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<sup>1</sup> Bernanke states that “there are signs that monetary policy in the United States and other industrial countries is reaching its limits”.

Given the short sample horizon, we need to use monthly data, which inevitably restricts the range of variables that can be examined. Even so, macroeconomic phenomena are slow. Standard monetary policy, for instance, is understood to affect the real economy after several quarters and unconventional policies may take longer to make a difference (Engen et al., 2015). It follows that monthly data may be more noisy than desirable. This explains why most studies of unconventional policies so far have looked at their effects on financial markets, which react fast. These studies have detected strong effects, but that is only the first step in actually fostering growth and raising inflation. The present paper bypasses that step and directly examines the impact on growth and inflation. It finds some evidence of decreasing effectiveness although the statistical significance of these results is limited, marred as it is by the limited time span under study.

The next section briefly reviews the channels of effects of unconventional policies, and informally provides arguments for the decreasing policy effectiveness hypothesis. Section 3 summarizes recent empirical research designed to measure the effects of unconventional policies and explains our own strategy. Section 4 presents a battery of tests designed to determine the empirical validity of the hypothesis in the case of the US, Japan, the UK and the Eurozone. The last section concludes.

## **2. Channels of Effects and the Decreasing Effectiveness Hypothesis**

A growing body of literature describes and evaluates how unconventional monetary policies affect the economy. They identify the potential channels through which these policies operate. The earlier literature focused on quantitative easing; contributions include Bernanke et al. (2004) and Krishnamurthy and Vissing-Jorgensen (2013). Recent reviews include Borio and Zabai (2016), Fratzscher et al. (2014), Santor and Suchanek (2016) and World Bank (2015). This section examines reasons why decreasing effectiveness could set in. It follows the traditional analysis of standard monetary policy that considers the direct interest rate channel, the confidence channel, the portfolio balance channel, the bank credit channel, the sovereign credit risk channel and the exchange rate channel.

Decreasing effectiveness means that the effect of the relevant instrument declines as it is used more intensively. It is an assertion that the relationship  $y = f(x, Z)$  between the instrument ( $x$ ) and the sought-after effect ( $y$ ) is not necessarily linear and, at any rate, becomes concave downward when  $x$  increases sufficiently, that is  $\partial f / \partial x > 0$  for low (normal) values of  $x$  and  $\partial^2 f / \partial x^2 < 0$ , at least beyond some threshold. In the present case, we will estimate  $\partial f / \partial x$  over different samples and test whether it is smaller over samples where  $x$  is large than where  $x$  is small. We also check whether the instrument loses potency over time, by comparing its effectiveness in over different periods. We do not attempt to identify the channels involved, leaving it for further work.

### **2.1. Non-standard monetary policies**

Unconventional monetary policies start when the policy interest rate has been brought to the Zero Lower Bound (ZLB). Having reached the ZLB, a number of central banks have looked for other ways to lift the inflation rate toward its target and promote growth. The two main instruments have been Quantitative Easing (QE) and negative

interest rates. They have supplemented these instruments with forward guidance, essentially committing to keep the policy rate at the ZLB or below for a long period of time and announcing a precise schedule of asset purchases spread over several quarters. We look at these two main instruments and their channels and ask whether there exist plausible reasons for entertaining the presence of decreasing effectiveness.

### **Negative interest rates**

Negative interest rates are often seen as a straightforward extension of standard policy, whereby there is no reason to see zero as particularly meaningful. In addition, what matters for economic activity is the real interest rate, which can be and has been negative independently of the level of the nominal rate. In fact, negative nominal interest rates are all but straightforward (Coeuré, 2016).

A fundamental reason is that cash money bears zero interest, which is why it is presented as a dominated asset. The usual explanation of why money exists at all is that it yields an implicit positive return in the form of transaction services. It follows that any asset that can be freely exchanged for money must offer a higher, i.e. a positive yield. Since central banks normally set the interest rate by intervening on very short-term maturity assets, they should not be able to bring the policy rate below zero. We now know that this conclusion is incorrect. The reason is that cash is costly to hold, at least in large amounts because of storage and insurance costs. This suggests that the opportunity cost of holding money is negative for amounts larger than those needed for transaction purposes. The implication is that there is a limit to how negative interest rates can be. The zero lower bound can be breached, but there must exist an effective lower bound (ELB). The position of this bound will remain unknown until it is breached. Even so, it is likely to differ from country to country depending on the structure of the banking system, taxation, regulation, etc.

### **Quantitative easing**

Quantitative easing (QE) includes many procedures and official names.<sup>2</sup> The defining purpose is to inject, without sterilization, large amounts of liquidity by buying assets held by banks or from the market, according to a preannounced purchase program. The assets usually are chosen to be safe, normally Treasury debt. Central banks have also bought privately issued assets either because they wanted to enhance transmission by removing risk from bank balance sheets or because they wanted to reduce the borrowing costs of corporations. The counterpart of these purchases is base money creation.

The relevant monetary theory principle is the elementary assertion that money and the price level grow hand in hand. QE, therefore, should lead to an acceleration of inflation. Figure 1 shows the case of the US. The left-hand chart indicates that the relationship was largely verified until QE was started, and then broke down. The right-hand chart that focuses in more detail over the period 2003-2006 shows that the

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<sup>2</sup> QE is called Large Scale Asset Purchases (LSAP) in the US, Asset Purchases Program (APP) in the Eurozone, Quantitative and Qualitative Easing (QQE) in Japan. Related interventions are Long term Refinancing Operations (LTRO) in the Eurozone, but these are not QE proper as they focus on improving intermediation. The increase in the size of the balance sheet is a, possibly unwanted, by-product, that is demand, not supply-driven.

link started to deteriorate before the crisis. The gradual deterioration of the relationship and its full-blown breakdown suggest serious limits of elementary principles.

Central banks can expand the money base at will when the interest rate is at the ZLB (Borio and Zabai, 2016) but monetary policy requires that monetary aggregates also increase, or that interest rates decline along the yield curve, or both, as discussed below. The link from the monetary base to the monetary aggregates is the well-known multiplier. If, as shown in Figure 1, the multiplier declines toward zero, a key link disappears. Even if the monetary aggregates increase, the link to prices and output operates through increased spending. Under normal conditions, spending responds and the Phillips curve mechanism delivers the expected effect. Yet, there may be conditions when monetary aggregates fail to raise spending and when the effect of economic activity on inflation may be limited. The apparently feeble impact of economic activity on inflation is the object of current research. Ball and Mazumder (2011) find that the slope of the Phillips curve declines when inflation is low and stable. Blanchard (2016b) points to the role of strongly anchored expectations and to the general imprecision of the relationship. The next sections investigate the reasons why economic may fail to respond to monetary aggregates, or responds with decreasing effectiveness. This calls for examining the various channels of unconventional monetary policy.

## **2.2. The direct interest rate channel**

A lower interest rate is expected to increase spending by households and firms by encouraging borrowing as it affects the intertemporal price of consuming and saving. Additionally, the exchange rate is expected to depreciate, which should raise net exports.

### **Low and negative interest rates**

It is well understood that it is not the very short-term policy rate that matters but rates further along the yield curve. An important condition for policy effectiveness is that the whole yield curve be lowered. This, in turn, requires that market expectations concerning the future evolution of the policy rate, both its level and the duration of the current policy stance, respond to monetary policy decisions. When the ELB is perceived to be close, the only direction of substantial future changes in the policy rate is upward, which prevents a further lowering of the longer end of the yield curve. This is why central banks have developed the signaling channel as they wish to indicate that the policy rate will remain low or negative for a long period. This has worked well, as indicated e.g. by Bean et al. (2015). Yet, the presence of a lower bound suggests that there is increasingly less room for the level effect, leaving only the duration effect.

The adverse effects of low or negative interest rates could well hamper the duration effect. These effects include aggressive risk-taking by investors and financial institutions eager to achieve better returns, more difficult price discovery (Santor and Suchanek, 2016), the risk of disintermediation and the harmful impact on bank profitability (Brunnermeier, 2016). If these effects do not last for too long, they probably can be reasonably harmless, but persistent risk taking, mispricing and

reduced profitability are bound to become toxic. At best, steps taken by financial institutions to mitigate growing vulnerabilities will reduce monetary policy effectiveness, possibly reversing the impact when markets increasingly expect that the policy rate will be raised and the yield curve will steepen. At worst, market fragility may lead to a crisis.

Even if the yield curve can be kept flat, possibly in negative territory along the ELB, the question is what happens to the economy. An important issue is why the previous interest rate reductions – those that brought the policy rate to the ZLB – have failed to lift spending. A variety of reasons have been invoked. Potential borrowers may be over-indebted and potential lenders may be over-leveraged. Lower rates shifts income from lenders to borrowers, which may help with over-indebtedness but at the expense of over-leveraging. Under these conditions, it is unclear why lowering the interest rates further would be more successful than previous reductions.

In addition, intertemporal substitution raises spending today at the expense of spending tomorrow. To sustain spending next year, a new lowering of the interest rate is needed. When the end of lowering interest rates is nearing, because the ELB is close by, further intertemporal substitution becomes impossible. Simply keeping the interest rate low does not provide continuing stimulus; indeed the time must come when spending falls because it has been brought forward previously.

Another aspect is the pass-through of lower wholesale interest rates to rates applied to consumers and firms. Bean et al. (2015), among others, report that the pass-through is limited close and below the zero lower bound. In some countries, banks cannot charge a negative interest rate. Where they may, they are reluctant to upset commercial relationships with customers. In addition, a flat yield curve erodes the profits from maturity transformation. If competition is imperfect, banks may elect to not lower their lending rates much.

### **Quantitative easing**

Large asset purchases by the central bank raise their prices and therefore lower their interest rates. The intention is to encourage borrowing or share issuance to prompt more spending by consumers and firms, fed by both lower borrowing costs and wealth effects. As stated, it does not look different from standard open market operations. In that case, the impact from lower very short-term rates to relevant longer-term rates is driven by market expectations of future policy rates, which can be strengthened through signaling. Other asset classes are affected by portfolio rebalancing, see next channel. QE differs because central banks can choose which assets and amounts they purchase, thus acting on particular interest rates and asset classes.

By and large, the reasons why policy effectiveness might be decreasing are similar to those examined in the previous section. An additional consideration is that the volume of assets to be bought is finite. If the central bank holds a significant share of some assets, the relevant market becomes shallow and therefore less efficient. It follows that there is limit to what central banks can purchase, aptly called the Effective Quantitative Bound (EQB) by Santor and Suchanek (2016). As we move closer to the

(unknown) EQB, markets may anticipate that QE is reaching its limits. Furthermore, the associated uncertainty can raise risk premia across the board.

Another often noted limit is the much-feared emergence of asset price bubbles. Mechanically, QE raise asset prices. These prices can remain at their fundamental level as long as they are matched by the present value of future earnings evaluated at prevailing low interest rates. Yet, because QE is by definition temporary, asset prices are expected to fall back once liquidity is being removed. Thus the long-run resale value must be lower than current prices, with considerable uncertainty as to when exit will take place and at which pace. The result is that the wealth effect may be increasingly reduced as asset prices rise and that the expectation of a subsequent crash may build up as QE unfolds.

### **2.3. The portfolio balance channel**

As any other price change, a lower policy rate is transmitted to other returns through a general equilibrium effect as investors rebalance demand for all asset classes. The portfolio balance channel represents investor willingness to take on more risk when the policy rate declines. Risk premia decline across the board.

#### **Low and negative interest rates**

The presumption must be that bringing interest rates into negative territory does not substantially alter the operation of the portfolio balance channel. The whole range of bond rates and asset prices should be re-jigged as usual. One can imagine two exceptions to this presumption. First, while existing bonds may have negative expected returns because high current prices are expected to decline, nominal illusion could make it prove difficult to issue bonds with negative rates. Second, in principle, asset prices are the present discounted value of future earnings. These (mostly implicit) calculations are problematic when the discount rate is negative, if only because the present value may become unbounded. This is one reason why markets fear ‘bubbles’, in fact major uncertainty rather a ‘bubblish’ equilibrium. A possible reaction is that the attendant uncertainty results in higher risk premia and therefore a muted response as the de facto discount rate does not decline as usual. Both features can result in decreasing effectiveness.

#### **Quantitative easing**

As some assets are withdrawn and their prices rise, investors are led to rebalance their portfolios by acquiring other assets. If the supply of these other assets does not rise to meet demand, their prices increase and their yields decline. This is indeed a key channel of transmission, one that central banks rely upon the impact of QE to spread. Its role is to reduce both term and risk premia.

The potential downside is that risk becomes mispriced and that investors – including banks, insurance companies and pension funds – ride up the flattened risk-return schedule with improper understanding of risk being taken or accepting risk because of pressing search for yield. As QE unfolds, more risk may be taken. This may not result in immediate loss of effectiveness but into subsequent financial difficulties once QE stops and is reversed.

## **2.4. The confidence channel**

Unconventional policies are meant to indicate that the central bank stands ready to take exceptional action when other standard means are no longer available. In addition, the ability to target specific assets implies that the central bank can address specific financial concerns, as with TARP in the US. Both readiness to act and the emergence of new instruments could help dispel fears on financial markets and beyond that serious problems remain unaddressed (Curdia and Woodford, 2011). The confidence channel is expected to boost spending, both directly by improving expectations and indirectly by reducing interest rate risk premia.

Since what matters is the signaling impact of the policy measures, we can consider negative rates or QE together. Both face the same challenge that the room for maneuver declines as the policies unfold. Negative rates face the existence of an unknown ELB, QE is ultimately limited by the size of the markets. These Knightian limits are bound to gradually erode policy effectiveness. They could even make nonstandard policies ineffective if faced with the perception that the end of the road is in sight and that the central bank has reached its limits, in effect forced to stop confidence-building measures.

One specific aspect of QE is that asset purchases can be used to repair malfunctioning markets where demand is reduced by fears of impending crisis. When confidence has returned in the affected markets, QE stand to be less efficient. This was the case in 2007-9. Indeed several papers (Krishnamurthy and Vissing-Jorgensen, 2013; Fratzscher et al., 2014) detect such an effect early on, but none once markets were stabilized.

## **2.5. The bank credit channel**

The literature on the credit channel (Bernanke and Gertler, 1995) argues that ample availability of liquidity encourages banks to increase lending, over and above its impact on the interest rate, meaning that this channel is specific to QE. When banks hold large amount of cash, they have a choice of holding it as part of their reserves at the central bank, or to lend to customers. Under the assumption that bank-lending rates exceed central bank deposit rates, it is expected that banks will prefer to lend to customers. Easier credit terms, in turn, are expected to encourage spending by both households and firms.

The bank credit effect could be muted when banks and/or their customers are highly leveraged. Thus, in contrast to the confidence channel, QE might become more effective when the situation improves.

Decreasing effectiveness may arise if it leads banks to chasing increasingly less reliable borrowers. In that case, either lending rates will rise or lending will start decreasing. Indirect evidence is provided by Figure 2, which plots the size of the balance sheet of the Federal Reserve – already shown in Figure 1 – and the monetary aggregate M2. The ratio between these two measures is the money multiplier, which captures the banking system lending response to liquidity injections by the central bank. As is well known, the money multiplier has declined considerably since the



start of QE: the ratio of M2 to the size of the Fed's balance sheet has declined from an average of 8.1 over 2003-2007 to 3.7 over 2009-2012 and 2.8 since 2013.

## **2.6. The sovereign credit risk channel**

The interest rate paid the Sovereign is usually the basis for all interest rates the country. This is because sovereign debt is, rightly or wrongly, treated as a safe(r) asset. It follows that any policy action that lowers *ceteris paribus* the interest rate of sovereign debt is potentially equivalent to a direct reduction of the policy rate. This channel concerns QE. Indeed, government debt purchases by the central bank in effect reduce public sector indebtedness. This is because debt service on purchased instruments implies payments to the central bank, which rebates profits to the Treasury or, equivalently, the public sector swaps interest-bearing debt for zero interest-bearing money. Insofar as a lower debt reduces the sovereign risk premium, this is an additional channel.

The channel faces limits, though. The temporary nature of QE means that the corresponding amounts of public debt are not fully written down but, as long as QE is in place, effective debt service is reduced and therefore the remaining debt held outside the central bank is comparatively safer. The result is lower risk premia, but decreasing as the end of QE becomes nearer. The “taper tantrum” of 2013 could be a manifestation of this effect (Foerster, 2014).

In addition, the channel is effective only if the debt interest rate is higher than the interest paid on money, i.e. if the interest rate is positive. If QE is supplemented with negative interest rates, the effect is reversed when the central bank purchases debt that was issued with a negative rate. Combining QE and negative interest rate therefore shuts off and turns into reverse this channel.

## **2.7. The international portfolio balance and exchange rate channels**

Finally, the portfolio rebalancing process means that residents will acquire foreign assets, possibly in amounts commensurate with the central bank purchases. This should lead to a depreciation of the exchange rate. In small open economies, the exchange rate channel is usually the main channel of standard monetary policy.

### **Low and negative interest rates**

In principle, the effect of the policy interest rate on the exchange rate is independent on its size.

### **Quantitative easing**

The experience so far is that the large countries have adopted QE policies more or less at the same time. As a result, their effective exchange rates have not moved much (Caballero et al. 2016; Eggertson et al. 2016). More significant movements have affected a host of other countries, but this is not an issue related to this paper.

### 3. Overview of the Evidence

A growing number of studies are attempting to evaluate the effectiveness of unconventional monetary policies. With a very short sample period, much of the early work has relied on high frequency observations and focused on the effect of nonstandard policies on various asset prices or on measures of asset price volatility. The impact of macroeconomic variables, which move much more slowly, has been examined only recently.<sup>3</sup>

Given the unsettled economic and financial situation, a key challenge is to disentangle the influence of policy decisions from other contemporary shocks, including those that have affected the financial markets and which led central banks to enact non-standard policies. As noted by Borio and Zabai (2016), two methods have been used.<sup>4</sup> First, using various types of VAR analysis, some authors test whether shocks designed to capture non-standard policies affect the variables of interests. To be valid, these tests should not include observations that predate the adoption of non-standard policies since these policies are designed to significantly alter the operations of financial markets. In addition, as usual, identification is particularly challenging because policy announcements are likely to be more important for asset markets than actual implementation. For instance, daily or monthly asset purchases may have little impact once the schedule of purchases has been announced. This is why a second approach has been recently adopted. This approach implements the event studies methodology by relying on policy announcements.

#### 3.1. Effects of QE on Financial Markets

Empirical evidence from the US, the UK and the Eurozone strongly backs the existence of an effect of QE on asset prices and interest rates at all maturity. In the case of the US, Krishnamurthy and Vissing-Jorgensen (2013) provide early evidence that the portfolio balance channel has been effective. This evidence has been confirmed by a large number of studies, including Engen et al. (2015), Gagnon et al. (2011) and Wu and Xia (2015). Similarly qualitative results are reported for the UK by Kapetanios et al. (2012) and the Eurozone by Frazscher et al. (2014).

Other channels have also been identified. Bauer and Rudebusch (2014) separate out the portfolio balance channel from the interest rate channel in the US and conclude that both have been operative. Altavilla and Giannone (2015) reports evidence on the interest channel via private forecasters in the US and the Eurozone. The risk channel receives some backing by the study Carpenter et al. (2013) on both the US and the Eurozone.

The bank liquidity channel is backed by studies that focus on the early phase of the financial crisis, e.g., Krishnamurthy and Vissing-Jorgensen (2013) for the US or Darracq-Paries and de Santis (2013) in the case of the Eurozone.

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<sup>3</sup> A number of studies are summarized in Den Haan (2016) and Borio and Zabai (2016).

<sup>4</sup> Borio and Zabai (2016) also mention simulation with DSGE models extended to include various financial frictions. This is not empirical evidence, however, as they rightly observe. These studies are properly understood as illustrating under which assumptions non-standard policies can produce some specific effects.

### **3.2. Effects of QE on Output and Inflation**

Fewer studies so far looked at the ultimate criterion of success of non-standard policies, namely whether they boost output and inflation. An important roadblock has been the measurement of unconventional policies. Macroeconomic variables cannot be measured at high frequency so that the small sample period available implies that too few observations are available. The solution is to extend the sample back to periods when unconventional policies were not in use. In principle, one can measure both the policy rate and the size of central bank balance sheets over long periods but it is likely that the adoption of unconventional policies represents a regime change. This implies that it is not problematic to carry out a single estimation over periods that correspond to different regimes.

A breakthrough has been the estimation of a shadow policy rate by Wu and Xia (2015). They use the term structure to model the shadow policy rate as a function of standard factors and allow this rate to diverge from the near-zero actual policy rate. Of course, the estimated shadow rate is subject to a number of assumptions. Using this shadow rate, Ball et al. (2016) conclude that QE in the US has reduced shadow policy interest rates by 200 to 300 basis points to conclude that there must have some output and inflation effect. Churm et al. (2015) perform a similar exercise for the UK.

More direct evidence is provided by a few studies that include output and/or inflation in various VAR formulations. Baumeister and Benati (2010) use the long-term interest spread at unchanged policy rate as a measure of QE in a time-varying SVAR that also include GDP growth and the GDP deflator inflation. They report a significant macroeconomic impact in the US, UK and the euro area. Our approach is close to that of Weale and Wieladek (2015) and Garcia Pascual and Wieladek (2016). They use asset purchase announcements in a Bayesian VAR (BVAR) model that includes the GDP and the CPI estimated over a sample period that starts in 2009. They also find significant effects in the US and the UK, as do Wieladek and Garcia Pascual (2016) in the Eurozone.

### **3.3. Negative Interest Rates**

The experience with negative interest rates is even more recent than with QE, making it challenging to seek formal evidence. The focus so far has been on the transmission of negative rates on financial conditions. Bech and Malkhozov (2016) informally find that negative policy rates have been transmitted to most other interest rates, with some exceptions like mortgage rates. Coeuré (2016) describes the ECB policy and accepts that adverse effects may set in because banks may eventually have to change their business models and, mostly, because there is still a minimum interest rate.

### **3.4. Non-Linearities and the Decreasing Effectiveness Hypothesis**

A number of papers have started to explore the decreasing effectiveness hypothesis, following the initial hint by Goodhart and Ashworth (2013) and the early observation by Krishnamurty and Vissing-Jorgensen (2012). Barnichon et al. (2016) examine whether the financial accelerator mechanism may lead to non-linearities. They find that increased credit supply has a stronger output effect in periods of weak growth when credit is constrained than during period of fast growth. They use data for the US

on a long sample that includes the post-2008 period. Their results can be seen as implying that QE may have been more effective early on when financial markets were impaired and illiquid than when abundant liquidity had already been created. Nishimura (2016) develops the view that “policy exhaustion” has set in, mostly in Japan but also in the US.

Kapetanios et al. (2012) conduct a counterfactual analysis of the Bank of England policies. They simulate three different VAR models (Bayesian with rolling regressions, Markov switching and time-varying parameters) estimated over long periods. They compare the impulse responses of GDP and inflation when long-term yields are reduced by 100 basis points. While they use estimates from the more recent period, the focus is not on detecting changes within the QE period.

To the best of our knowledge, this is the first paper that attempts to detect changes within the QE period.<sup>5</sup> We look at the Eurozone, the US, the UK and Japan on samples that cover as long a sample period as data would allow us to. Policy is captured. We use shadow policy rates, but we first expunge non policy-related variations by fitting them on policy announcements. We use two very different estimation methods: BVAR (we follow closely Weale and Wieladek, 2015) and linear projections (Jordà, 2005). We test for decreasing effectiveness by estimating the models over subperiods, typically before/after the adoption of the relevant unconventional policy or when the policy instrument is at the end of its distribution.

#### **4. Empirical Results: the US, UK and Eurozone**

In this section we look at the US, UK and Eurozone, while the following section deals with Japan. The reason for this split is that, while in the former group of countries unconventional monetary policies only started after the onset of the global financial crisis, Japan has a longer history of unconventional monetary policies. We will thus use similar subperiods of analysis for the US, UK and Eurozone and different subperiods for Japan.

There are two challenges associated with testing the hypothesis that unconventional monetary policies in the US, UK and Eurozone have decreasing effectiveness on economic activity. First, the short time span of these policies prevents us from using quarterly data, as it is commonly done in the monetary policy literature. Second, there is no commonly agreed quantitative indicator of unconventional monetary policies.

We address these challenges by using monthly data and two different proxies for non-standard monetary policies. Even with monthly data, we have limited degrees of freedom (especially when we try to assess whether the parameters vary over time). The point estimates may thus be sensitive to small changes in the sample or estimation technique. We address this issue by comparing the results of two different econometric approaches.

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<sup>5</sup> The contribution by Demertzis and Wolff (2016) is closest to our own investigation in its intentions. Informally, it interprets the evidence as indicating that the ECB’s QE had a positive effect on investment spending after its announcement in 2015 but that the increased demand in early 2016 did not produce such an effect.

#### 4.1. Measuring unconventional monetary policy

The policy stance of the central bank is normally measured with a policy interest rate (like the Fed Fund rate in the US) or with a monetary aggregate (such as M1 or M2, as originally suggested by Friedman and Schwartz, 1963). The presumption is that these instruments can be controlled by the central bank and are stably related to economic activity (Leeper, Sims, and Zha, 1996). Unconventional monetary policy starts when the central bank loses control over these instruments, either because the policy rate hits the zero lower bound (Figure 3) or because the main monetary aggregates no longer respond to the injection of base money (Figure 2). This is why the evaluation of unconventional monetary policies requires alternative indicators of policy stance.

Our first indicator of unconventional policy is the “shadow” (i.e., non-observable) policy rate derived from a statistical model of the yield curve. The shadow interest rate is an attempt at measuring how the policy rate would look like if the zero lower bound had not been binding. One way to recover this shadow rate is to build a statistical model of the lower end of the yield curve and then use this model to build a counterfactual estimate for the overnight rate.<sup>6</sup>

The idea of using the yield curve to build a shadow term structure is due to Black (1995) and was recently operationalized for the US, UK, and the Eurozone by Xia and Wu (2016).<sup>7</sup> Xia and Wu (2016) show that when the US policy rate is above 50 basis points, their estimate for the US shadow rate coincides with the observed rate (Figure 3a; the coincidence, instead, is not perfect for the UK and the Eurozone) and that their shadow rate can be used to assess the effectiveness of monetary policy after the observed rate hits the zero lower bound. One advantage of using the shadow rate as a measure of policy stance is that this indicator is directly comparable with policy rates in normal times. One challenge related to the use of this measure is that the shadow rate is model-specific and that different specifications can yield alternative measures of the shadow term structure (Christensen and Rudebusch, 2015).

Another potential problem with the shadow rate is that any event that affects the slope of the yield curve will also have an impact on the estimated shadow rate, even if this event has nothing to do with monetary policy actions. While the unobservable shadow rate is not a policy instrument (it is a proxy for a series of unconventional monetary policy instruments, including the announcement of asset purchases discussed above), it can be treated as a policy instrument if we assume that policymakers target the shadow rate and reverse-engineer non-standard monetary policies to achieve this target.<sup>8</sup>

Changes in the shadow rate could therefore be decomposed into changes linked to policy decisions and changes that are not directly related to policy decisions and are instead due to other factors that shift the slope of yield curve. To separate these two components, we compile a monthly dataset of monetary policy announcements (they

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<sup>6</sup> An alternative approach is to use a large number of variables and then estimate the shadow rate by applying dynamic factor analysis to these variables (Lombardi and Zhu, 2014).

<sup>7</sup> Other papers that use the term structure to estimate a shadow policy rate include Christensen and Rudebusch (2015) and Krippner (2013).

<sup>8</sup> We would like to thank an anonymous referee for pointing this out.

could be changes in the policy rate, announcements of asset purchases, forward guidance, announcements about changes in monetary policy strategy) and build a proxy for the policy component of the shadow rate by regressing the shadow rate on a set of dummy variables that take a value of one during months for which there was a monetary policy announcement. Formally, suppose that in a given country we identify  $N$  policy announcements, then we estimate the following model:

$$SR_t = \alpha + \sum_{i=1}^N \beta_i D_{i,t} + \varepsilon_t \quad (1)$$

where,  $SR_t$  is the shadow rate in month  $t$  and  $D_{i,t}$  is a set of dummies associated with policy announcements (we include as many dummies as policy announcements).<sup>9</sup> Finally we use the predicted values of this model to build an adjusted shadow rate that only varies in months characterized by a policy announcement. The adjusted shadow rate plotted in Figure 3b is defined as:

$$ASR_t = \hat{\alpha} + \sum_{i=1}^N \hat{\beta}_i D_{i,t} \quad (2)$$

For our second indicator of unconventional policy, we follow Weale and Wieladek (2015) and use the announcements of large scale asset purchases (quantitative easing) by the Federal Reserve and the Bank of England. While this indicator has the advantage of being based on an observable measure of unconventional policy (unlike the shadow policy rate, it is not model specific), it has the disadvantages of not being directly comparable with standard monetary policy instruments and of not incorporating policy measures (such as forward guidance) that go beyond and above asset purchases. As the experience of the European Central Bank with quantitative easing is too short for our own purposes of evaluating potential decreasing effectiveness to this policy (see, however, Garcia Pascual and Wieladek, 2016, for an evaluation the macroeconomic effects of quantitative easing in the Eurozone), in the case of the Eurozone we substitute asset purchases with the balance sheet of the ECB (these two measures are closely related, Figure 4).

## 4.2. Econometric methodology

As a first step, we assess the effect of unconventional monetary policies on output and prices with the linear projections method (Jordá, 2005). Specifically, we estimate the following model:

$$y_{t+h} = \alpha + \beta_h M_{t-1} + \sum_{i=1}^L \phi_i y_{t-i} + \varepsilon_t \quad (3)$$

Where  $y$  is the variable of interest (either the log of GDP or the log of the consumer price index) and  $M$  is the unconventional monetary policy instrument (either the adjusted shadow policy rate or the announcement of asset purchases). Within this set

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<sup>9</sup> Assume that there are 3 monetary policy announcement, the first in month  $t$ , the second in month  $t+s$ , and the third in month  $t+s+z$ .  $D_1$  will take value 0 from month 1 until month  $t-1$ , it will then take value 1 from month  $t$  to month  $t+s-1$ , and value zero from month  $t+s$  to month  $T$ .  $D_2$  will take value 0 from month 1 until month  $t+s-1$ , it will then take value 1 from month  $t+s$  to month  $t+s+z-1$ , and value zero from month  $t+s+z$  to month  $T$ .  $D_3$  will take value 0 from month 1 until month  $t+s+z-1$  and value 1 from month  $t+s+z$  to month  $T$ .

up,  $\beta_h$  measures how a monetary policy shock affects the dependent variable  $h$  months ahead. We set  $h = \{1, 2, \dots, 12\}$  and  $L = 6$ .

Note that the  $\beta_h$  terms jointly are our measure of policy effectiveness. We estimate equation (3) for the post-Lehman period (October 2008-May 2016) and test the decreasing effectiveness hypothesis by allowing  $\beta_h$  to take different values over different periods. When we measure unconventional policies with the adjusted shadow rate we use the same sub-periods (2008m9-2011m12 and 2012m1-2016m3) for all the three countries (or group of countries) that we study. When we estimate the effect of asset purchases we use country-specific subsamples which depend on different phases of unconventional policy (see Figures 3 and 4).<sup>10</sup> When we use the policy rate we also compare the pre and post zero-lower-bound periods (for the pre zero lower bound period we use the actual policy rate and for the post zero lower bound period we use the adjusted shadow rate).

Note that we allow  $\beta_h$  to vary across subsamples by using interactive dummies. We are thus economizing degrees of freedom by assuming that the parameters on the autoregressive terms do not vary across subsamples.

In Equation (3),  $\beta_h$  measures of the response of output (or prices) to the policy instrument under the assumption that the policy decision is exogenous with respect to the future path of nominal GDP. As central banks set policy on the basis of their forecasts of GDP and prices, this assumption never holds. We nevertheless start with model (3) because, at a minimum,  $\beta_h$  tells us something about the correlation between the policy instrument and the policy objective. Moreover, under the natural assumption that policymakers relax policy when they expect low growth or low inflation, we also know that endogeneity leads to a downward bias in the parameter estimates. Finally, as our objective is to compare the values of  $\beta_h$  in two different sub-periods, endogeneity is not a major problem for our exercise, as long as the endogeneity bias is the same in the two periods.

We also use two alternative strategies to address the endogeneity issue. First, we use identification through heteroskedasticity (Rigobon 2003 and Lewbel 2010) to build instruments for the policy variable in Equation (1). Second, we follow Weale and Wieladek (2015) and identify the effect on non-standard policy with a Bayesian VAR with sign restrictions.

There are tradeoffs related to the use of different estimations techniques. While identification through heteroskedasticity has the potential of addressing endogeneity problems and the Bayesian VAR described below has the advantage of allowing us to model the complex interactions among unconventional monetary policy, output, prices, long term rates, and equity prices, these estimation techniques are more demanding in terms of data quantity than the simple OLS regressions used to estimate the baseline linear projection model. For instance, in certain subsamples we only have 50 observations. In the VAR model with 5 variables and 2 lags we need to estimate 11 parameters (and 5 variances) leaving us with less than 40 degrees of freedom. Potential multicollinearity among the variable included in the VAR can amplify the

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<sup>10</sup> The results are robust to switching the sample breaks.

problems associated with limited degrees of freedom.<sup>11</sup> These problems could be attenuated by imposing tight priors in the BVAR estimates. However, tight priors also have costs because they may not let the data speak (Weale and Wieladek 2015).

### Identification through heteroskedasticity

Identification through heteroskedasticity (IH) is a standard instrumental variable regression where the instruments are built using the presence of heteroskedasticity in the regression residuals. This technique does not require external instruments (i.e., the instruments do not have a direct effect on the dependent variable, they only have an indirect effect on the dependent variables through the endogenous variable that is being instrumented). It only requires that in the estimating equations there are at least as many exogenous variables as endogenous variables.

We model the policy instrument ( $M$ ) and the first lag of the dependent variable as endogenous and lags 2-6 as exogenous (with a standard IV that use lags as instruments, we would need to exclude lags 2-6 from the model and only use them in the first stage; IH, instead, allows to have them in the estimating equation).<sup>12</sup>

### Bayesian VAR

For our Bayesian VAR, we use the set of variables, lag structure, and uninformative prior of Weale and Wieladek (2014). We also adopt one of their identification strategies (they explore four alternative identification strategy). Specifically, we use monthly data to estimate the following reduced-form VAR model:

$$Y_t = A + B_1 Y_{t-1} + B_2 Y_{t-2} + E_t \quad (4)$$

Where  $Y$  is a vector of the following five variables: (i) the log of monthly GDP; (ii) the log of the consumer price index (CPI); (iii) the log of real equity prices (measured by dividing a stock market index by the CPI) (iv) the yield on ten-year government bonds, and (v) a measure of unconventional monetary policy. With respect to this last variable, while Weale and Wieladek (2014) only use announcements of asset purchases, we also experiment with the adjusted shadow policy rate.  $B_1$  and  $B_2$  are matrixes of parameters associated with the lagged dependent variables and  $E$  is a vector of normally distributed residuals with mean zero and variance covariance matrix  $\Sigma$ .

<sup>11</sup> These problems are compounded by the fact that monthly GDP data are noisier than the quarterly data which are normally used to estimate the effect of monetary policy.

<sup>12</sup> We provide a brief description of identification through heteroskedasticity (based on Eichengreen and Panizza, 2016) for the benefit of readers who are not familiar with this technique. Assume that we are interested in estimating the following model:  $y_1 = a + bX + cy_2 + u_1$ , where  $X$  is a matrix of exogenous variables, but  $y_2$  is endogenous ( $y_2 = \alpha + \beta X + \gamma y_1 + u_2$ ). To the standard assumptions that  $u_1$  and  $u_2$  are uncorrelated with the matrix of exogenous variables  $X$  and are also uncorrelated with each other (i.e.,  $E(X, u_1) = E(X, u_2) = \text{cov}(X, u_1, u_2) = 0$ ), we add an heteroskedasticity assumption (i.e.,  $\text{cov}(X, u_2^2) \neq 0$ ). Then we can use  $Xu_2^2$  as an instrument for  $y_2$ . Assuming that  $\text{cov}(X, u_1, u_2) = 0$  guarantees that  $Xu_2^2$  is uncorrelated with  $u_1$  (the exogeneity condition for a valid instrument), while heteroskedasticity ( $\text{cov}(X, u_2^2) \neq 0$ ) guarantees that  $Xu_2^2$  is correlated with  $y_2$  (the relevance condition).



In order to interpret the results of the reduced form VAR of Equation (2), it is necessary to impose a set of identifying assumptions that allow recovering the structural parameters from the estimates of  $\mathbf{B}_1$ ,  $\mathbf{B}_2$ , and  $\mathbf{\Sigma}$ . As mentioned above, Weale and Wieladek (2014) experiment with 4 alternative identifications schemes. The first is a simple Cholesky ordering, the second imposes a series of sign restrictions, the third jointly uses sign and zero restrictions, and the fourth uses sign and variance decomposition restrictions. In our baseline model we use the second identification scheme, but we also experiment with the third identification scheme.

When we estimate how the announcements of asset purchases affect prices and GDP, we use exactly the same sign restrictions as in Weale and Wieladek (2014). Specifically, we assume that expansionary policy at the zero lower bound signals that short-term interest rate will remain low for the foreseeable future and thus reduces long-term yields and increases equity prices. As Weale and Wieladek (2014), we impose these sign restrictions (i.e., that expansionary unconventional policy reduces long-term interest rates and increases real equity prices) at impact and also for the month that follows the policy action. We also follow Weale and Wieladek (2014) in identifying demand and supply shocks. With a positive demand shocks both output and prices increase, and this also leads to an increase in the long-term interest rate and real equity prices. With a positive supply shock, income increases, prices decrease, and long-term interest rates and real equity prices increase.

When we estimate how the adjusted shadow rate affects prices and GDP, we add one restriction to those listed above. Specifically, we restrict the contemporary impact on prices and output of a reduction of the adjusted shadow rate to be non-negative.<sup>13</sup> While this additional restriction rules out that an expansionary monetary policy (as captured by the adjusted shadow rate) will lead to lower output or prices on impact, it does not rule out the possibility that expansionary policy will have a negative effect on output and prices starting one month after the implementation of the policy. As we maintain this restriction for all subperiods for which we estimate the model, the restriction does not affect the relative magnitude of the output and price responses across estimation periods (which is what we are interested in).

As mentioned above, we use the same uninformative priors as Weale and Wieladek (2014) who, in turn, follow Uhlig (2005) in assuming that the priors are drawn from a Normal–Wishart density multiplied with an indicator variable that takes a value one when the impulse response satisfies the sign restriction. Therefore, the priors are not exogenously chosen for each country. They are instead based on the country-specific impulse response functions that satisfy the sign restrictions.

### **Testing for the decreasing effectiveness hypothesis**

There are at least two possible ways to test for the decreasing effectiveness hypothesis. One possibility is to explicitly allow for non-linearities by, for instance,

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<sup>13</sup> If we do not impose this restriction, we obtain imprecise estimates (i.e., much larger confidence bands) across subperiods.

including the square of the adjusted shadow rate or squared asset purchases.<sup>14</sup> Another possibility is to check whether the effectiveness of unconventional monetary policy has decreased over time by splitting the sample into different subperiods.

We opt for the second option because, while it is straightforward to introduce nonlinearities in the linear projection estimates, it is more difficult to explicitly include nonlinearities in the VAR framework described above.

Going back to the discussion of Section 2, we use different subsample to look at how  $\partial f/\partial x$  varies when  $x$  surpasses a certain threshold or to check if the value of  $\partial f/\partial x$  is affected by the duration of the nonstandard policy.

When we work with the policy rate, we first split the sample between periods in which the policy rate is above and below 1 percent (when the policy rate is below 1 percent we use the adjusted shadow rate) and then we split the below 1 percent period into two subperiods of similar length to check if the effectiveness of non-standard policies decreases with time.

When we work with asset purchases announcements we use country-specific thresholds that are based on the size of asset purchases. In most cases, we choose the subperiods to make them coincide with the switch from standard to unconventional monetary policies and, within the second period, with different phases of unconventional monetary policy (for instance, for the US we separate QE1 and QE2 from Operation Twist and QE3 and for the UK we separate QE1 from QE2 and QE3). However, for the Eurozone, we cannot match the subperiods with different phases of unconventional policies (for instance with the introduction of quantitative easing) because some of the resulting subperiods would be too short to yield meaningful estimates. Therefore, we arbitrarily split our sample into subsamples of similar length.

In describing the results of the various exercises described above, we will compare the magnitude of the responses of output and prices to monetary policy across subperiods and also discuss whether the responses are statistically significant in one period and not in another one. However, will not provide tests of whether the responses are significantly different from each other across periods. As our confidence bands often overlap across periods, such an exercise would tell us that, while in some rare cases there seem to be a statistically significant difference across subperiods, in most cases the difference is not statistically significant. This lack of a statistically significant difference could be due to one of two factors: (i) there is no difference between the two periods; or (ii) our short estimation period and the fact that in some cases there is an overlap between the two samples do not give us enough power to precisely estimate the difference across periods. The fact that the difference between impulse responses is not generally statistically significant across subperiods is an important caveat to our conclusion.

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<sup>14</sup> For the adjusted shadow rate one could define the following variable:  $SASR = N \times ASR^2$ , where  $ASR$  is the adjusted shadow rate and  $N = -1$  when  $ASR < 0$  (with  $N=0$  when the adjusted shadow rate is nonnegative).

## Data

As mentioned above, all of our estimations use monthly data, over 1980:1 to 2015:11 for the US and to 2016:5 for the UK, and over 1999:1 to 2016:5 for the Eurozone. GDP data for the US are from Macroeconomic Advisers, GDP data for the UK are from the National Institute of Economic and Social Research, and GDP data for the Eurozone were built using data on GDP growth from the EuroCoin indicator. Price index (CPI) and policy rate data for the US and the UK are from the FRED database maintained by Saint Louis Fed. For the Eurozone, instead, we use data from the European Central Bank (we measure the policy rate with the ECB refinancing rate). The shadow policy rates are from Xia and Wu (2016) and data on asset purchase announcements are from Weale and Wieladek (2015). Finally, data on equity prices and long term interest rates are from Datastream. For the Eurozone, we measure long-term interest rate using 10-year German bunds and equity prices using a weighted average of the French, German, Italian, and Spanish stock markets.<sup>15</sup>

### 4.3. The effect of unconventional policies as proxied by the adjusted shadow policy rate

#### Linear projection estimates

We start by estimating Equation (3) with the adjusted shadow rate as a measure of non-standard policy. As mentioned above, we test the decreasing effectiveness hypothesis by allowing  $\beta_h$  to vary over time. Before comparing subperiods within the unconventional policy subsample, we check whether monetary policy (as proxied by the adjusted shadow policy rate) became less effective when the actual policy rate hit the zero lower bound (ZLB). Since the US and the UK did not bring their interest rates to zero, we define the ZLB as reached when the interest rate is at or below 1%.<sup>16</sup>

Figure 5 reports the results for both OLS (top graphs of each panel of Figure 5) and IH (bottom graphs of each panel of Figure 5) estimates of Equation (3). We examine the effects of a 1-percentage point reduction of the policy rate. Our results show that in the US and the Eurozone the policy rate had a larger impact on future GDP before hitting the zero bound. For the UK, we do not find any difference between the periods before and after the zero lower bound.

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<sup>15</sup> We use the following weights: German DAX 0.3, French CAC 0.3, Italian MIB 0.2, and Spanish IBEX 0.2. These weights reflect the different capitalizations of these 4 stock markets before the global financial crisis. For the UK and the US, we use the FTSE 100 and S&P 500 indexes, respectively. We use the German bunds because our intention is to control for how unconventional policy actions are reflected in the long-term risk-free rate. It may be, however, claimed that the objective of non-standard policy in the Eurozone was to reduce the risk premium in the periphery. Our results are robust to substituting the German Bund rate with the average yield of German Bunds and Italian 10 year government bonds.

<sup>16</sup> The corresponding ZLB periods are 2008:10 to 2015:11 (end of sample) for the US, 2009:2-2016:5 for the UK and 2009:5-2016:5 for the Eurozone. An alternative would have been to set the zero lower bound when the shadow rate reaches zero. We prefer our definition because we want to look at the effectiveness of unconventional policies when the central bank effectively loses its ability to adjust the policy rate.

Figure 6 presents results of the same estimations for the price level. In all cases, the difference is dramatic since reductions of the (shadow) interest rate lead in the post ZLB period to lower prices. Taken at face value, this would suggest that monetary policy at the ZLB is not just less effective but actually counter-productive. Three possible interpretations come to mind. The first one is based on the Phillips curve. Figure 5 does not suggest that output rises, or not much, so this cannot be downward pressure on prices. This would leave price expectations as the driving force, implying that further cuts in the adjusted shadow rate are seen as a signal that the situation will worsen. The second interpretation concerns reverse causality. We try to address this problem with the IH approach, but if the instruments are weak, IH would not be sufficient to address reverse causality brought about by the fact that policy responds to declining inflation. The alternative use of BVAR below provides some support for this interpretation. Finally, our results for could indicate that the adjusted shadow interest rate is an inadequate measure of the policy stance.

Next, we split the post-Lehman sample into sub-periods of similar length and look at how a one percent decrease in the adjusted shadow rate affects log GDP and log CPI in the 12 months that follow the policy change. Figure 7 plots the results for GDP and Figure 8 focuses on the evolution of the consumer price index. As before, the top graphs in each panel are simple OLS estimates of Equation (3) and the graphs at the bottom of the panel are identification through heteroskedasticity estimates of the same equation.

Figures 7 and 8 broadly support the decreasing effectiveness hypothesis. In almost all regressions, the impact of the adjusted shadow rate on either GDP or prices was much larger in the first period of unconventional policies. The only exception is the top part of Figure 7a (OLS estimates of the GDP response for the US), where there seems to be no difference between the two periods. However, the bottom graphs of Figure 7a (which uses the IH estimator) suggest that the response of GDP to a shock of the adjusted shadow rate was larger in the first period of non-standard policy. Figure 8 shows that the negative effect of cuts in the adjusted shadow rate concern the latter sample period. This observation might provide support for the first (the role of expectations) and third (doubts on the shadow rate) of the three interpretations suggested above, lessening concerns about the validity of the IH approach.

In Figure A1 of the Appendix, we estimate Equation (3) for the 12-month ahead ( $\beta_{12}$ ) response of log GDP (Panel A1.a) and log CPI (Panel A1.b) using rolling regressions with a 48 months window. We report results for the US, UK, Eurozone and then we pool the three countries (group of countries for the Eurozone) together, controlling for country and time fixed effects. Both panels show that the smaller effect in the latter period is not a consequence of our choice of sub-periods (the UK is a partial exception to this pattern, as we observe first a drop and then an increase of  $\beta_{12}$ ).

We also estimate Equation (3) for the pre-Lehman period (going back to 1970 for the US, 1973 for the UK and 1999 for the Eurozone) and allow  $\beta_h$  to vary for periods when the actual policy rate was below the 25<sup>th</sup> percentile of the distribution of the rate. Figure A2 in the Appendix show that monetary policy appears to be less effective (the impact on GDP is either smaller or less precisely estimated) when the actual policy rate is low, even before reaching the zero lower bound. When we focus on prices instead (Figure A3) there is no clear difference across different levels of

policy rate (in the UK monetary policy appears to be more powerful when rates are low).

### **Bayesian VAR estimates**

Next, we move to the impulse response functions obtained with the Bayesian VAR (BVAR) identified with sign restrictions.<sup>17</sup> In order to have at least 50 observations for each subperiod, we include part of 2012 in the first subperiod and 2011 in the second. This small overlap between the two subsamples can potentially bias our estimates against finding different responses to monetary policy in the two periods.

Figures 9a-9c report the response of log GDP to an adjusted shadow policy rate shock – as before, a 1 percentage point cut – and Figures 10a-10c report the response of log CPI. Each panel of Figures 9 and 10 has 4 sub-plots. The top left graph shows the impulse response functions obtained by estimating the model over 1995-2008 (before Lehman), the top right graph shows the results based on the full post-Lehman period and the plots at the bottom of the panel shows the results for the first and second half of the post Lehman period.

The results reported in the top two panels of Figure 9 are again consistent with the decreasing effectiveness hypothesis: in the US and the UK, the responses of output and prices to a adjusted shadow rate shock tend to be smaller in the second period of unconventional policies. In the case of the Eurozone, instead, the two subperiods are almost identical and, if anything, the GDP response seems to be slightly larger in the post 2011 period (bottom panel of Figure 9). This difference in results may be due to the fact that the European Central Bank was late in implementing unconventional policies. It could also reflect that the ECB shifted its policy in 2012 by adopting a more active stance (“whatever it takes”). Hence, the 2011 breakpoint may not be appropriate for the Eurozone.

Looking at the response of CPI to the adjusted shadow rate shock, we confirm a smaller impact in the second period for the US and the UK (Figures 10a and 10b) and no substantial difference for the Eurozone (Figure 10c). Interestingly, the perverse effect of interest rate cuts, detected in Figures 6 and 8, is not confirmed here, possibly raising doubts about reverse causality in the linear projection approach.

Summing up, when we measure unconventional policies with the adjusted shadow rate, most of evidence (either based on linear projections or BVAR estimates) is consistent with the hypothesis that in the US and the UK policy was more effective in the first period of unconventional policies. Results for the Eurozone are mixed, possibly due to the late shift of the policy stance.

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<sup>17</sup> As described above, we impose that a lower shadow rate has a non-negative effect on impact on prices and output, a positive effect on equity prices on impact and with a one-month lag and a negative effect on long-term rates on impact and with a one-month lag. We also impose sign restrictions on demand and supply shocks.

#### 4.4. The effect of large asset purchases announcements

We now move to our second indicator of unconventional monetary policy. For the US and the UK, we follow Weale and Wieladek (2016) and measure unconventional monetary policy with the announcements of asset purchases by the US Federal Reserve and the Bank of England. For the Eurozone, instead, we use the balance sheet of the European Central Bank (the data on QE are too short for any meaningful econometric estimate).

##### Linear projection estimates

As before, we start by using linear projections and compare how QE announcements (or the central bank balance sheet in the case of the Eurozone), in each case an increase of 1% of GDP, affect log GDP and log prices during two periods of similar length. In this case, rather than using common definitions of the two sub-periods, we use country-specific sub-periods to make them coincide with the first and second phase of QE. We label these two periods “First phase” and “Second phase. For the US, the first phase of QE is 2009m1-2011m8 (QE1 and QE2) and the second phase is 2011m9-2015m12 (Operation Twist and QE3). For the UK, the first phase is 2009m1-2011m9 (QE1) and the second phase is 2011m10-2016m4 (QE2 and QE3). For the EZ, we arbitrary set the second phase as starting in 2013 (it would have been impossible to estimate the model if we had set the after period when QE started in 2015).

Figure 11 shows the GDP response to QE announcements. In the US and the UK (top two panels of Figure 10), there is no evidence of decreasing effectiveness to unconventional policy. In fact, the GDP response is always larger (and statistically significant) in the second phase of unconventional monetary policy and it is rarely significant in the first phase. In the case of the Eurozone, instead, we always find that GDP does not respond to the size of the ECB balance sheet (bottom panel of Figure 11).

When we look at prices, instead, we do find some evidence of decreasing effectiveness in the case of the UK (Figure 12). In the US, instead, the price responses in the two periods are quantitatively similar. However, the estimates for the first phase of QE are more precise than those for the second phase. As before, the results for the Eurozone do not show any evidence of decreasing effectiveness. If anything, we find a stronger response of prices in the post 2012 period.

##### Bayesian VAR estimates

Next, we move to the Bayesian VAR with sign restrictions. We conduct the same exercise and use the sign restriction identification strategy of Weale and Wieladek (2016).<sup>18</sup> As we have a slightly longer sample (our data end in early 2016, while their data stop in 2014), we start by reproducing their results with our data. The top left

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<sup>18</sup> Specifically, we use their second identification strategy which imposes sign restriction based on separating demand and supply shocks and that announcements of asset purchases have a positive effect on equity prices and a negative effect on long-term rates (all restrictions are imposed on impact and with one month lag).

graphs of the two panels of Figures 13 and 14 show that our results are essentially identical to those of Weale and Wieladek (2016). We do not report results for the Eurozone because either our model did not converge or produced unstable impulse response functions, with very large confidence bands.

The remaining graphs of Figures 13 and 14 split the sample into two sub periods of equal length (as in the BVAR estimates for the adjusted shadow rate, there is an overlap because we wanted to have at least 50 observations in each of the two subsamples).<sup>19</sup> We find that the GDP response to US QE is essentially identical in the two sub periods (slightly smaller but more precisely estimated in the first period and larger but less precisely estimated in the second period, Figure 13a). Looking at the UK, we find that the magnitude of the GDP response does not vary across periods (Figure 13b) but that the response of GDP is statistically significant in the first period and not significant in the second period.<sup>20</sup>

When we look at prices, we find that in the US the response of prices is slightly smaller but more precisely estimated in the first period (Figure 14a, essential the same as the GDP response). For the UK, instead, we find a larger and statistically significant response in the first period and a smaller and insignificant response in the second period (Figure 14b).

As already mentioned, our results corroborate Weale and Wieladek's (2016) findings that there is no statistically significant response of British GDP to QE when the BVAR is applied to the whole sample and the impulse response functions are derived with their second identification scheme. Therefore, we also experiment with their third identification scheme.<sup>21</sup> In this case, we find that the responses of output and prices are always statistically significant for both US and UK (Figures A4 and A5 in the appendix), but we do not find any evidence of decreasing effectiveness (if anything the UK price response seems to be larger in the second period).

Summing up, when we use the QE announcements, most of evidence (either based on linear projections or BVAR estimates) does not support the decreasing effectiveness hypothesis. While we do find some weak evidence that in the UK price response to QE announcements was stronger in the first phase of QE, this result is not robust to alternative identification strategies.

## **5. Empirical Results: Japan**

We now estimate a set of models similar to the ones described above using quarterly data for Japan. As for the US, UK, and Eurozone, we start with a linear projection model and then we move to a five variables Bayesian VAR.

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<sup>19</sup> As above, there is an overlap between the two periods which, other things equal, will bias our estimates against finding a difference across subsamples.

<sup>20</sup> The whole sample estimate for the UK yields an insignificant response. This is in line with what by Weale and Wieladek (2016) found with their second identification scheme, which we are using here.

<sup>21</sup> This identification scheme does not impose restrictions on the effects of asset purchases on equity and bond prices but imposes the restriction that demand and supply shocks do not have an immediate effect on announcements of asset purchases.

We source GDP and CPI data from the FRED database, long-term rates and equity prices from Datastream, and the shadow rate data from IMF (2015).<sup>22</sup> As before, we estimate our models by combining the actual policy rate and the adjusted shadow rate described in Equation (2).<sup>23</sup> Specifically, we use the actual policy rate until 1995 and the adjusted shadow rate afterwards.

To assess the decreasing effectiveness hypothesis we start by splitting the sample into two periods. The period when the policy rate was at or above 1.75% (1966Q1: 1995Q1) and the period when the policy rate went below 1.75% (1995Q2: 2016Q1). We choose this sample split because the policy rate decreased to 1% in 1995Q2 and then to 0.5% in 1995Q3. From that moment on, it changed very rarely and never went above 0.75%. Therefore, we identify 1995-2016 as the period of unconventional monetary policy. A comparison between these two subperiods will provide evidence on the relative effectiveness of standard and unconventional monetary policies. Next, we split the second period into two sub-periods of equal length (1995-2005 and 2006-2016). A comparison between these two subperiods will provide evidence on the hypothesis that unconventional monetary policy has become less effective overtime.

We start by estimating the effect of a 1 percent decrease of the adjusted policy rate with the linear projections model described in Equation 3. Since, we are using quarterly data, we set  $L=4$  and  $h=8$ .

We always find that a decrease in the interest rate is followed by an increase in output and prices. However, Figures 15a and 16a show that the output and price responses are much larger in periods characterized by higher interest rates (the results are robust to the IH estimator). Along similar lines, Figures 15b and 16b show that the output and price responses to monetary easing were stronger in 1995-2005 than in 2006-2016. These findings are consistent with the idea Japanese unconventional policy is now less effective than what it used to be.<sup>24</sup>

Next, we estimate a Bayesian VAR with sign restrictions using the same set of variables (adjusted shadow rate, log GDP, log CPI, long-term rates, and real equity prices), identification restrictions, and priors that we used for the US, UK, and the Eurozone.

We start by estimating the model for our full sample (1966Q1: 2016Q1) and then we use the same sample splits that we used for the linear projection models described above. As before, we look at both output and prices. When we estimate the model using the full sample, we find that a decrease in the policy rate has a positive effect on GDP (Figure 17a), but that the effect is only statistically significant for the period 1966Q1: 1995Q1 (Figure 17b). In the period of low policy rates (below 1.75%), we find a marginally significant effect immediately after the policy easing (one quarter after the easing), but no significant effect afterwards.

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<sup>22</sup> For the moment we concentrate on the policy rate, in the future we plan to extend the analysis to asset purchase announcements. A preliminary analysis based on the balance sheet of the Bank of Japan did not yield any interesting result.

<sup>23</sup> The results are robust to using the standard shadow rate.

<sup>24</sup> This statement implicitly assumes that the effect of unconventional policies on the shadow rate has not increased with time. When we split the sample, we do not have enough observations to use the IH estimator.



When we further split 1995Q1:2016Q1 into two subperiods of equal length. We include 2005 in both subperiods to have more than 50 observations in each of the subsamples as before having an overlap between the two samples can potentially bias our estimates against finding different responses to monetary policy in the two periods- We find almost identical impulse response functions. In both cases, the effect is statistically significant in the first quarter, but soon becomes negative and not statistically significant.

Taken together, the results of the BVAR estimate for GDP provide mixed support the decreasing effectiveness hypothesis. They show that unconventional monetary policy is less effective than standard monetary policy in stimulating output, but that there are no differences across periods of unconventional policy.

When we move to the BVAR estimates for the consumer price index, we find that estimates for the full sample never yield a statistically significant effect of monetary easing on prices (Figure 18a) and that the impulse response functions are only significant in the low interest rate period (1995Q1: 2016Q1, Figure 18b). In general, our estimates do not find any evidence of decreasing effectiveness to monetary policy. If anything, they suggest that the effect of monetary policy on prices was larger in 2005-15 than in 1995-2005.

## 6. Conclusions

Table 1 summarizes the results of our exercises. One conclusion is that how we measure unconventional policies matters for the test of the decreasing effectiveness hypothesis. When we use the adjusted shadow policy rate our evidence is broadly consistent with decreasing effectiveness both when we use linear projections and Bayesian VARs with sign restrictions (the exceptions being the BVAR GDP model for the Eurozone and the BVAR CPI model for Japan). However, when we use QE announcements, we rarely find evidence that is consistent with the decreasing effectiveness hypothesis (with the exception of a price effect for the UK which, however, does not appear to be robust across estimation methodologies).

**Table 1: Evidence on decreasing effectiveness**

	Measure of unconventional policy			
	Adjusted Shadow rate		QE Announcements*	
	Econometric approach			
	Linear projections	BVAR	Linear projections	BVAR
US-GDP	YES	YES	NO	NO
US-CPI	YES	YES	MIXED	NO
UK-GDP	YES	YES	NO	NO
UK-CPI	YES	YES	YES	NO
EZ-GDP	YES	NO	NO	N/A
EZ-CPI	YES	YES	NO	N/A
Japan-GDP	YES	MIXED	N/A	N/A
Japan-CPI	YES	NO	N/A	N/A

\*Balance sheet of the central bank for the Eurozone

The mixed evidence presented here may indicate that it is too early to assess the decreasing effectiveness hypothesis. This would explain why the results vary with the choice of econometric techniques. Alternatively, we could conclude that QE is not subject to decreasing effectiveness but that lower interest rates are. Tempting as this conclusion may be, it remains that the evolution of the adjusted shadow rate largely reflects QE once the actual policy rate is at the lower bound. In this view, the evidence provided here is contradictory unless forward guidance, also captured by the adjusted shadow rate, is the source of decreasing effectiveness.

A careful conclusion is that we detect some footprints of decreasing effectiveness but we cannot ascertain they come from. This would require tracking down which channels through which unconventional monetary policy may be subject to decreasing effectiveness. Such an investigation is left for future work, presumably when more degrees of freedom become available.

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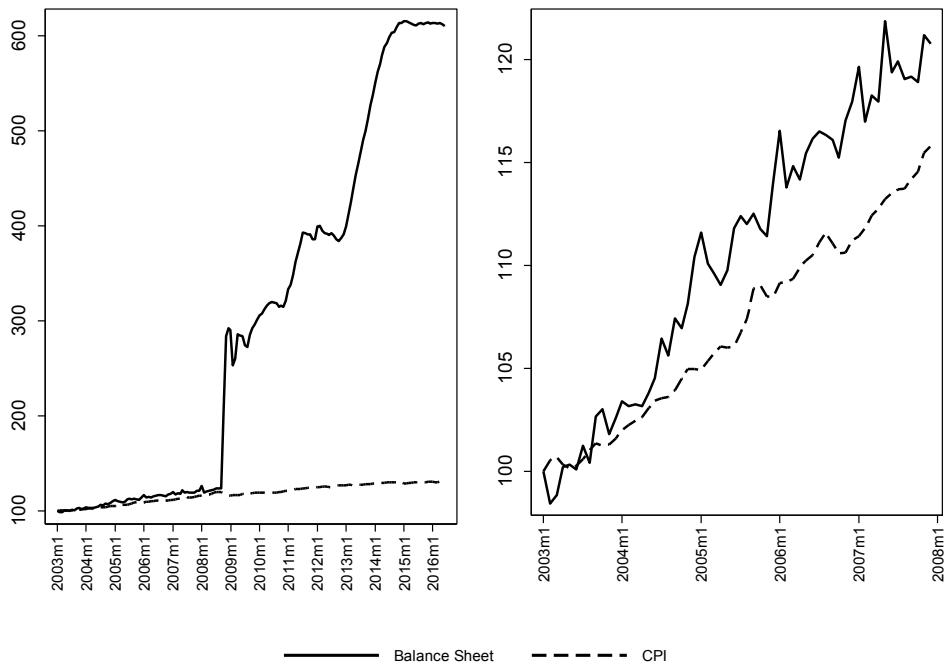
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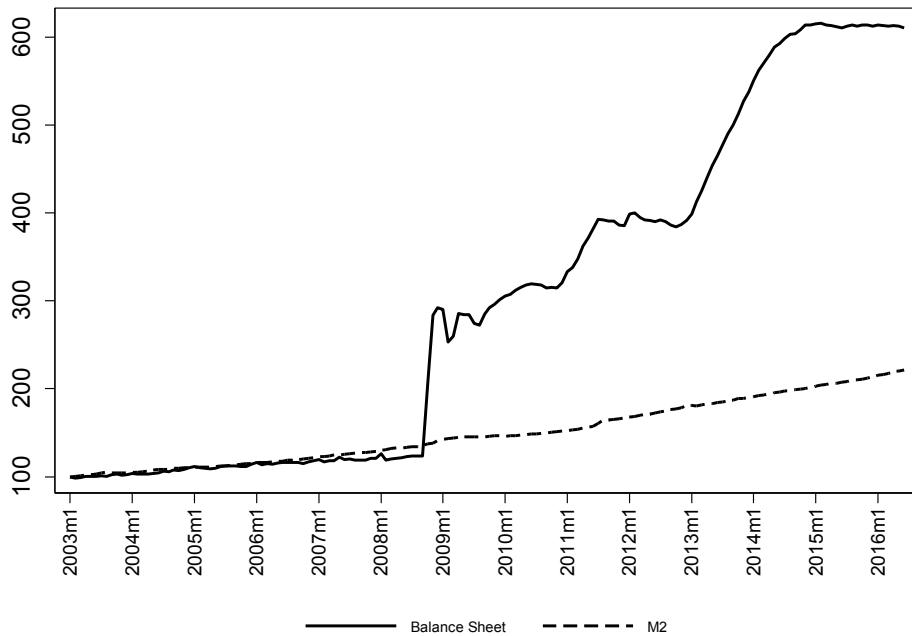
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**Figure 1: The Fed's balance sheet and CPI (January 2003 = 100)**



Source: FRED, Federal Reserve Bank of Saint Louis

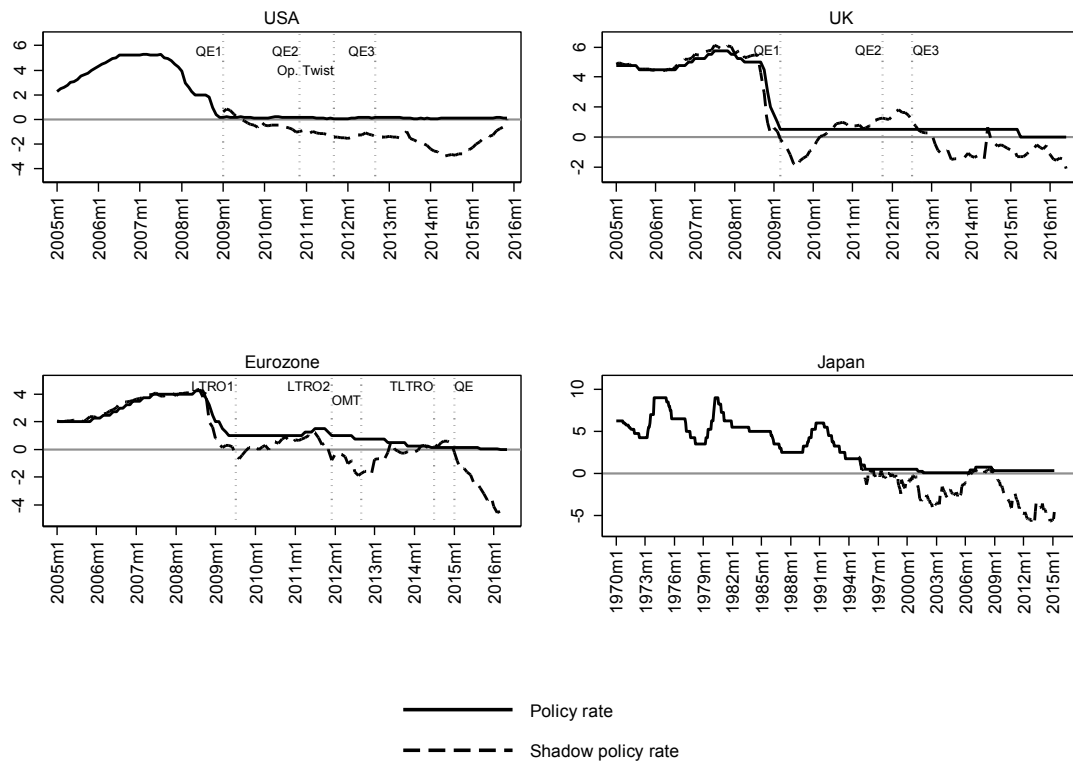
**Figure 2: M2 and the Fed's Balance Sheet (January 2003 = 100)**



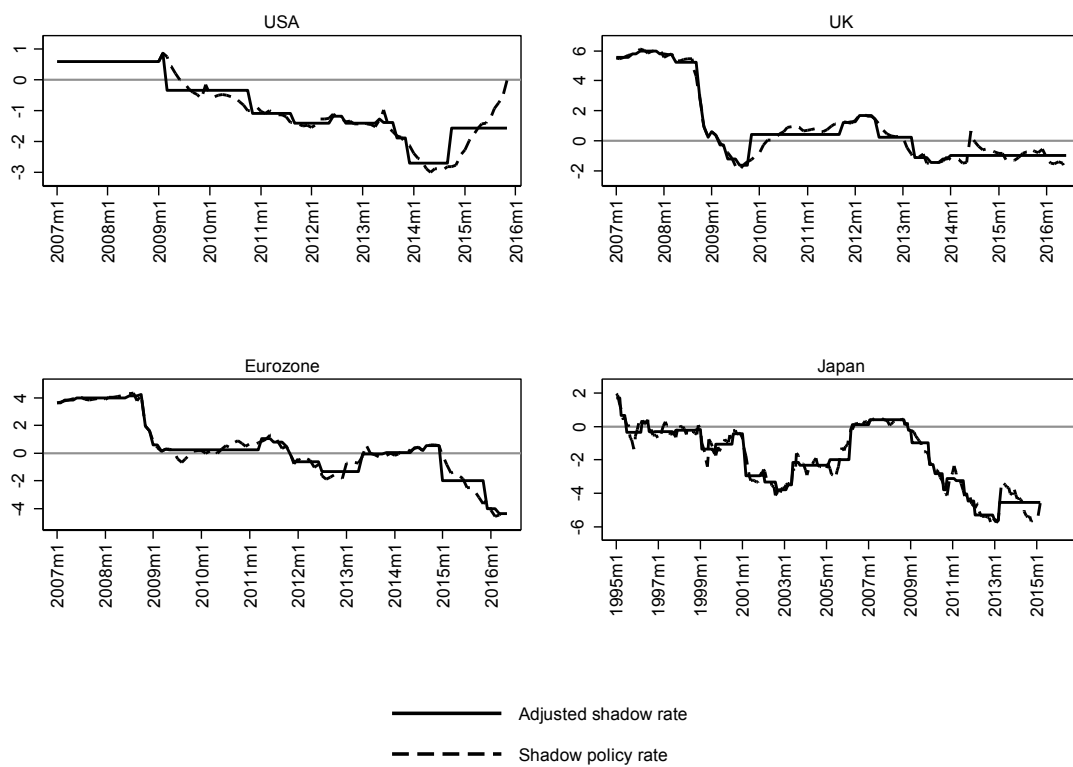
Source: FRED, Federal Reserve Bank of Saint Louis



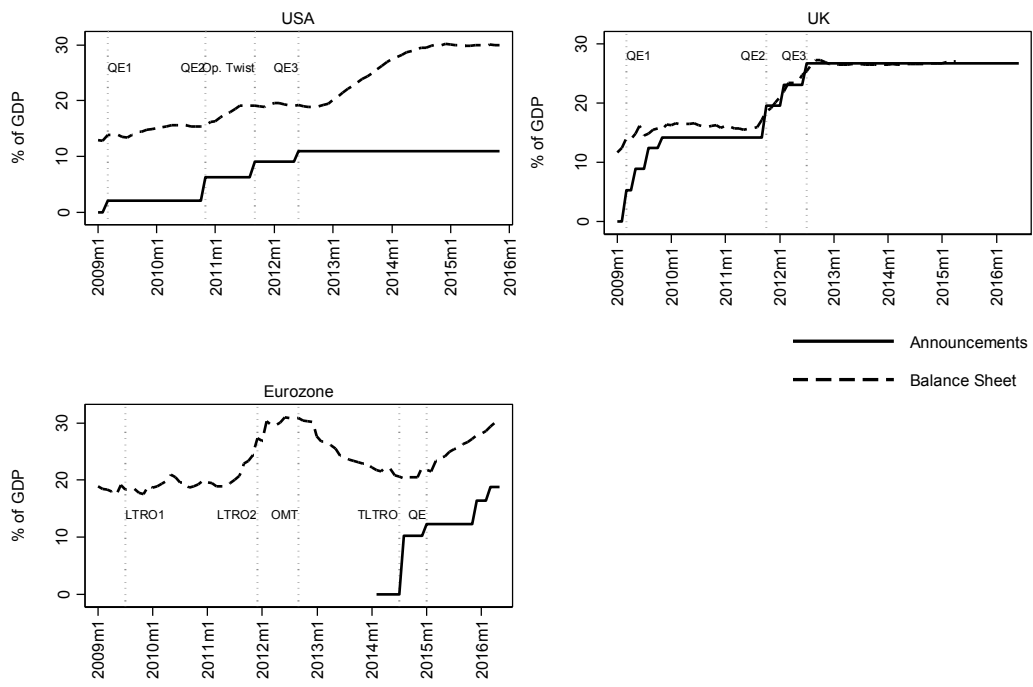
**Figure 3a: Actual and Shadow Policy Rate**



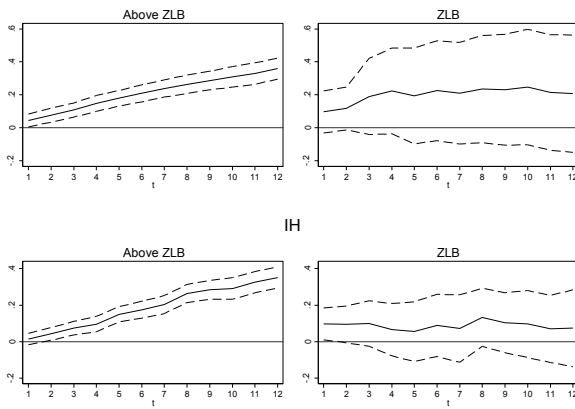
**Figure 3b: Shadow Policy Rate and Adjusted Shadow Policy Rate**



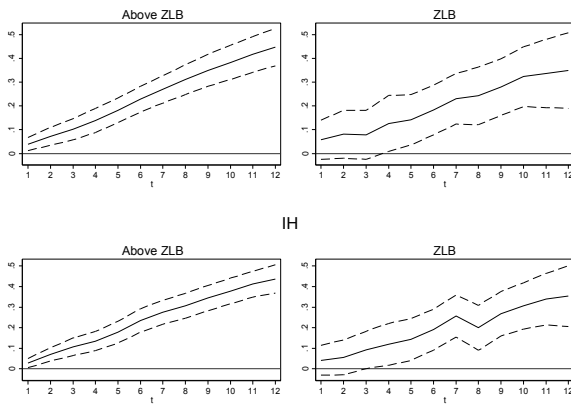
**Figure 4: QE Announcements and Central Bank Balance Sheets**



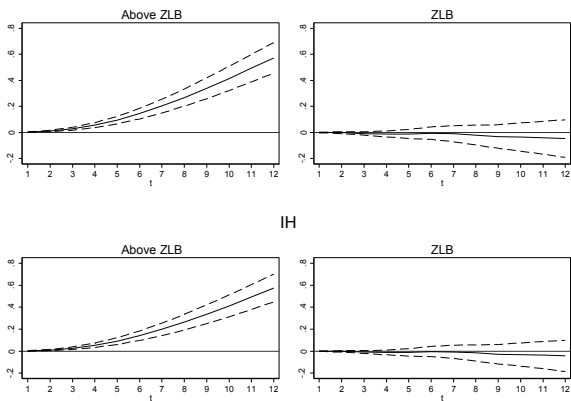
**Figure 5a: GDP Response to the policy rate (US), linear projections**



**Figure 5b: GDP Response to the policy rate (UK), linear projections**

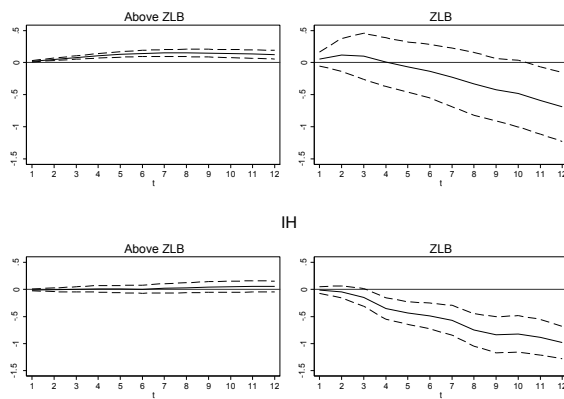


**Figure 5c: GDP Response to the policy rate (Eurozone), linear projections**

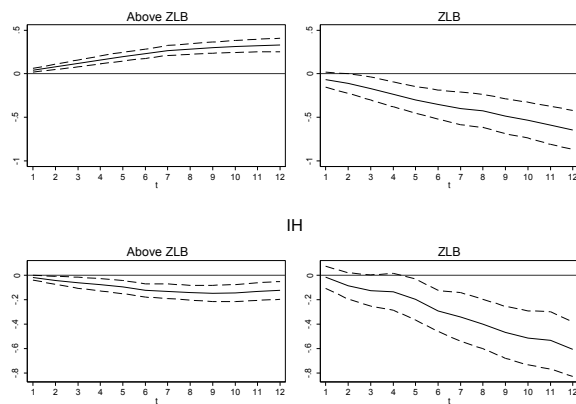


The solid lines plot the  $t$ -periods ahead responses of log GDP to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

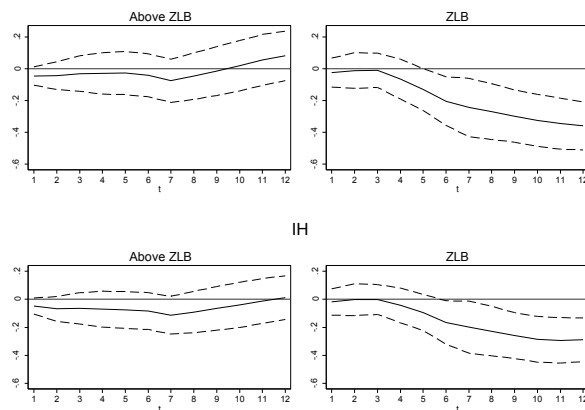
**Figure 6a: CPI Response to the policy rate (US), linear projections**



**Figure 6b: CPI Response to the policy rate (UK), linear projections**

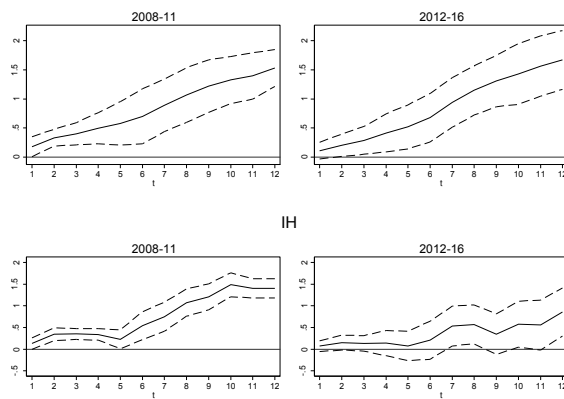


**Figure 6c: CPI Response to the policy rate (Eurozone), linear projections**

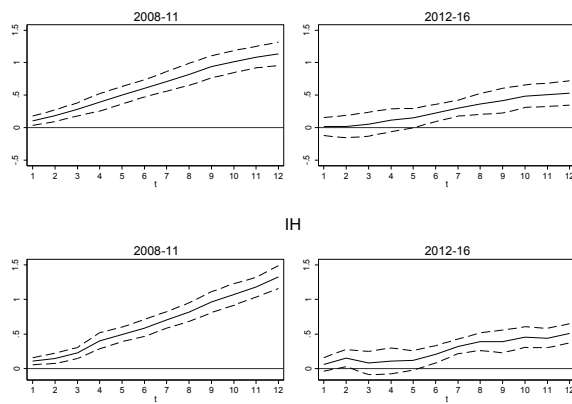


The solid lines plot the  $t$ -periods ahead responses of log CPI to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

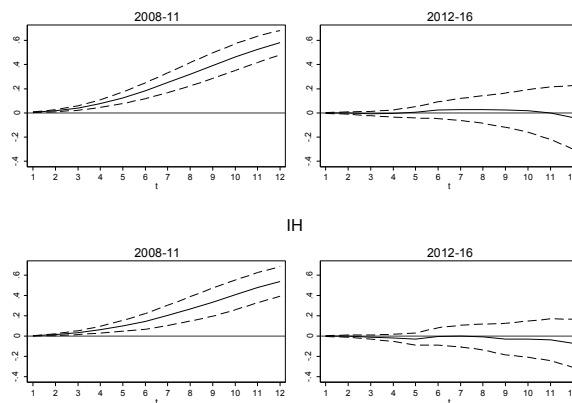
**Figure 7a: GDP Response to the policy rate (US), linear projections**



**Figure 7b: GDP Response to the policy rate (UK), linear projections**

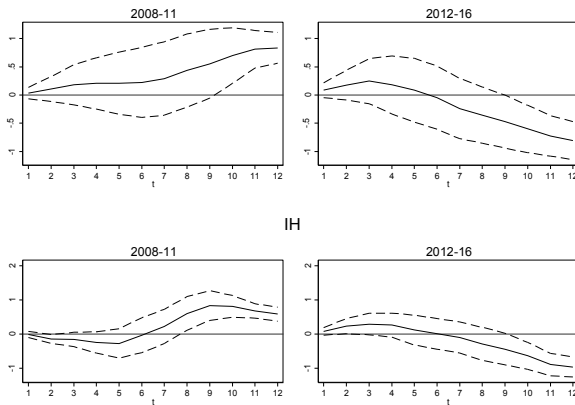


**Figure 7c: GDP Response to the policy rate (Eurozone), linear projections**

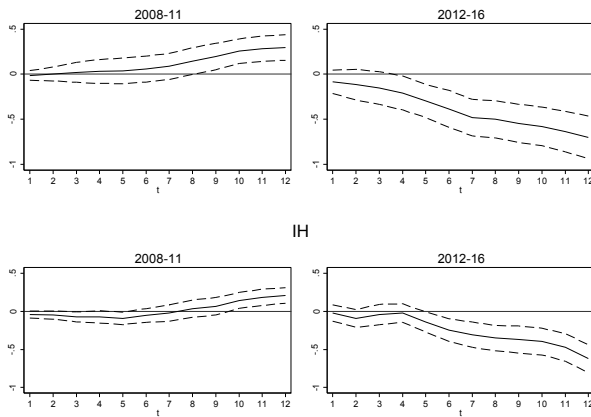


The solid lines plot the  $t$ -periods ahead responses of log GDP to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

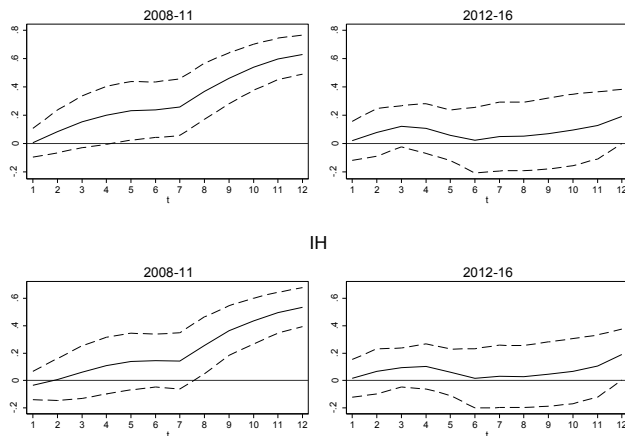
**Figure 8a: Price Response to the policy rate (US), linear projections**



**Figure 8b: Price Response to the policy rate (UK), linear projections**

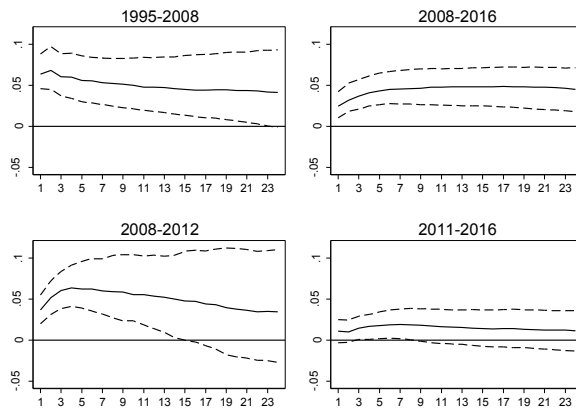


**Figure 8c: Price Response to the policy rate (Eurozone), linear projections**

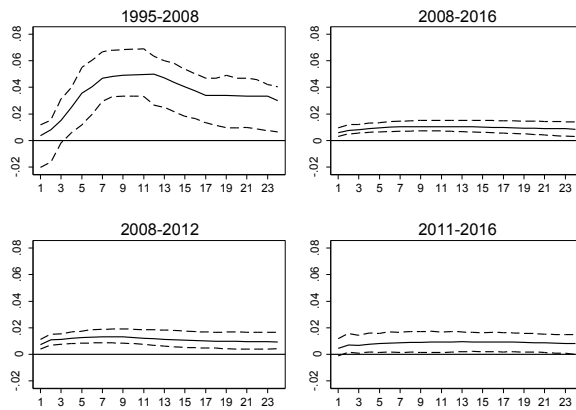


The solid lines plot the  $t$ -periods ahead responses of log GDP to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

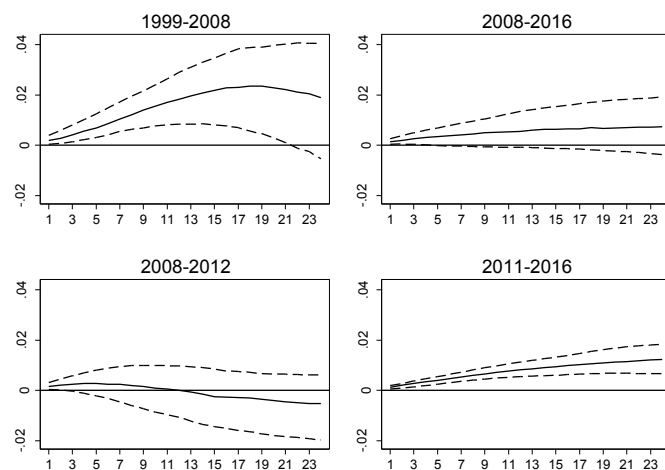
**Figure 9a: GDP Response to the policy rate (US), BVAR with sign restrictions**



**Figure 9b: GDP Response to the policy rate (UK), BVAR with sign restrictions**

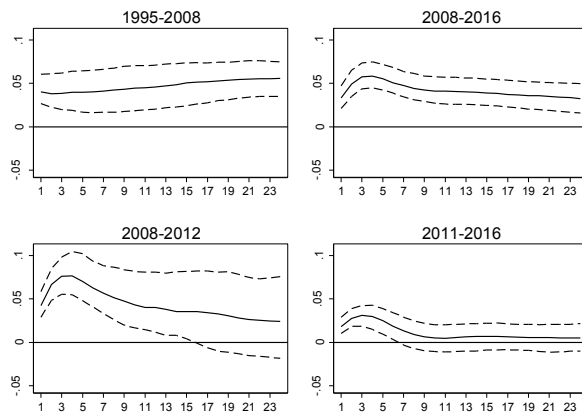


**Figure 9c: GDP Response to the policy rate (Eurozone), BVAR with sign restrictions**

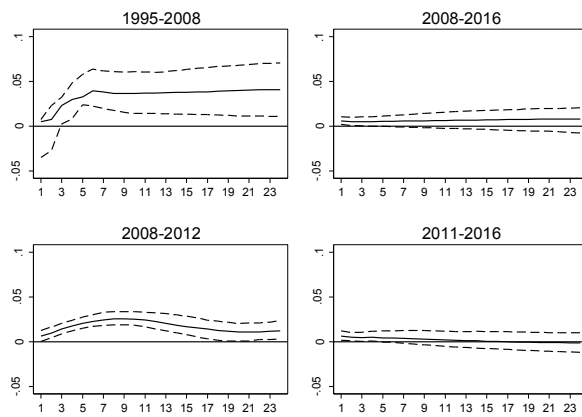


The solid lines plot the median responses of log GDP to a 1 percent decrease of the shadow policy rate. The dashed lines plot the 68% Bayesian credible confidence set.

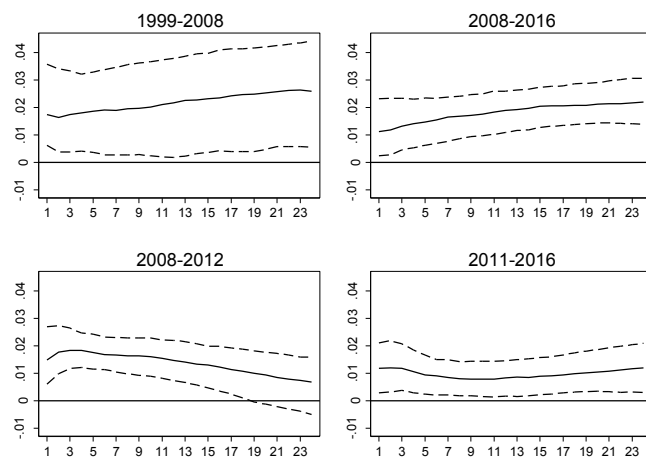
**Figure 10a: Price Response to the policy rate (US), BVAR with sign restrictions**



**Figure 10b: Price Response to the policy rate (UK), BVAR with sign restrictions**



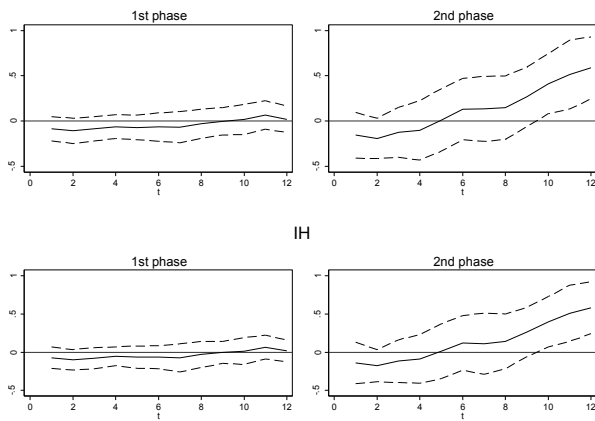
**Figure 10c: Price Response to the policy rate (Eurozone), BVAR with sign restrictions**



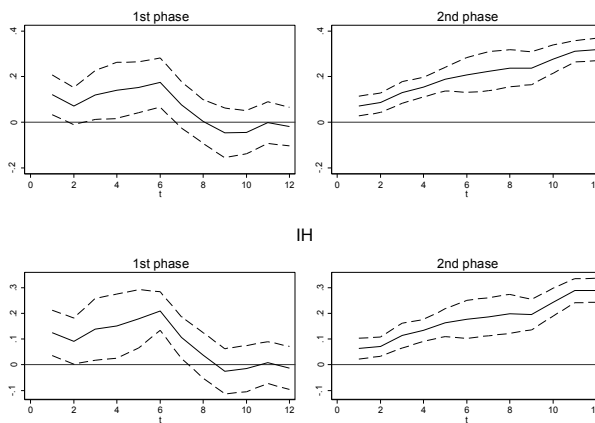
The solid lines plot the median responses of log CPI to a 1 percent decrease of the shadow policy rate. The dashed lines plot the 68% Bayesian credible confidence set.



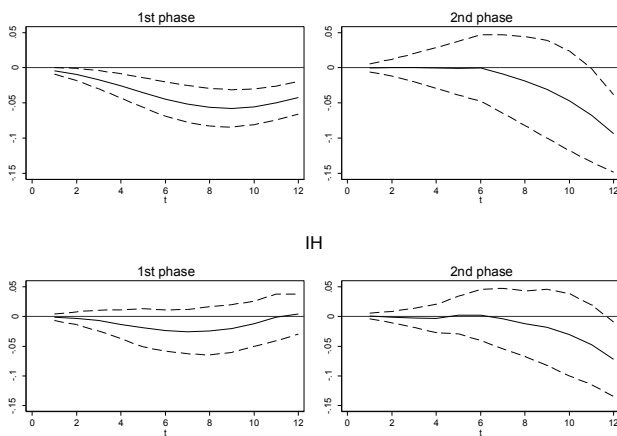
**Figure 11a: GDP Response to QE Announcements (US), linear projections**



**Figure 11b: GDP Response to QE Announcements (UK), linear projections**

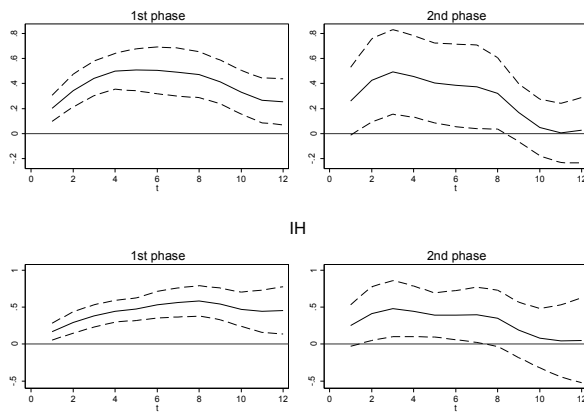


**Figure 11c: GDP Response to ECB balance sheet, linear projections**

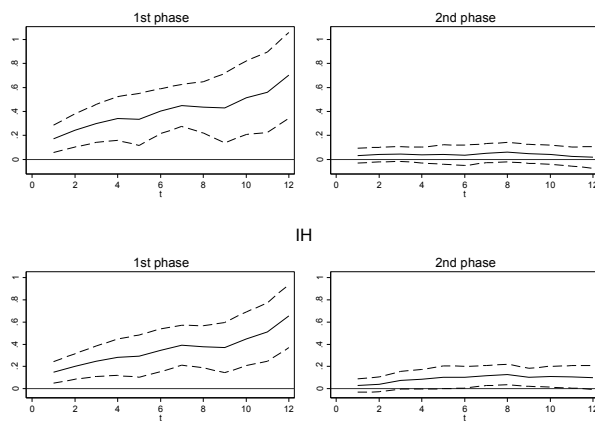


The solid lines plot the  $t$ -periods ahead responses of log GDP to announcement of asset purchases. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

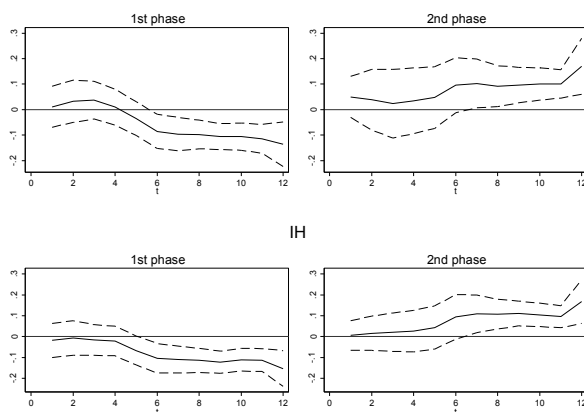
**Figure 12a: CPI Response to QE Announcements (US), linear projections**



**Figure 12b: CPI Response to QE Announcements (UK), linear projections**

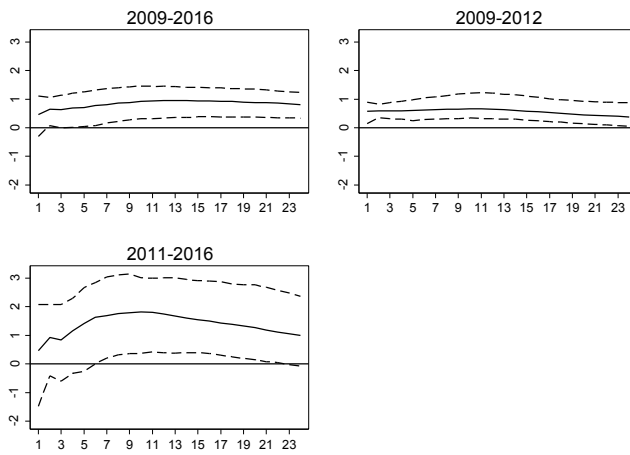


**Figure 12c: CPI Response to ECB balance sheet, linear projections**

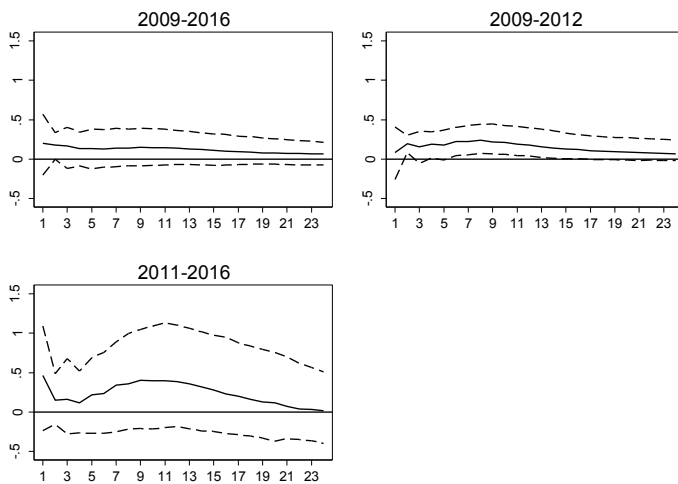


The solid lines plot the t-periods ahead responses of log CPI to announcement of asset purchases. The dashed lines are 95% confidence intervals. The top panel of each figure is based on OLS estimates of Equation (1). The bottom panel, instead, is based on IH estimates of Equation (1).

**Figure 13a: GDP Response to QE announcements (US), BVAR with sign restrictions**

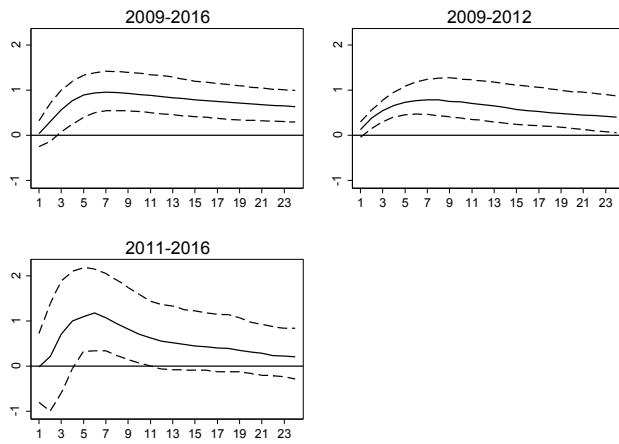


**Figure 13b: GDP Response to QE announcements (UK), BVAR with sign restrictions**

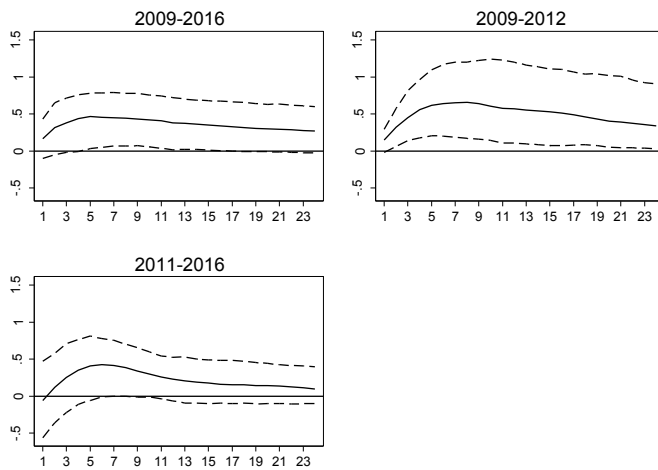


The solid lines plot the median responses of log GDP to an announcement of a 1 percent of GDP asset purchase. The dashed lines plot the 68% Bayesian credible confidence set.

**Figure 14a: CPI Response to QE announcements (US), BVAR with sign restrictions**

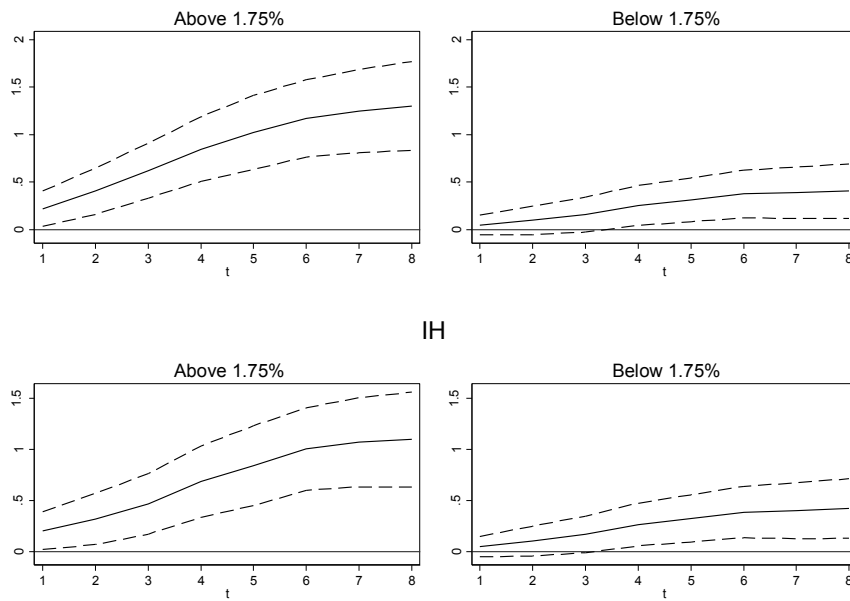


**Figure 14b: CPI Response to QE announcements (UK), BVAR with sign restrictions**

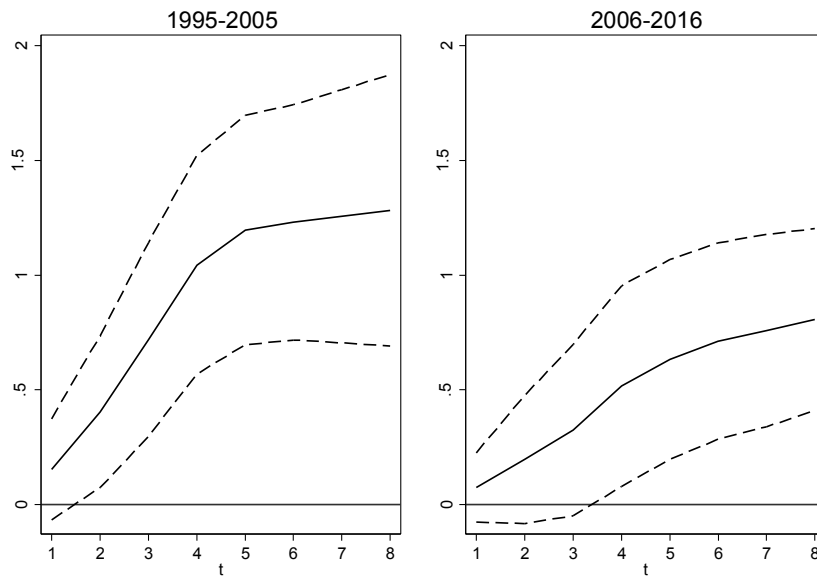


The solid lines plot the median responses of log CPI to an announcement of a 1 percent of GDP asset purchase. The dashed lines plot the 68% Bayesian credible confidence set.

**Figure 15a: Japanese GDP response to the policy rate, linear projections**

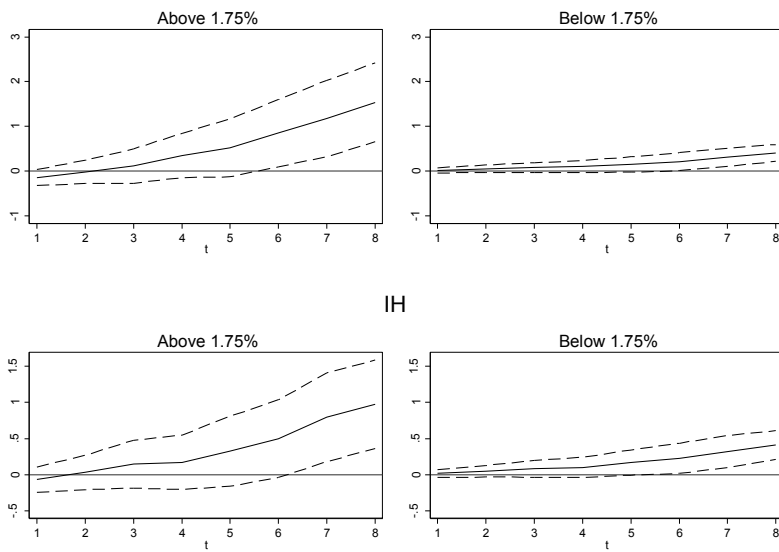


**Figure 15b: Japanese GDP response to the policy rate, linear projections**

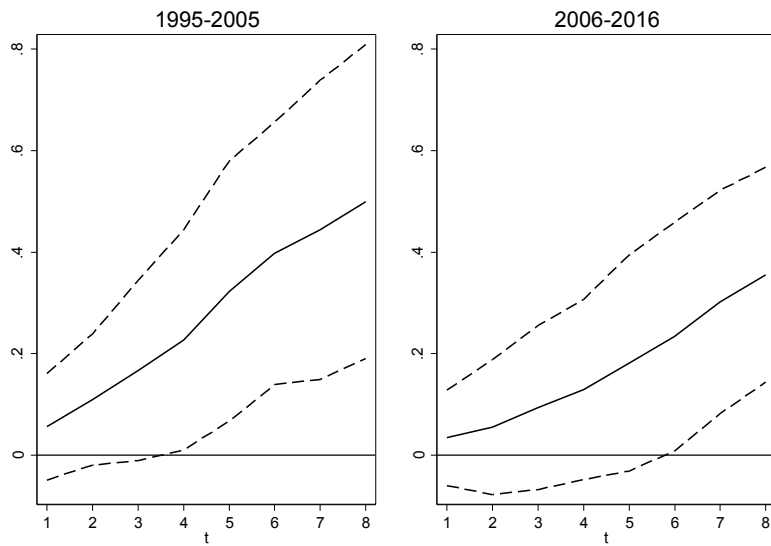


The solid lines plot the  $t$ -periods ahead responses of log GDP to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of figure 15a is based on OLS estimates of Equation (1) and the bottom panel is based on IH estimates of Equation (1). Figure 15b only reports OLS estimates

**Figure 16a: Japanese CPI response to the policy rate, linear projections**

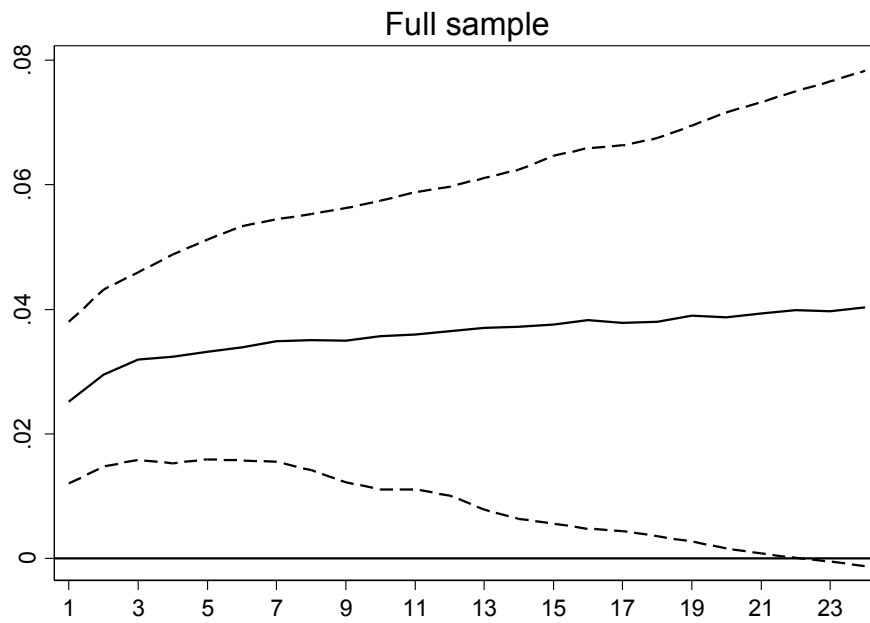


**Figure 16b: Japanese CPI response to the policy rate, linear projections**

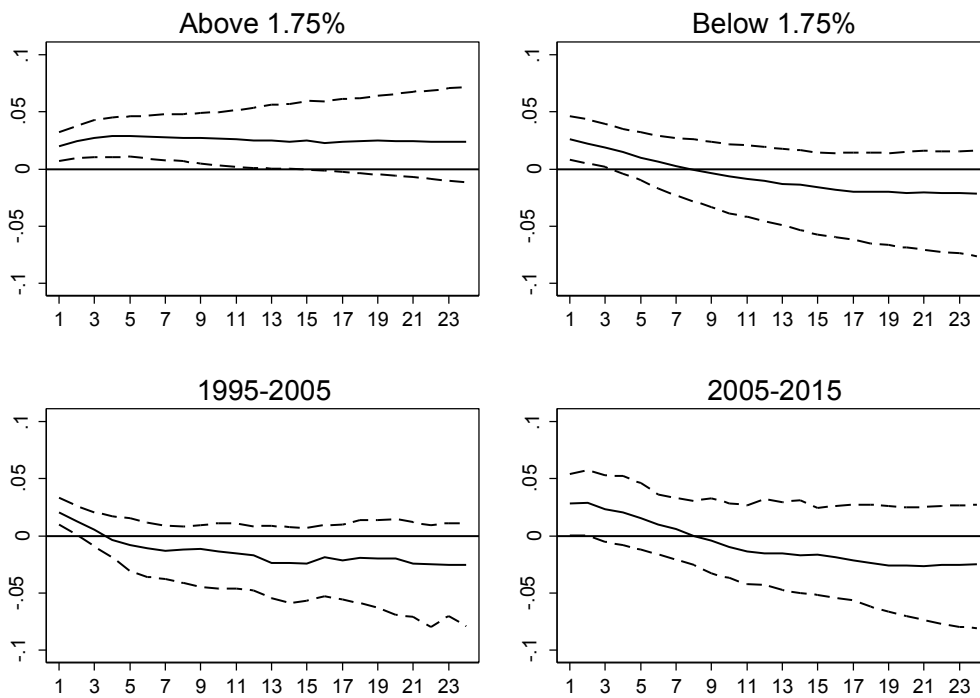


The solid lines plot the t-periods ahead responses of log CPI to a 1 percent decrease of the policy rate. The dashed lines are 95% confidence intervals. The top panel of figure 15a is based on OLS estimates of Equation (1) and the bottom panel is based on IH estimates of Equation (1). Figure 15b only reports OLS estimates

**Figure 17a: Japanese GDP response to the policy rate, BVAR**

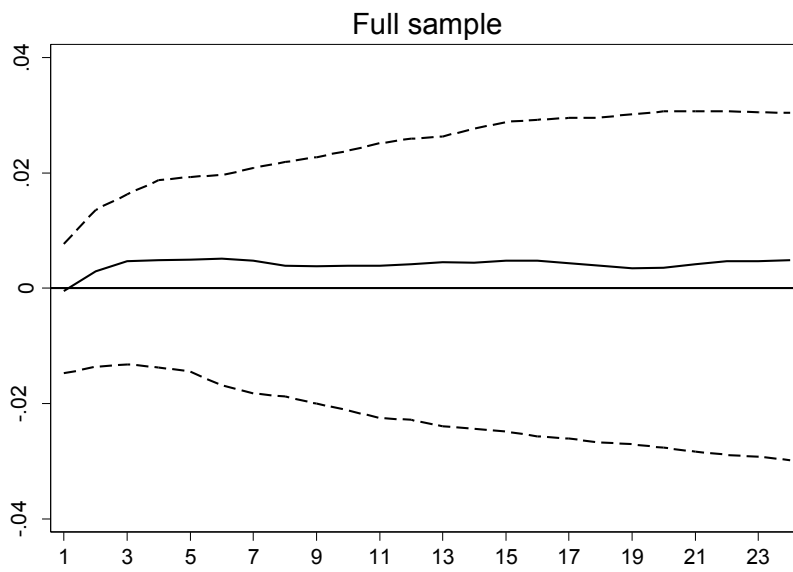


**Figure 17a: Japanese GDP response to the policy rate, BVAR**

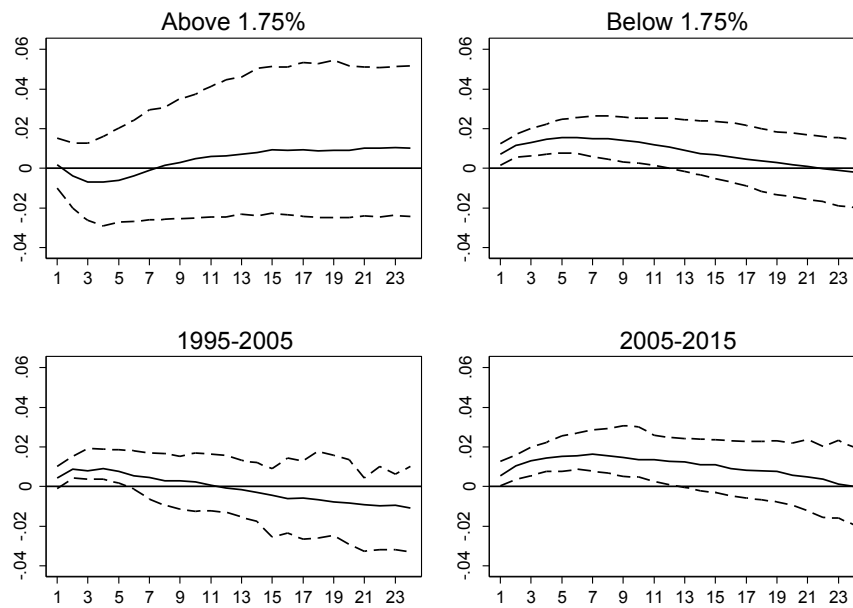


The solid lines plot the median responses of log GDP to a 1 percent decrease of the shadow policy rate. The dashed lines plot the 68% Bayesian credible confidence set.

**Figure 18a: Japanese CPI response to the policy rate, BVAR**



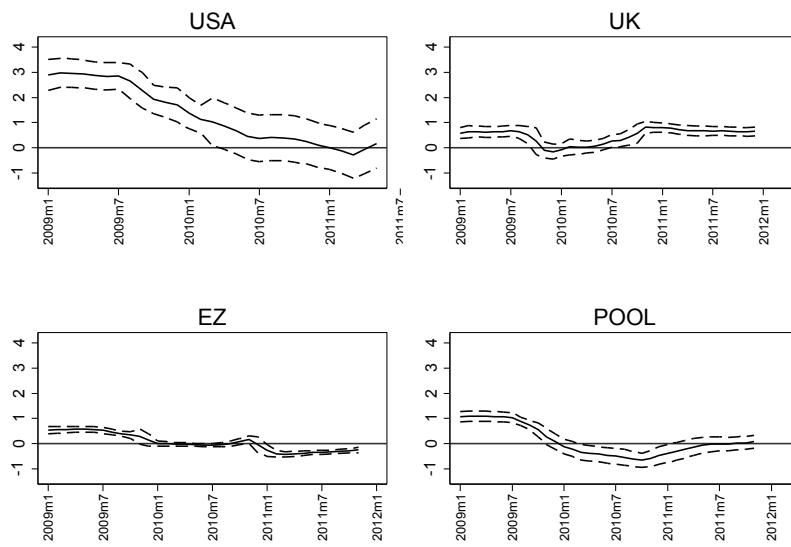
**Figure 18b: Japanese CPI response to the policy rate, BVAR**



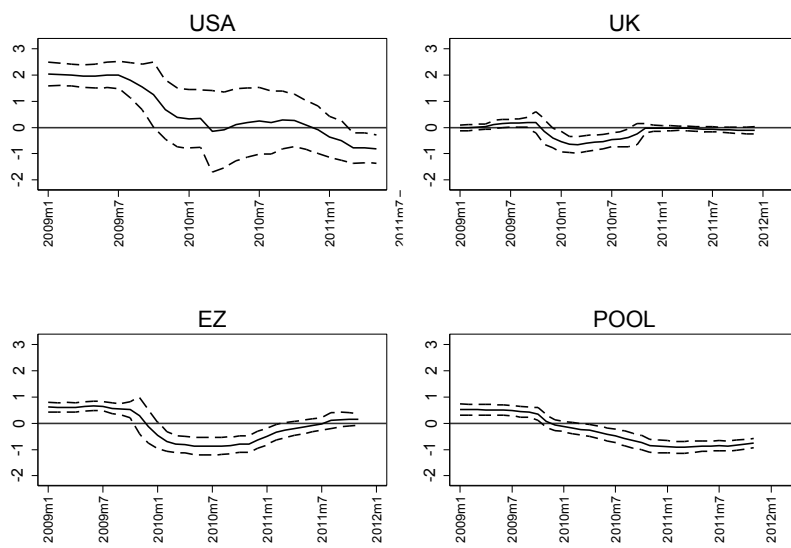
The solid lines plot the median responses of log CPI to a 1 percent decrease of the shadow policy rate. The dashed lines plot the 68% Bayesian credible confidence set.



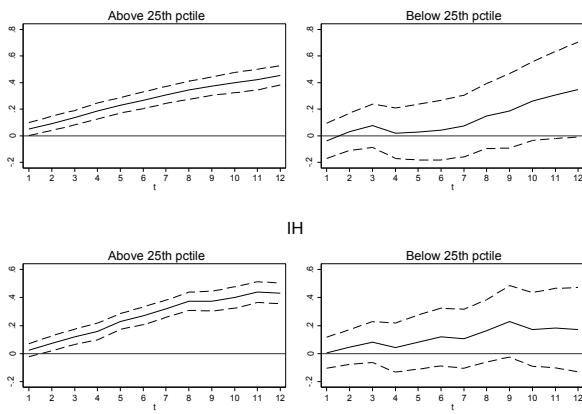
**Figure A1.a**  
**12 months ahead GDP response to shadow rate, 48 months rolling linear projections**



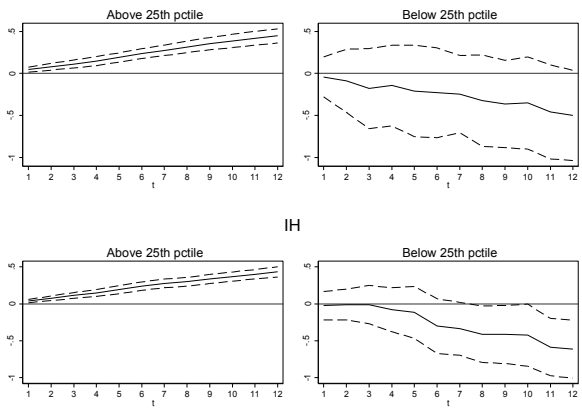
**Figure A1.b**  
**12-months ahead CPI response to shadow rate, 48 months rolling linear projections**



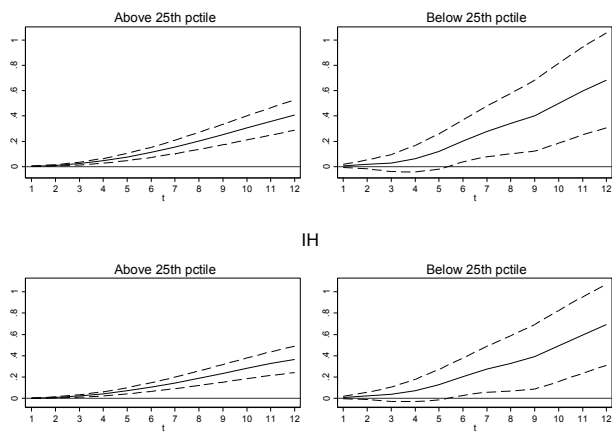
**Figure A2.a: LP estimations of GDP response to low policy rate (US)**



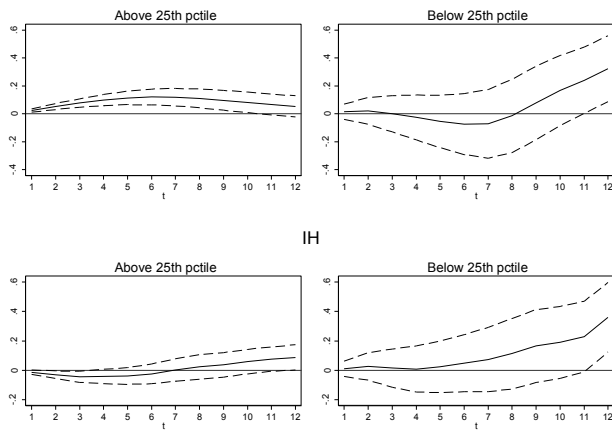
**Figure A2.b: LP estimations of GDP response to low policy rate (UK)**



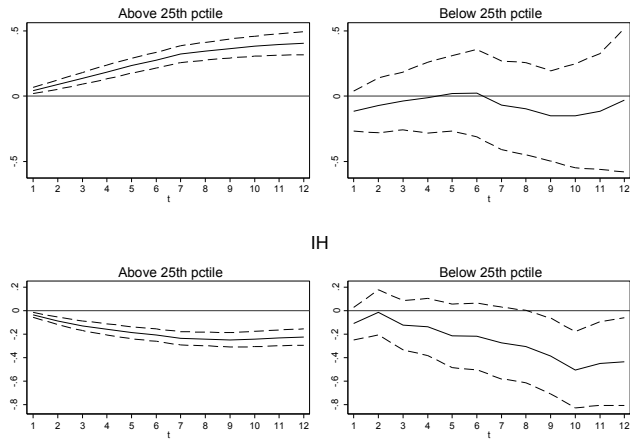
**Figure A2.c: LP estimations of GDP response to low policy rate (EZ)**



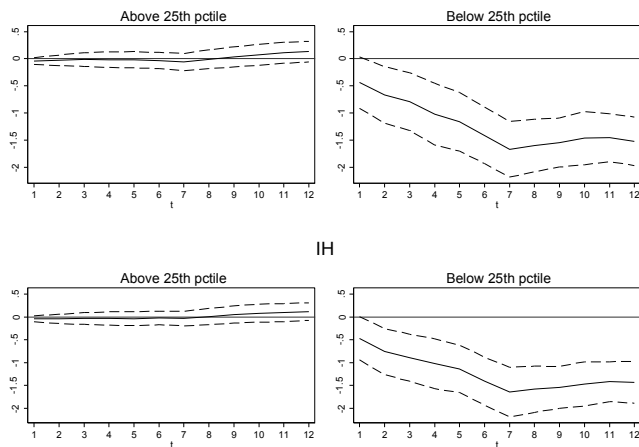
**Figure A3.a: LP estimations of CPI response to low policy rate (US)**



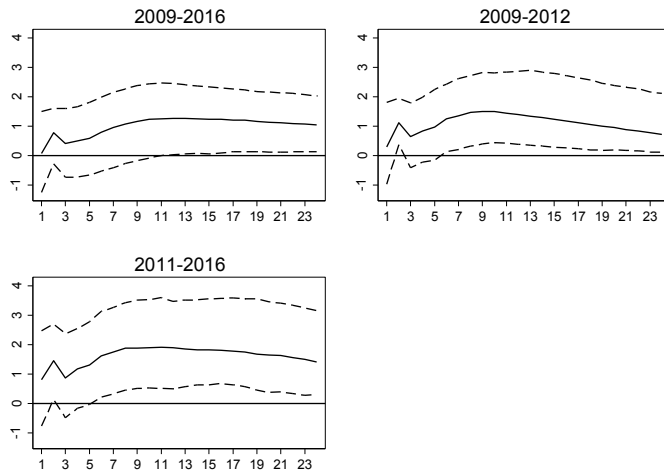
**Figure A3.b: LP estimations of CPI response to low policy rate (UK)**



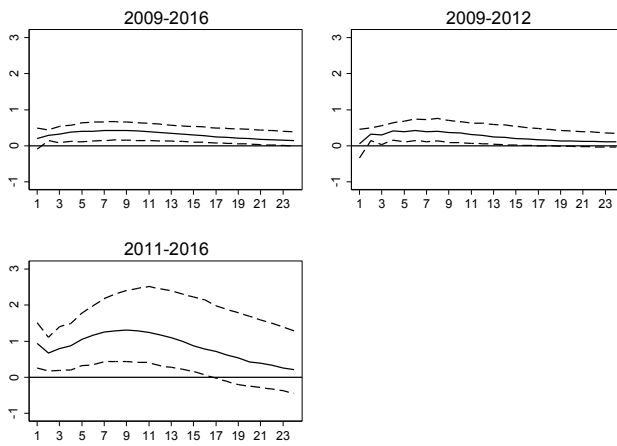
**Figure A3.c: LP estimations of CPI response to low policy rate (EZ)**



**Figure A4a: GDP Response to QE announcements (US), BVAR with sign and zero restrictions**

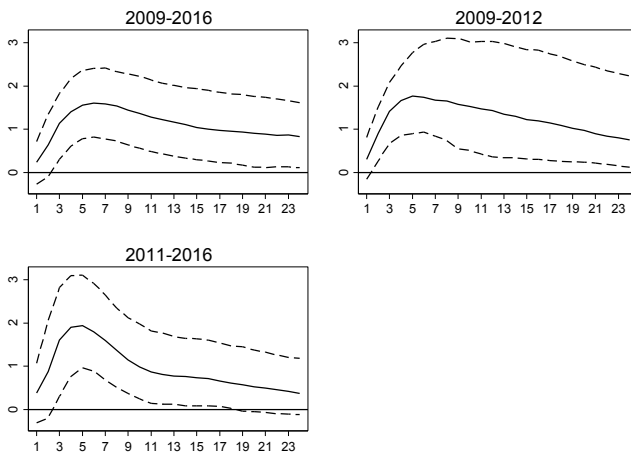


**Figure A4b: GDP Response to QE announcements (UK), BVAR with sign and zero restrictions**

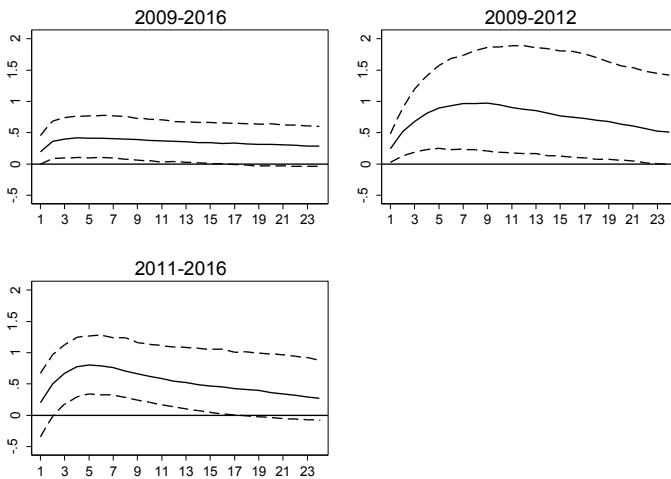


The solid lines plot the median responses of log CPI to an announcement of a 1 percent of GDP asset purchase. The dashed lines plot the 68% Bayesian credible confidence set.

**Figure A5a: CPI Response to QE announcements (US), BVAR with sign and zero restrictions**



**Figure A5b: CPI Response to QE announcements (UK), BVAR with sign and zero restrictions**



The solid lines plot the median responses of log CPI to an announcement of a 1 percent of GDP asset purchase. The dashed lines plot the 68% Bayesian credible confidence set.