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THE MACROECONOMIC EFFECTS OF MONETARY POLICY: A NEW MEASURE FOR THE UNITED KINGDOM*

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Abstract

This paper estimates the effects of monetary policy on the UK economy based on a new, extensive real-time forecast data set. Employing the Romer–Romer identification approach we first construct a new measure of monetary policy innovations for the UK economy. We find that a one percentage point increase in the policy rate reduces output by up to 0.6 per cent and inflation by up to 1.0 percentage point after two to three years. Our approach resolves the price puzzle for the UK and we show that forecasts are crucial for this result. Finally, we show that the response of policy after the initial innovation is crucial for interpreting estimates of the effect of monetary policy. We can then reconcile differences across empirical specifications, with the wider VAR literature and between our UK results and the larger narrative estimates for the US.

JEL: E31, E32, E52, E58.

KEYWORDS: monetary policy, narrative identification, real-time forecasts, business cycles.

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Contents

1. Introduction

The efficacy of monetary policy has often been the subject of heated debate and despite considerable research in the academic literature there remains disagreement about its effect on the macroeconomy. A range of empirical estimates have emerged in the literature and the effects on prices and output of a one percentage point innovation to the policy rate tend to be between 0.5 and 1 per cent. A notable exception — the so-called narrative method pioneered by Romer and Romer (2004) (RR) — has found considerably larger effects.[1] To our knowledge, and despite the attention given to these results, there are no other applications of this methodology to identify the effects of monetary policy. In addition, much of the empirical research on monetary policy has focused on the United States and results for other countries such as the United Kingdom are sparse. This paper fills both these gaps, providing new narrative-based estimates of the effect of monetary policy in the United Kingdom.

We focus on the effect of changes in the central bank's policy interest rate rather than on unconventional measures. Whilst the effect of unconventional measures is clearly an important topic in its own right, it seems likely that interest rates will remain a key policy instrument once economies are able to move away from the zero lower bound. Furthermore, looking at changes in policy interest rates is important for understanding the effects of monetary policy in the past and to be comparable with the existing literature. The effect of interest rates on the macroeconomy therefore remains of considerable interest, both to macroeconomists and policymakers.

Identifying the effects of changes in monetary policy requires confronting at least three econometric issues. First, monetary policy instruments, interest rates, and other macroeconomic variables are determined simultaneously as policymakers respond to macroeconomic fluctuations and intend their decisions to affect the economy. Second, policymakers are likely to react to expected future economic conditions as well as current and past information. Third, policymakers base their decisions on real-time data, not ex-post data often used in other empirical studies.

A major advantage of the Romer and Romer (2004) approach is that we can directly tackle all three of these empirical challenges. First we need to disentangle cyclical movements in short-term market interest rates from policymakers' intended changes in the policy target rate. A particular advantage of studying the United Kingdom (UK) is that the Bank of England's policy rate — Bank Rate[2] — *is* the intended policy target rate. We therefore do not need to construct the implied policy target rate from central bank minutes as in RR. As a second step, the target rate series is purged of discretionary policy changes that were responding to the changes in macroeconomic variables within the policymakers' information set. This information set may

[1] This follows earlier work using a slightly different narrative identification strategy in Romer and Romer (1989). Narrative approaches have also been employed to identify tax shocks (Romer and Romer, 2010; Cloyne, 2013) and government spending shocks (Ramey and Shapiro, 1998; Ramey, 2011).

[2] Previously Bank Rate was also referred to as Minimum Lending Rate / Repo Rate / Official Bank Rate.

include real-time data and forecasts that determine the policy reaction to anticipated economic conditions. We therefore use historical sources to reconstruct a proxy for the information set on which policy decisions were made. Specifically we construct an extensive new data set of historical Bank of England forecasts, private sector forecasts and real-time data. Our detailed new data set and shock series will hopefully provide a useful resource in itself.

In general many studies in the literature rely on ex-post data which were not the data actually available to policymakers at the time of their decision. Orphanides (2001) has shown that this can significantly affect estimates of the response of monetary policy to macroeconomic variables. Since our data are real-time, we naturally address this concern.

We perform a first stage regression to purge the intended policy target rate of systematic policy changes, producing a new series of monetary policy innovations. The academic literature has typically referred to these as structural monetary policy shocks. We show that this series is unpredictable on the basis of various macroeconomic time series.

Armed with our new series of monetary policy innovations, and following Romer and Romer (2004), we first estimate the effects of monetary policy using simple autoregressive distributed lag (ADL) models. A one percentage point permanent contractionary monetary innovation causes a significant fall in inflation of 1.5 percentage points and a 2.3 per cent fall in industrial production after two to three years. We show that these estimates are very similar to comparable results using the Romer and Romer (2004) method for the US.[3]

As noted by Coibion (2012) for the US, we also show that the profile for the shock plays a key role in determining the size of the effects of monetary policy. Being in first differences, simulations from ADL models implicitly assume a permanent shock to the level of the policy rate. When we employ our new shock measure in a VAR framework, we find that a one percentage point contractionary shock to the policy target rate leads to a peak decline in output of 0.6 per cent[4] and a 1.0 percentage point fall in inflation. These estimates are our baseline results. We show that differences between our ADL and VAR results are — at least for the UK — largely a result of different paths for the policy shock. Our estimates are therefore also in line with the magnitudes found elsewhere in the VAR literature.

However, unlike many VAR-based studies, and in keeping with RR for the US, we find a negative, significant and theoretically plausible response for inflation and prices. We therefore solve the so-called "price puzzle" — first documented in Sims (1992) — for the UK, where prices and inflation increase following a monetary contraction in conventional VARs. Investigating the issue further, we find that including forecast data in our methodology is crucial for this result.[5]

Many VAR studies, following Christiano, Eichenbaum, and Evans (1996, 1999), are based

[3] We have extended the RR shock series to 2007 so we can compare our results to the same sample period for the US.

[4] As measured by monthly industrial production. For quarterly GDP the peak effect is -0.5 per cent.

[5] Castelnuovo and Surico (2010) show that including forecast data can resolve the US price puzzle in VARs. They argue this is necessary in periods of indeterminacy, where policy did not respect the Taylor Principle.

on a recursiveness assumption with the policy instrument (typically interest rates) ordered last. Intuitively, this identification strategy allows all variables to contemporaneously affect interest rates, but interest rates have a lagged effect on the other macroeconomic variables. In response to a one percentage point contractionary monetary policy innovation, these studies typically find an effect on output of around 0.5 to 1 per cent at the peak and similar for inflation.[6] However, as noted above, there is often a sizable short-term increase in prices in response to a monetary tightening, which has lead some to question the result. When we employ the common recursive VAR approach, where Bank Rate is ordered last and monetary policy is assumed to affect the economy with a lag, we also find a large price puzzle for the UK. The price puzzle remains even after controlling for commodity prices, oil prices and exchange rates.

Bernanke, Boivin, and Eliasz (2005) argue that typical VARs use too narrow information sets. These authors use factor augmented VARs (FAVARs) to exploit a wide range of US data, finding a peak decline in GDP of 0.6 per cent and in prices of 0.7 per cent, to a one percentage point monetary contraction. Mumtaz, Zabczyk, and Ellis (2011) estimate a FAVAR model for the UK, finding a maximum GDP decrease of 0.5 per cent and a price level decline of up to 2 per cent.[7] An advantage of our approach is that forecasts can be seen as summary statistics of the policymakers' information set. Consequently, this approach does not require the very large data sets used in the FAVAR literature, many of which are only available at a quarterly frequency.

Another strand of the literature, following Uhlig (2005), has proposed using sign-restrictions on the direction of the impulse responses. Specifically, a contractionary innovation to monetary policy is assumed to lower prices and output on impact. For a monetary contraction of one per cent, Uhlig (2005) finds a GDP peak decrease of 0.8 per cent and a maximum decline in prices of 0.4 for the US economy. Mountford (2005), applying this methodology to the UK, finds a maximum GDP fall of 0.6 per cent and a decline in the GDP deflator of 0.15 per cent. One potential drawback of this approach is that the impulse responses are only set-identified: there tends to be a set of structural coefficients matrices consistent with the sign restrictions imposed.

A growing literature has also attempted to isolate surprises in monetary policy from forward-looking financial market data as in Kuttner (2001); Faust, Swanson, and Wright (2004); Bernanke and Kuttner (2005); Gürkaynak, Sack, and Swanson (2005); Barakchian and Crowe (2013) and Wingender (2011). Recently, Barakchian and Crowe (2013) construct a measure of policy surprises based on Fed Funds Futures. Using this measure in a VAR specification, the authors report that a one per cent monetary contraction causes a fall in industrial production of around 0.9 per cent, although a small price puzzle emerges. Unfortunately there is no exact equivalent of Fed Funds Futures for the UK and many financial markets data are not available

[6] For the US Christiano et al. (1999) find a decline in industrial production of 0.7 per cent and a peak decline in prices of 0.6 per cent. For the UK Dedola and Lippi (2005) find a drop in industrial production of 0.5 per cent and an insignificant price response.

[7] The GDP effect is similar across the two sub-samples. The inflation effect, however, is considerably smaller in the 1975-1991 sample at around -0.5 percentage points at the peak.

at high frequency back to the 1970s.

Romer and Romer (2004) find that a one percentage point monetary tightening in the US has much larger effects than typically reported in the rest of the literature. For example, in their baseline ADL specification industrial production falls by 4.3 per cent and the level of consumer prices falls by 3.6 per cent.[8] These results are large and the magnitudes have naturally raised two questions. First, is there something inherent in this 'narrative' approach that produces large effects? Second — and more fundamentally — are the effects of monetary policy large or small? We also find larger effects of monetary policy using an ADL specification. These are comparable to narrative results for the US. However, as mentioned before, we show that, at least for the UK, our ADL and VAR evidence can be reconciled by comparing similar monetary policy shocks across the two methods. Our baseline VAR implies that a one percentage point contraction leads to a fall in output and inflation of 0.6 per cent and 1 percentage point respectively.

The remainder of this paper is structured as follows. Section 2 addresses the econometric challenges in more detail and presents our new real-time database. Section 3 estimates our new monetary policy measure and investigates its properties. Section 4 presents the baseline results. Section 5 shows that our results are robust to a variety of different specifications. This section also shows that forecast data are important for our results. Section 6 examines the effect of monetary policy since 1992. Section 7 concludes.

2. Methodology

2.1. Identification and the first stage regression

In estimating the effects of monetary policy the researcher needs to overcome at least three econometric challenges. First, interest rates and other macroeconomic variables (e.g. output, inflation) are determined simultaneously, generating a challenging identification problem. Second, policymakers are likely not only to react to the current state of the economy, but also to anticipated future macroeconomic conditions. Third, policymakers base their decision on real-time data, whereas many studies employ final revised data.

More formally, we aim to isolate the innovations m_t from the systematic movements in the intended policy variable S_t in the following equation:

$$S_t = f(\Omega_t) + m_t \ . \qquad (1)$$

The systematic component of S_t is driven by the policymakers' response to data in their information set Ω_t, where $f(\cdot)$ is a function capturing the systematic reaction and the term m_t

[8] The level of producer prices falls by nearly 6 per cent. These effects are based on the original RR sample from 1969 to 1996.

reflects unexpected shifts in monetary policy.

The VAR literature has mainly tackled the simultaneity problem of interest rates and macroeconomic fluctuations. Often this literature has imposed a timing restriction: macroeconomic variables do not contemporaneously (within the period) react to interest rates (e.g. Christiano et al., 1996, 1999). The equation of the VAR that describes interest rates is therefore directly related to equation (1) above. Other papers in the literature have used sign-restrictions — following Uhlig (2005) — to identify m_t. This method assumes that a contractionary monetary policy shock is one that, for example, raises interest rates but lowers output and inflation on impact.

Two further issues are often overlooked in commons approaches. First, forward-looking policymakers may well include forecasts in their information set Ω_t and central banks devote a great deal of resources forecasting the future path of the economy. Moreover, since contemporaneous estimates of the state of the economy are rarely available in real-time, the policymakers' forecasts also include a forecast of the current period. It is worth noting that, in practice, the forecasts may be based on additional information and judgements not readily available to the econometrician.

Second, since monetary policy responds to information available to policymakers at the time of the decision, any regression designed to recover the structural shocks to policy m_t should be based on the real-time data rather than ex-post revised data. As noted, key papers in the existing literature, among these Christiano et al. (1999) and Uhlig (2005), have employed ex-post data. Orphanides (2001, 2003) and Molodtsova, Nikolsko-Rzhevskyy, and Papell (2008) show that estimated monetary policy reaction functions based on ex-post revised data are considerably different when using real-time data.[9]

We apply the Romer and Romer (2004) approach to identify monetary policy innovations m_t. Following the literature we refer to this as a narrative approach because it makes careful use of historical documents to construct the intended policy target rate and the information set of the policymakers prior to their decisions. The first stage of this approach requires constructing a measure of the intended policy target rate (S_t) at *each policy decision*. RR construct the target rate from minutes of the *Federal Open Market Committee* meetings. One advantage of the UK monetary framework is that the policy rate — Bank Rate — is the intended policy target. Batini and Nelson (2009), in their extensive history of UK monetary policy, argue that short-term interest rates have always implicitly been an intended target, even in the periods where the government publicly emphasised money supply or exchange rates.

Armed with a series for the intended policy rate we then estimate a first stage regression

[9] Ex-post data for some variables, such as real output growth, often turn out to differ substantially from real-time estimates, as shown in Appendix A.

addressing the econometric challenges discussed above. The precise regression estimated is

$$\begin{aligned} \Delta i_m &= \alpha + \beta i_{t-d14} + \sum_{i=-1}^{2} \gamma_i \hat{y}^F_{m,i} + \sum_{i=-1}^{2} \varphi_i \pi^F_{m,i} \\ &+ \sum_{i=-1}^{2} \delta_i (\hat{y}^F_{m,i} - \hat{y}^F_{m-1,i}) + \sum_{i=-1}^{2} \vartheta_i (\pi^F_{m,i} - \pi^F_{m-1,i}) + \sum_{i=1}^{3} \rho_i u_{t-i} + \epsilon_m \ , \end{aligned} \tag{2}$$

where the dependent variable is measured at a meeting-by-meeting frequency as indicated by subscript m. The subscript i denotes the quarter of the forecast relative to the meeting date and the subscript $t-1$ refer to information from the previous month, not information at the previous meeting. In particular we follow RR and regress the change in the intended policy target (Δi_m) around the policy decision (in practice, between two meetings) on the one and two quarter ahead forecasts of real GDP growth ($\hat{y}^F_{m,i}$) and inflation ($\pi^F_{m,i}$) as well as the real-time backdata of the previous period and the forecast for the current period. We also include revisions in the forecasts relative to the previous round of forecasts (e.g. $\hat{y}^F_{m,i} - \hat{y}^F_{m-1,i}$). In addition, we control for recent economic conditions by including interest rates two weeks before the meeting (i_{t-d14}) and the unemployment rates of the previous three months (u_{t-i}).

It is also worth noting that in collecting forecast data for the UK economy we are directly constructing a real-time data set to capture the information set of policymakers at each period in time. We therefore take seriously the concerns raised by Orphanides (2001) and others about using ex-post revised data.

To include forecasts in a regression such as equation (1) they need to be orthogonal to m_t.[10] To achieve this, we carefully exploit the timing of forecast releases to ensure they do not already include the effects of the relevant (subsequent) policy change. We therefore aim to capture the information set of policymakers *prior* to the policy decision.

Using forecast data to identify monetary policy innovations also has a further advantage. In principle the researcher may need to include a large number of time series in the VAR as many variables could enter the information set Ω_t. This is the motivation behind the data-rich FAVAR approach of Bernanke et al. (2005). Forecasts are particularly useful, however, because they neatly summarize a wider range of macroeconomic information, as well as the anticipated movements in the macroeconomy.

The estimated residuals of the first stage regression are our new exogenous monetary policy shock measure. Our definition of a monetary policy 'shock' therefore captures an unpredictable surprise that is not taken in response to information about current and future economic developments.[11] As such, the 'shock' reflects an unpredictable surprise movement in the target variable

[10] In our specification in equation (2) the forecasts need to be orthogonal to ϵ_m. Later we transform the residual to a monthly shock series that we denote m_t.

[11] Given that the relevant endogeneity of the target rate is with respect to variables in the policymakers' information set, the relevant forecasts are those of the policymakers. It may still be the case that endogenous policy changes are surprises relative to the forecasts of the private sector. We address this issue in the robustness section.

and could represent a variety of factors including deliberately induced policy surprises, over- and under-reactions or temporary shifts in the preferences of policymakers. This new meeting-by-meeting measure of monetary policy shocks is converted to a monthly series and, in second stage regressions, is used to estimate the effect of monetary policy on the macroeconomy.

2.2. Data construction

As noted above, the official Bank Rate series serves as our intended policy target rate. This is available from the Bank of England website.

Since 1997 the Bank of England has had operational independence in setting interest rates to meet an inflation target. To capture the information set of policymakers the natural starting point is to use official Bank of England forecasts for inflation and output growth. Since the Bank of England actually began inflation targeting in 1993, forecasts are available from the quarterly *Inflation Report* (IR) and the forecasts themselves provide quarterly projections for several years ahead.[12]

The Bank of England publishes two sets of forecasts. One set is conditioned on a constant interest rate path which *ex-post* includes the effect of the Monetary Policy Committee's (MPC) Bank Rate decision. The other set is conditioned on a path for Bank Rate implied by market interest rates *prior* to the meeting. As discussed above, a crucial assumption to ensure identification is that forecasts do not already contain the effect of the policy decision (in other words, they are uncorrelated with the error term ϵ_m). If the forecasts already included the effect of the policy change the regression results would be biased. We therefore use the latter set of forecasts and we assign these data to the relevant meeting of the MPC.[13]

Before 1997 monetary policy decisions were made by the UK Treasury. Official Treasury forecasts were produced but only two per year are publicly available and the published forecast is not detailed enough for our purposes. Furthermore, monetary policy was not set at a regular meeting but was changed periodically as deemed necessary. To tackle this problem we also collect forecasts produced by the *National Institute for Economic and Social Research* (NIESR).[14]

NIESR is Britain's longest established independent economic research institute, which is widely respected and close to the UK policy debate. Furthermore, unlike forecasts from other professional bodies, NIESR forecasts are available for a long time period, at a quarterly frequency and for a large number of possible variables of interest.

[12] Until 2003 the inflation target was defined in terms of the retail prices index excluding mortgage interest payments (RPIX) — first as a band, then as a point target of 2.5 per cent at an annual rate after 1997. After 2003 the inflation target was specified in terms of the consumer prices index (CPI), with a target of 2 per cent annual rate.

[13] In addition, MPC minutes are published shortly after the Bank Rate decision, providing further insights into the decision making process.

[14] Although in the baseline analysis we use Bank of England forecasts from 1993 to 1997 where available, regarding them as a closer proxy for Treasury forecasts.

We collect NIESR forecasts for our full sample, even for periods when we have Bank of England forecasts. The reason for doing so is twofold. First, we can confirm that the NIESR and Bank of England Inflation Report forecasts are highly correlated (at least for the two quarters ahead we use).[15] Second, we are able to re-estimate our results using only NIESR forecasts for the full sample. Later we show this makes little difference to the results. NIESR forecasts therefore appear to be good proxies for official forecasts. Moreover, new releases of NIESR forecasts have received much attention in the media (e.g. the Financial Times) indicating that these are likely to be known to the private sector and policymakers.

To address the possible endogeneity of forecasts to the policy change we collect all the forecast embargo dates and finalisation dates from the historical hard-copies. We also consult historical editions of the Financial Times archive to confirm the forecast release date. We are therefore able to ensure that a forecast did not already contain the effects of the relevant policy change.

All data pre-1991 have been manually digitised from the hard-copies of the National Institute Economic Review. To illustrate the data source Figure 1 provides an extract from the NIESR February 1983 issue of the National Institute Economic Review. For example, we transform GDP forecasts in column 'GDP Index 1975=100' into quarterly growth rates of GDP.

We use forecast data for real GDP growth and inflation from our new data set. The relevant inflation index varied over our sample. We therefore use the consumer prices deflator (1975-87), retail prices index (RPI) (1987-92), retail prices index excluding mortgages (1993-2003), and the harmonised consumer prices index (2003-07).

As noted above, we use the forecast for the current period (real-time estimates of the current period were rarely available to policymakers) and the forecasts for the two quarters ahead. We collect the relevant real-time backdata, which may also differ from the finally revised series. These are available either from the forecast publications themselves or the Bank of England's real-time data set. Our new data set contains 170 potential variables at quarterly frequency from 1975:1 to 2007:4, although not all variables are used in this study. We exclude the most recent years after 2007 when interest rates were maintained close to the zero lower bound. This is a rich data set, which should also prove useful for future research (for further details see Table 6 in Appendix A).

Since our first stage regression is conducted at a decision-by-decision frequency, the new real-time forecast data set is carefully matched to relevant Bank Rate decisions. In the first part of our sample Bank Rate is changed infrequently, whereas meetings are held on a monthly basis after 1997. Table 1 illustrates the construction of our data set using both sources — Bank of England forecasts and NIESR forecasts. The first column lists the date of the Bank Rate decision and the second column specifies the contemporaneous quarter. Forecasts are denoted by $\mathcal{F}^{\text{Source}[\text{Forecast quarter, Forecast year}]}_{\text{Publication date}}$, where we distinguish between the source

[15] The correlation between NIESR and Bank of England's forecasts for inflation as well as real GDP growth are at around 0.7 for up to two quarter ahead forecasts in the overlapping sample period (1993Q1-2007Q4).

Figure 1: Extract from National Institute Economic Review (Vol. 103)

Table 15. Estimates and forecasts of the gross domestic product

The forecast figures are not intended to be more precise than the general statements in the text

£ million, 1975 prices, seasonally adjusted

	GDP(a)		Consumers' expenditure	General government current spending	Gross fixed investment	Exports of goods and services	Stock-building	Residual (b)	Total final expenditure(a)	Imports of goods and services	Adjustment to factor cost
	Index, 1975=100	At factor cost									
1981	104.5	98,561	71,871	24,306	18,774	32,329	−1,871	−706	144,703	34,040	12,102
1982	105.0	99,080	72,645	24,601	19,307	32,451	−835	−1,241	146,928	35,336	12,513
1983	*106.5*	*100,430*	*72,109*	*24,750*	*19,679*	*33,451*	*3*	*−1,077*	*148,915*	*36,263*	*12,222*
1984	*108.2*	*102,098*	*72,156*	*24,900*	*19,778*	*34,618*	*1,024*	*−1,095*	*151,380*	*36,963*	*12,319*
1981 I	104.3	24,599	18,040	6,055	4,690	7,850	−642	−561	35,432	7,673	3,160
II	104.0	24,528	17,926	6,052	4,667	8,028	−694	−266	35,713	8,249	2,936
III	104.7	24,693	17,934	6,127	4,663	8,131	−226	247	36,876	9,240	2,943
IV	104.9	24,740	17,971	6,072	4,754	8,320	−309	−127	36,681	8,878	3,063
1982 I	104.6	24,670	17,927	6,147	4,908	8,010	−49	−428	36,515	8,687	3,158
II	104.9	24,740	17,998	6,113	4,702	8,250	14	−353	36,724	9,075	2,909
III	105.3	24,835	18,242	6,191	4,865	7,923	−300	−193	36,728	8,827	3,066
IV Estimate	105.3	24,835	18,478	6,150	4,832	8,268	−500	−266	36,962	8,747	3,380
1983 I Forecast	*105.8*	*24,949*	*18,147*	*6,175*	*4,864*	*8,231*	*−204*	*−268*	*36,945*	*8,942*	*3,054*
II	*106.3*	*25,070*	*18,026*	*6,175*	*4,921*	*8,310*	*7*	*−269*	*37,170*	*9,046*	*3,054*
III	*106.6*	*25,147*	*17,978*	*6,200*	*4,947*	*8,414*	*53*	*−270*	*37,322*	*9,120*	*3,055*
IV	*107.1*	*25,264*	*17,958*	*6.200*	*4,948*	*8,496*	*147*	*−271*	*37,478*	*9,154*	*3,059*
1984 I	*107.7*	*25,394*	*17,923*	*6,225*	*4,953*	*8,561*	*197*	*−272*	*37,588*	*9,133*	*3,060*
II	*108.3*	*25,537*	*18,041*	*6,225*	*4,954*	*8,628*	*259*	*−274*	*37,834*	*9,217*	*3,080*
III	*108.2*	*25,521*	*18,028*	*6,225*	*4,927*	*8,691*	*265*	*−274*	*37,862*	*9,263*	*3,079*
IV	*108.7*	*25,647*	*18,164*	*6,225*	*4,943*	*8,738*	*303*	*−275*	*38,097*	*9,350*	*3,100*
Percentage changes											
1982/81	0.5	0.5	1.1	1.2	2.8	0.4			1.5	3.8	3.4
1983/82	*1.4*	*1.4*	*−0.7*	*0.6*	*1.9*	*3.1*			*1.4*	*2.6*	*−2.3*
1984/83	*1.7*	*1.7*	*0.1*	*0.6*	*0.5*	*3.5*			*1.7*	*1.9*	*0.8*
1982IV/81IV	0.4	0.4	2.8	1.3	1.6	−0.6			0.8	−1.5	10.3
1983IV/82IV	*1.7*	*1.7*	*−2.8*	*0.8*	*2.4*	*2.8*			*1.4*	*4.7*	*−9.5*
1984IV/83IV	*1.5*	*1.5*	*1.1*	*0.4*	*−0.1*	*2.9*			*1.7*	*2.1*	*1.3*

Source: *Economic Trends*, NIESR estimates.
(a) Output measure.
(b) The discrepancy between output and expenditure estimates of GDP.

(IR/NIESR), the quarter and the year the forecast was produced for, and the forecast publication date.[16]

A complication we face is that we do not not have new forecasts for every Bank Rate decision as policy meetings take place at higher frequency: there are more Bank Rate decisions than forecast releases. This is also true, although to a lesser degree, in Romer and Romer (2004). There are a few possible ways to deal with this issue. One option is to only consider Bank Rate changes after a new quarterly release of forecasts (and exclude all other changes). However, this procedure reduces the number of observations substantially. Alternatively we could assign the latest available forecast to each policy meeting, while still controlling for developments between the last forecast and the policy decision, for example by including unemployment data.

[16] As noted, Bank of England forecasts are officially published *after* the Bank Rate decision they were prepared for. For example, the Bank Rate decision on 6th May 1997 was based on Bank of England forecasts published on 13th May 1997. We assign the 1997Q2 forecast to the contemporaneous quarter, i.e. $\hat{y}_{m,i}$, since it is conditioned on the market path about interest rates prior to the policy announcement. NIESR forecasts released after the policy decision would be endogenous. Therefore, NIESR forecasts are assigned to the Bank Rate decision that is *subsequently* implemented.

Table 1: Assignment of forecasts to Bank Rate decisions

Bank Rate	Current quarter	$\hat{y}^F_{m,t-1}$	$\hat{y}^F_{m,t}$	$\hat{y}^F_{m,t+1}$	$\hat{y}^F_{m,t} - \hat{y}^F_{m-1,t}$
15/03/83	Q1 83	$\mathcal{F}^{N[Q4,82]}_{24-02-83}$	$\mathcal{F}^{N[Q1,83]}_{24-02-83}$	$\mathcal{F}^{N[Q2,83]}_{24-02-83}$	$\mathcal{F}^{N[Q1,83]}_{24-02-83} - \mathcal{F}^{N[Q1,83]}_{30-11-82}$
⋮					
06/05/97	Q2 97	$\mathcal{F}^{IR[Q1,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q2,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q3,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q2,97]}_{13-05-97} - \mathcal{F}^{IR[Q2,97]}_{12-02-97}$
06/06/97	Q2 97	$\mathcal{F}^{IR[Q1,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q2,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q3,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q2,97]}_{13-05-97} - \mathcal{F}^{IR[Q2,97]}_{12-02-97}$
10/07/97	Q3 97	$\mathcal{F}^{IR[Q2,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q3,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q4,97]}_{13-05-97}$	$\mathcal{F}^{IR[Q3,97]}_{13-05-97} - \mathcal{F}^{IR[Q3,97]}_{12-02-97}$
⋮					

Notes: Forecasts are denoted by $\mathcal{F}^j_m, m =$ Publication date, $j =$ Source[Forecast quarter, Forecast year], where we distinguish between the source (IR/NIESR), the quarter and the year the forecast was prepared for (t), and the forecast publication date (m). The remaining variables are matched following the same procedure indicated in this table.

A further issue arises in the earlier sample when we have a new forecast and no change in policy but we do not know whether there was a meeting to decide to leave the rate unchanged. We could either treat the forecast release itself as a decision to keep the rate fixed in the face of new economic developments, or we could disregard these cases.

Having carefully considered these options our preferred specification is to keep all Bank Rate decisions and assign the latest available forecast to that decision. However, we disregard the cases where new forecasts are available but we do not observe a Bank Rate change (since we cannot be sure these are genuine monetary policy *decisions*). This approach maintains a large number of observations and is closest to the implementation in Romer and Romer (2004).

3. The new measure

3.1. Stage 1: stripping out the systematic component

After assigning the real-time forecast data to Bank Rate decisions, we isolate innovations to Bank Rate that are orthogonal to the real-time information set of policymakers that we consider. We include all Bank Rate changes between 1975 and 2007 except those taking place at very high frequency (i.e. within the same two weeks). The sample covers 235 Bank Rate decisions.

Table 2 reports the results from estimating equation (2). The estimation results indicate that UK monetary policy was conducted countercyclically over the sample. Summing up the coefficients on the real GDP growth forecasts yields 0.15 for the *level* and 0.23 for the *change* in the growth forecast. Thus, a one percentage point increase in the real GDP growth forecast from one forecast release to the next was associated with an increase in Bank Rate of 39 basis points. The effect on Bank Rate is comparable to the US results of RR, who find a response of 29 basis points in the intended target rate. The response to a one percentage point increase in the inflation forecast leads to a rise in Bank Rate of 30 basis points, of which 3 basis points are due to the absolute change in inflation forecasts and 27 basis points are due to the change relative to the last forecast release. The policy target rate in the UK reacts more strongly (30 basis points) than the intended Federal Funds rate in the US (which increases by 7 basis points) to a one percentage point change in the inflation forecasts. A one percentage point increase in the unemployment rate in each of the past three months keeping everything else equal reduces the policy target rate by around 5 basis points in the UK economy.

In summary, the point estimates for the UK and those for the US in RR are qualitatively similar, although not identical. The results in Table 2 also appear to have reasonable and expected signs and magnitudes. Importantly, having stripped out the systematic component of policy, the residual of equation (2) is our new measure of monetary policy changes orthogonal to the information set of policymakers.

3.2. Properties of the new shock series

We now transform the first stage residuals into a monthly series of monetary policy innovations that we use to estimate the macroeconomic effects of changes in monetary policy. Note that the residuals from the first stage regression are dated according to the policy decision (given that we have the exact date of the decision). We therefore transform the residuals into a monthly series as follows. In a month without a Bank Rate decision we set the observation to zero. Otherwise we assign the shock to the respective month in which the policy change occurred. For months with multiple policy changes, we sum the shocks. Figure 2 shows our new monthly series of exogenous monetary policy shocks. As above, we denote the monthly shock series by m_t.[17]

The new series is more volatile in the first half of the sample until 1993. This observation fits well with the view that there was a regime change around 1993. Since October 1992 the Bank of England has explicitly targeted inflation. The policy making process also has become more transparent due to regular publications of the Inflation Report (since 1993) and MPC Minutes (since 1997). It is therefore interesting that we find a decrease in the volatility of the new innovation series. Since the independence of the Bank of England in 1997 we find no large surprise monetary policy innovations.[18] Later we examine results for the post-92 sub-sample.

[17] We find no evidence of serial correlation in the residuals based on the ACF/PACF correlogram at a 1% significance level.

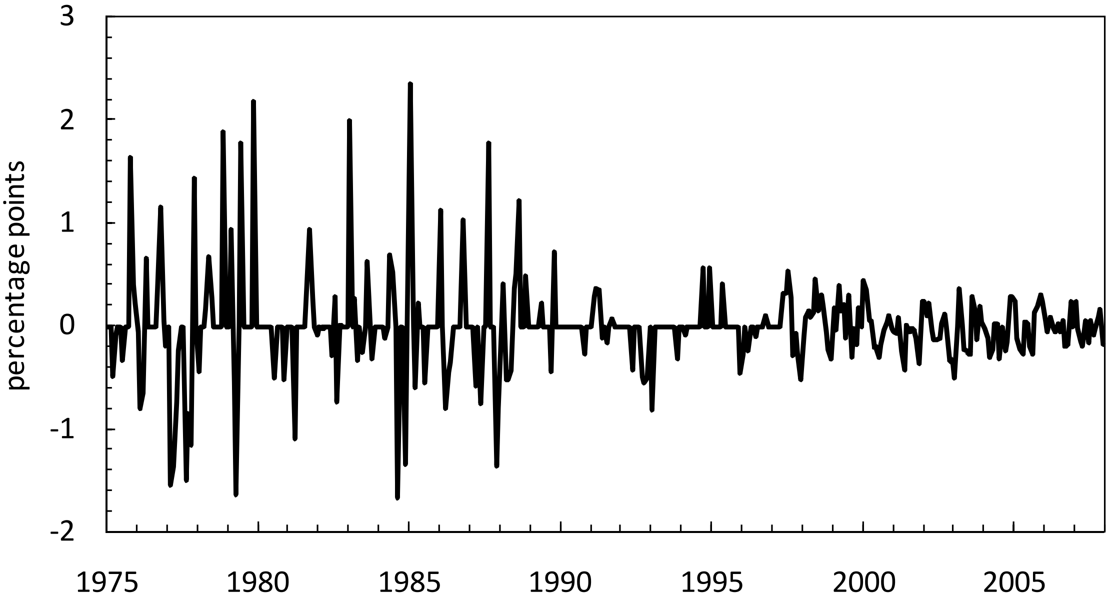
[18] Larger shocks in the first part of the sample also might reflect that the average level of Bank Rate was higher than in the second part of the sample. See also Figure 12 in Appendix B for a comparison of the exogenous Bank Rate path compared to the average Bank Rate.

Table 2: Determinants of the change in Bank Rate

Variable	Coefficient	Standard error
Constant (α)	-0.177	0.279
Initial Bank Rate (i_{t-1})	-0.002	0.026
Forecasted output growth ($\hat{y}^F_{m,i}$),		
Quarters ahead:		
-1	0.011	0.035
0	0.073*	0.041
1	0.049	0.047
2	0.019	0.060
Forecasted inflation ($\hat{\pi}^F_{m,i}$),		
Quarters ahead:		
-1	0.131**	0.065
0	-0.200*	0.104
1	0.003	0.104
2	0.099	0.075
Change in forecasted output growth ($\hat{y}^F_{m,i} - \hat{y}^F_{m-1,i}$),		
Quarters ahead:		
-1	0.061**	0.030
0	0.062*	0.033
1	0.034	0.040
2	0.077	0.049
Change in forecasted inflation ($\pi^F_{m,i} - \pi^F_{m-1,i}$),		
Quarters ahead:		
-1	0.035	0.114
0	0.354*	0.182
1	-0.208	0.169
2	0.090	0.100
Change in unemployment rate (u_{t-i}),		
Months:		
-1	-0.953*	0.496
-2	0.242	0.797
-3	0.659	0.492

Dependent variable: Change in policy target rate Δi_m. $^{*}/^{**}/^{***}$ indicate significance at $10/5/1$ per cent level. R^2 = 0.29, D.W. = 1.80, F-Statistic = 4.40, N = 235. Sample covers all Bank Rate changes over the period 1975M3 to 2007M12 that are at least two weeks apart. The estimated equation is: $\Delta i_m = \alpha + \beta i_{t-1} + \sum_{i=-1}^{2} \gamma_i \hat{y}^F_{m,i} + \sum_{i=-1}^{2} \varphi_i \pi^F_{m,i} + \sum_{i=-1}^{2} \delta_i (\hat{y}^F_{m,i} - \hat{y}^F_{m-1,i}) + \sum_{i=-1}^{2} \vartheta_i (\pi^F_{m,i} - \pi^F_{m-1,i}) + \sum_{i=1}^{3} \rho_i u_{t-i} + \epsilon_m$.

Figure 2: New monthly UK monetary policy innovations series



3.3. Predictability of the new measure of monetary policy changes

Our constructed monthly series should, in principle, be unpredictable from movements in ex-post revised data. Before proceeding, it is worth confirming this using a series of Granger causality tests. Specifically, we regress the monetary innovations m_t on a set of lagged macroeconomic variables including industrial production, inflation and the unemployment rate:

$$m_t = c + \sum_{i=1}^{I} \beta_i x_{t-i} + u_t \ . \tag{3}$$

The null hypothesis is that our new measure of monetary innovations is not predictable from lags of these macroeconomic variables. Table 3 reports F-statistics and P-values for the null hypothesis based on estimation of equation (3). With all P-values well above 25 per cent (and mostly above 50 per cent) we cannot statistically reject the hypothesis of unpredictability of the shock series. The lack of predictability is reassuring and suggests our shock series is a suitable new measure to use to identify the effect of monetary policy.

4. The effects of monetary policy

Armed with our new measure of monetary policy innovations, we estimate the effects on output and inflation for the full sample from 1975 to 2007. Given our shock series, the direct way to examine the effects of monetary policy innovations on the economy is to include our new series in an auto-regressive distributed lag model for the variable of interest. We first employ this direct approach. However, this method (being estimated in differences) implicitly

Table 3: Predictability of monetary policy innovations

Variable	I = 3 lags		I = 6 lags	
	F-statistics	P-values	F-statistics	P-values
Change in industrial production	0.34	0.80	0.66	0.68
Monthly inflation	1.04	0.38	0.82	0.55
Unemployment rate	0.00	1.00	0.50	0.81
Money growth M4	0.35	0.79	0.44	0.85
Commodity price inflation	1.32	0.27	0.81	0.57
Change in FTSE	0.52	0.67	0.59	0.74

Notes: The table reports F-statistics and P-values for the null hypothesis that all coefficients β_i are equal to zero. Data on money growth M4 are only available from 1982:6 onwards. The standard errors are corrected for the possible presence of serial correlation and heteroskedasticity using a Newey-West variance covariance matrix.

simulates a permanent shock. The wider literature on the effects of monetary policy tends to employ Vector Autoregressions (VARs), where shocks are temporary. To compare our results with this wider literature, we then follow Romer and Romer (2004) and Coibion (2012) in using our shock series in a VAR framework. For our baseline results, we prefer this latter approach for comparability across studies. Importantly, however, in Section 4.3 we show that these two approaches produce comparable results when the same shock path is simulated.

4.1. Single equation results

We first use our new shock series in an auto-regressive distributed lag framework, following Romer and Romer (2004). More precisely, we regress each macroeconomic variable (x_t) on its lags and lags of the policy innovations m_t directly estimated from the first stage:

$$\Delta x_t = c + \sum_{i=1}^{P} \beta_i \Delta x_{t-i} + \sum_{j=1}^{Q} \gamma_j m_{t-j} + \epsilon_t \,. \quad (4)$$

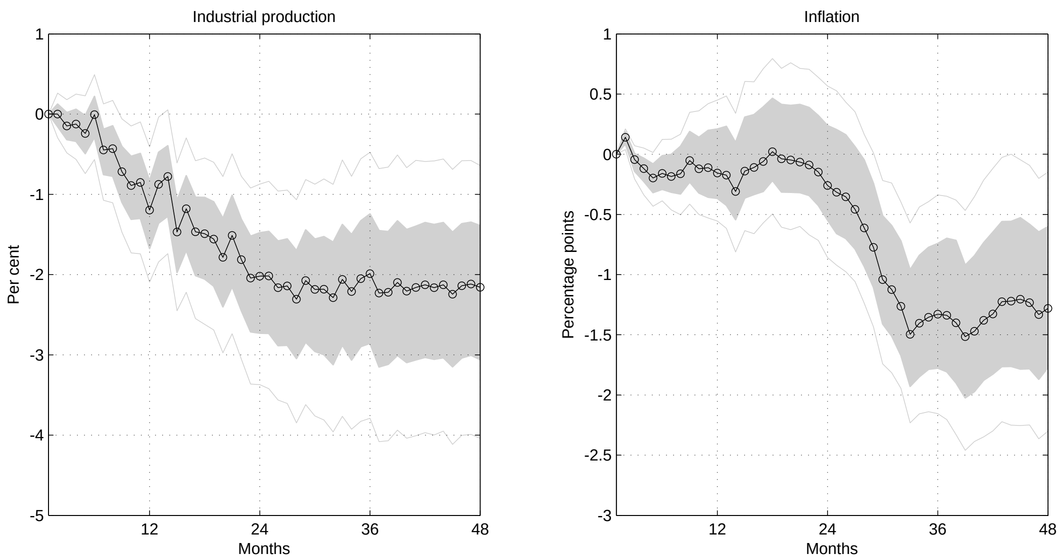
To follow Romer and Romer (2004) we assume that the shock does not contemporaneously affect the macroeconomic variable x_t. However, given the precise formulation of our first stage regression and that our forecast data do not contain the effects of the subsequent policy changes, we will argue in Section 5 that this timing assumption can actually be relaxed, yielding similar results. As mentioned above, the data are monthly. To ensure comparability with Romer and Romer (2004) we set $P = 24$ and $Q = 36$ for industrial production and $P = 24$ and $Q = 48$ for prices and inflation.

Figure 3 presents our results for the effect of a one percentage point shock to the monetary policy target rate on industrial production and inflation, as measured by the twelve month percentage change in the retail prices index (excluding mortgage interest payments, so-called RPIX). Precise data definitions are given in Appendix A. The 68 and 95 per cent confidence bands are bootstrapped using 2,000 repetitions.[19]

The first panel displays the response of industrial production. Industrial production declines after the shock and reaches a minimum of around -2.3 per cent after around 24 months. The second panel shows that inflation declines significantly by nearly 1.5 percentage points after four years. In Appendix B.2 we also show that the effect on GDP is similar to that of industrial production when using quarterly data. All these results are significant at the 95 per cent level.

The signs of all these responses are consistent with the predictions of a variety of theoretical models (e.g. Smets and Wouters, 2007) and accord well with economic intuition: contractionary monetary policy shocks generate a sizable and persistent decline in output and inflation. That said, the magnitudes are notably larger than one might have expected. Later we show that these larger magnitudes likely reflect the shock profile.

Figure 3: Single equation regressions



Notes: Impulse responses to a permanent one percentage point contractionary shock to monetary policy. Confidence bands indicate 68 and 95 per cent intervals.

4.2. Baseline Vector Autoregression results

As discussed above, the wider empirical literature on the effects of monetary policy changes typically employs vector autoregression based methods to examine the macroeconomic effect of changes in monetary policy. Romer and Romer (2004) and Coibion (2012) also consider a

[19] The bootstrapped confidence intervals are robust to a higher number of repetition, e.g. 10,000.

VAR specification where their new shock measure is used instead of the central bank's policy rate in a VAR.

One advantage of this approach is that the results will be more comparable with the wider literature. The VAR approach, as commonly implemented, considers temporary monetary policy shocks, which naturally makes comparisons of VAR studies with the magnitudes presented in the previous section more complicated. A further advantage, as noted in Coibion, Gorodnichenko, Kueng, and Silvia (2012), is that including the lagged dependent variables and controlling for other shocks may yield more precise estimates in shorter samples. The VAR framework allows us to control for the joint dynamics of other variables, including controlling for commodity prices, which has generated much debate in the literature.[20]

We consider a parsimonious VAR specification using four macroeconomic variables: the log of output as measured by industrial production (seasonally adjusted) (y_t), the 12m rate of the retail prices index excluding mortgage interest payments (π_t), a measure of commodity prices (com_t) and our new measure of monetary policy. This is the same VAR specification as in Romer and Romer (2004), with commodity prices added. While not important for our results, it will be useful to control for commodity prices for our later discussion regarding the price puzzle in standard VARs. Appendix B.3 shows that our results are robust to a larger specification, including adding unemployment and the actual policy rate. Precise data definitions are given in Appendix A.

We estimate the effects of monetary policy based on the following VAR:

$$\boldsymbol{X}_t = \boldsymbol{A_0} + \boldsymbol{A_1 t} + \boldsymbol{B(L)}\boldsymbol{X}_{t-1} + \boldsymbol{\epsilon}_t \; , \tag{5}$$

where $\boldsymbol{B(L)}$ is a lag polynomial with P lags. The vector of observables is $\boldsymbol{X}_t = [y_t, \pi_t, com_t, cum.shock_t]'$.[21]

Since conventional VARs are based on interest rates in levels (Bank Rate for the UK) we follow Romer and Romer (2004) and Coibion (2012) and cumulate our new monetary policy series ($cum.shock_t = \sum_{i=0}^{t} m_i$) and order this series last in the VAR, assuming that the non-policy variables in the VAR do not react within the month to a change in policy.[22] The data are monthly and we estimate the VAR with $P = 24$ lags. The VAR in RR includes 36 lags but their single equation regressions are based on including lags of two years for the endogenous variables. We therefore prefer to include two years of lags to estimate fewer parameters. We also experimented with different values for P and show that the results are robust (as shown

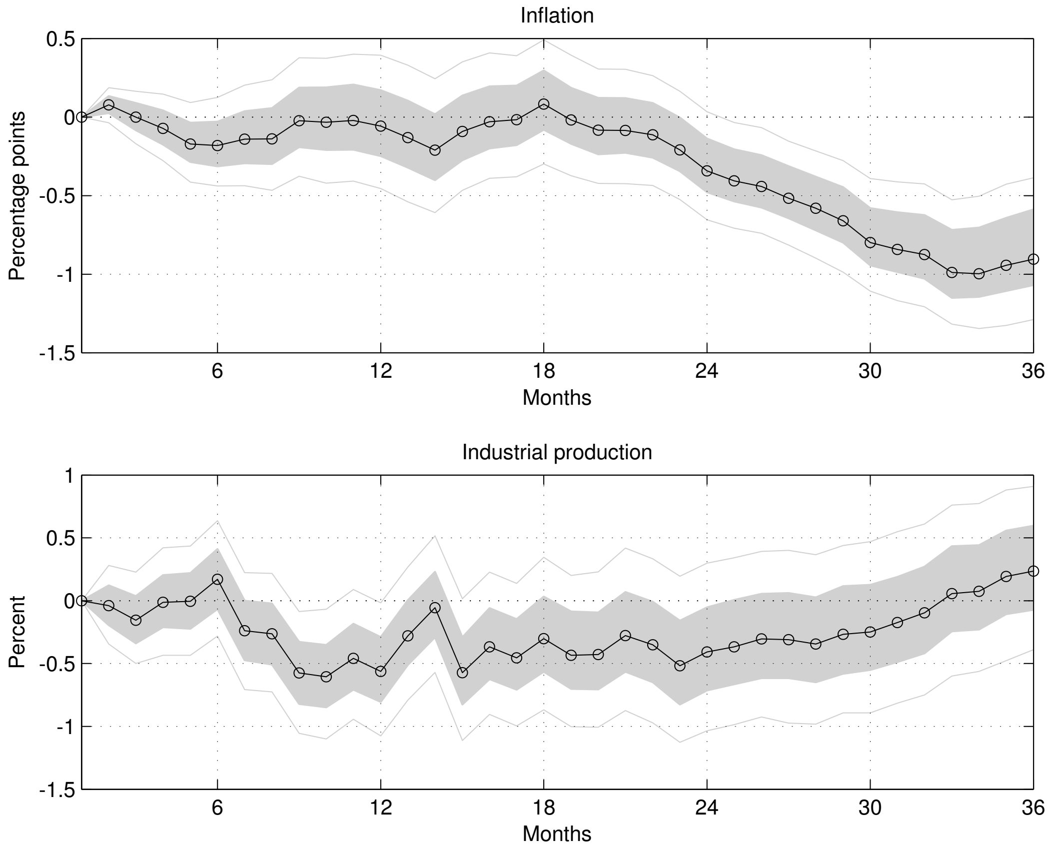
[20] If there is any residual endogeneity of the shock measure with respect to the ex-post revised data the VAR will strip this out as well.

[21] An alternative approach to using narrative shocks directly in a VAR has recently been developed by Mertens and Ravn (2013) for tax shocks. This approach treats narrative shocks as proxies for the true structural shocks in a VAR. Narrative identified tax shocks, however, are directly derived from administrative sources. The shocks in our approach are produced by a first stage regression, in this sense that are not precisely the same type of "narrative" shock as used in the fiscal policy literature.

[22] Importantly, we relax this assumption later. That said, estimating a monthly VAR as we do, the assumption is less restrictive when compared with quarterly VARs.

in the Appendix B.4). All figures below report impulse responses together with 68 and 95 per cent bootstrapped confidence intervals using 2,000 replications.

Figure 4: The macroeconomic effects of a monetary policy innovation



Notes: Impulse responses to a one percentage point contractionary monetary policy shock. VAR with industrial production, inflation rate (RPIX12m), commodity prices and our new monetary policy measure. P=24. Sample: 1975-2007. Confidence bands indicate 68 and 95 per cent intervals.

In terms of quantitative magnitudes, Figure 4 presents the main result of this paper. In response to a one percentage point positive innovation to the monetary policy target rate, the inflation rate falls by up to -1.00 percentage points.[23] Industrial production has a peak decline of -0.61 per cent. In Section 5 we show a similar effect on GDP using a quarterly version of the VAR. The drop in industrial production peaks two years after the shock. Unlike the single equation results, the industrial production response is not highly significant. That said, the response is still significant at 90 per cent between periods 9 and 12. Weaker significance may reflect the greater number of variables and parameters in the estimation relative to the more parsimonious ADL specification. Inflation does not react strongly on impact, but declines sharply 18 months after the shock, reaching its peak effect after 34 months. These results

[23] The results are robust to using the alternative price measures RPI and CPI as presented in Figure 15 in Appendix B.4.

confirm the findings from the previous section, that monetary policy contractions lead to a decline in output and inflation. The magnitudes are, however, noticeably smaller — an issue we now examine further.

4.3. Reconciling the single regression and VAR approaches

Our VAR results have the same qualitative signs as the results from the single equation regressions, but have a quantitatively smaller magnitude and a different persistence. In this section we show that these differences can largely be explained by the different implied shock paths in the two methods. Being specified in differences, simulations of equation (4) assumes that the shock to the level of the policy rate is permanent. In the VAR specification above the shock is temporary. As noted in Coibion (2012), the persistence of the shock could significantly affect the magnitudes reported from impulse response functions.

Figure 5 reproduces the VAR results from the previous section for the response of industrial production and inflation and, for reference, also shows the actual response of the policy rate.[24] In addition, we take the shock profile from the VAR and use this to simulate the single equation model in Section 4.1. The results of these ADL simulations are shown in the blue dotted lines. This procedure directly allows us to assess whether the shock path accounts for the quantitatively different results of these two approaches.

When we use this alternative shock profile in the single equation method, it is quite striking how close these two sets of results become, suggesting the two methods differ largely due to the size and dynamics of the shock. It is also worth noting that the effect on the policy rate itself is now similar across both methods. The Bank Rate response from the single equation regression lies well within the 95 per cent confidence bands of those obtained in the VAR, although it is slightly larger in the short term.[25] This, in turn may explain the slightly larger effect on industrial production using this method.

In summary, while the estimates in Section 4.1 initially seem large, this section shows they can, at least for our UK results, be reconciled with the VAR estimates. Since VARs are dominant in the wider empirical literature, we prefer to cite our VAR-based results as the baseline estimates.

4.4. Comparison to the literature

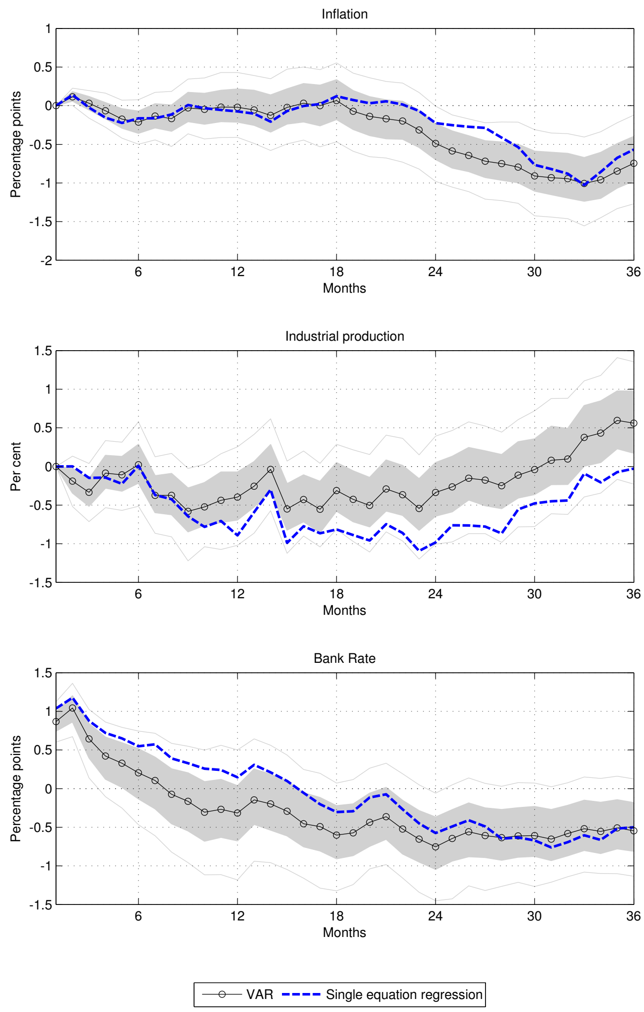
4.4.1. Other studies

In comparing our results to the literature, it is worth first discussing how our findings compare to Romer and Romer (2004) for the US. While the original data set is based on the sample from

[24] In the VAR case, the policy rate is added to the VAR as the final variable, implying that our shocks affect the policy rate immediately.

[25] In contrast the Bank Rate response in the single regression to a permanent policy rate shock is highly persistent and well outside the 95 confidence bands of the Bank Rate response in the VAR (not shown in figure).

Figure 5: VAR shock path in the single equation approach



Notes: Impulse responses to one percentage point contractionary monetary policy shock. Confidence bands indicate 68 and 95 per cent intervals.

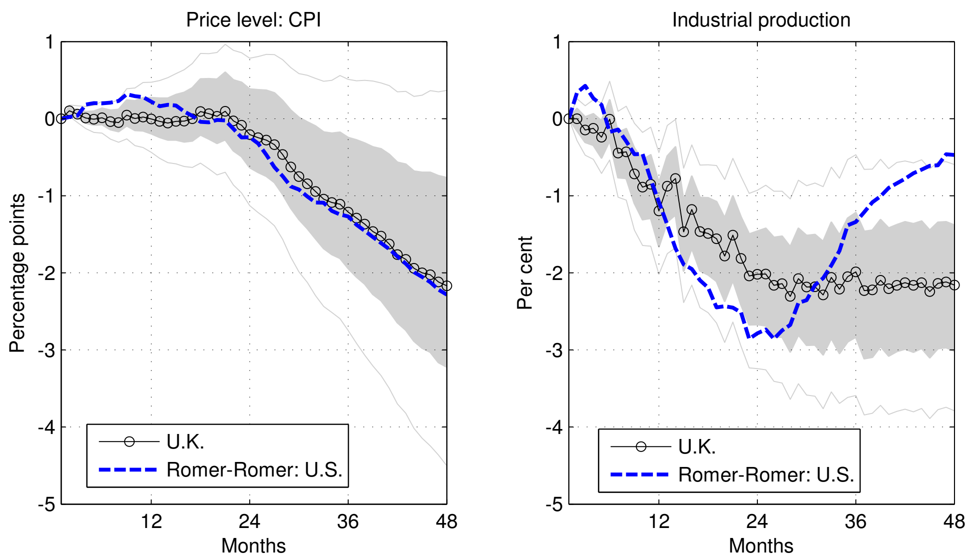
1969 to 1996 we have extended the RR shock series up to 2007.[26] To exactly compare to the UK results we use the same sample period, i.e. from 1975 to 2007, for both countries.[27] Comparing the single equation results, Figure 6 shows that our findings are very similar to those for the US following the RR method.

It is noteworthy that the industrial production response for the US is largely within the 95 per cent confidence bands of the UK industrial production response. In both countries the peak decline is reached after around two years, although in the US industrial production returns faster towards zero.

[26] Due to a publication lag of five years US Greenbook forecasts are currently available until December 2007.
[27] Extending the US sample to 1969-2007 does not alter the results.

Published long run prices data in the UK are not seasonally adjusted and, when seasonally adjusting these data ourselves, these data lead to noisier estimates than using 12 month RPIX inflation used above.[28] However, to be directly comparable with the RR results for the US, we compare the response of the price level. The dynamics and the magnitude of the response of consumer prices in the US almost exactly matches the estimated price dynamics for the UK. It is also remarkable that the price response is relatively small for both countries in the first two years, but falls significantly thereafter.[29]

Figure 6: Single equation regressions for the UK and the US



Notes: Impulse responses to a permanent one percentage point contractionary monetary policy shock. Confidence bands indicate 68 and 95 per cent intervals.

There is, of course, a wider literature on the empirical effects of monetary policy using VAR methods (such as the recursive method of Christiano et al. (1996) or sign-restrictions discussed in the introduction). Much of this research has been for the US but there exists a smaller range of VAR studies for the UK.

For the UK, Dedola and Lippi (2005) also report a fall of around 0.5 per cent in industrial production. Mountford (2005) and Mumtaz et al. (2011) find that GDP falls by 0.6 and 0.5 per cent respectively. These results are in line with our findings. However, there is much more disparity in the estimated response of inflation and prices. For example, in Dedola and Lippi (2005), the price level rises following a monetary contraction. Below we also show a 'price

[28] In the comparison to the US we use the consumer price index for both countries as the UK producers price index is not available for our full sample.

[29] As a further comparison, we examine whether the US single equation regression also produces similar results to the UK VAR once we make use of the shock profile implied by the VAR. We find that the peak effects for the US are then in line with the VAR results reported in the previous section for the UK (see Appendix B.5).

puzzle' exists using the recursive identification methodology in a conventional VAR with Bank Rate as the policy variable (rather than our series).

Most studies conducted for the US and other countries also find that real activity as measured by industrial production or total output declines between 0.5 and 1 per cent to a one percentage point increase in the interest rate. A concise overview of key studies can be found in Table 4.

In summary, the main conclusion we draw from this wider literature is that our shock series produces results for the UK that are of the order of magnitude found by other VAR-based methods in the literature. Furthermore, we have shown that the larger estimates from our single equation specification can be reconciled with these magnitudes.

Table 4: The effects of monetary policy innovations in previous studies

Authors	**Country**	**Method**	**Peak Effects (in %)**	
			Output	**Prices/Inflation**
Romer and Romer (2004)	US	narrative	-1.9 to -4.3 (IP)	-3.6 to -5.9 (CPI/PPI Level)
Coibion (2012)	US	narrative	-1.6 to -4.3 (IP)	-1.8 to -4.2 (CPI)
Dedola and Lippi (2005)	UK	VAR	-0.5 (IP)	0.2 (CPI Level)
Mountford (2005)	UK	sign-restriction	-0.6 (GDP)	-0.15 (GDP defl.)
Mumtaz et al. (2011)	UK	FAVAR	-1.0/-2.0 (IP, 75-91/92-05)	-0.3/-2 on CPI (75-91/92-05)
			-0.5/-0.5 (GDP,75-91/92-05)	
Bernanke and Mihov (1998)	US	VAR	-0.6 to -1 (GDP)	-0.7 to -1.6 (GDP defl.)
Christiano et al. (1999)	US	VAR	-0.7 (GDP)	-0.6 (GDP defl.)
Bernanke et al. (2005)	US	FAVAR	-0.6 (IP)	-0.7 (CPI)
Uhlig (2005)	US	sign-restriction	-0.8 to 0.8 (GDP)	-0.4 (GDP defl.)
Barakchian and Crowe (2013)	US	Fed Futures data	-0.9 (IP)	-0.1 (CPI)

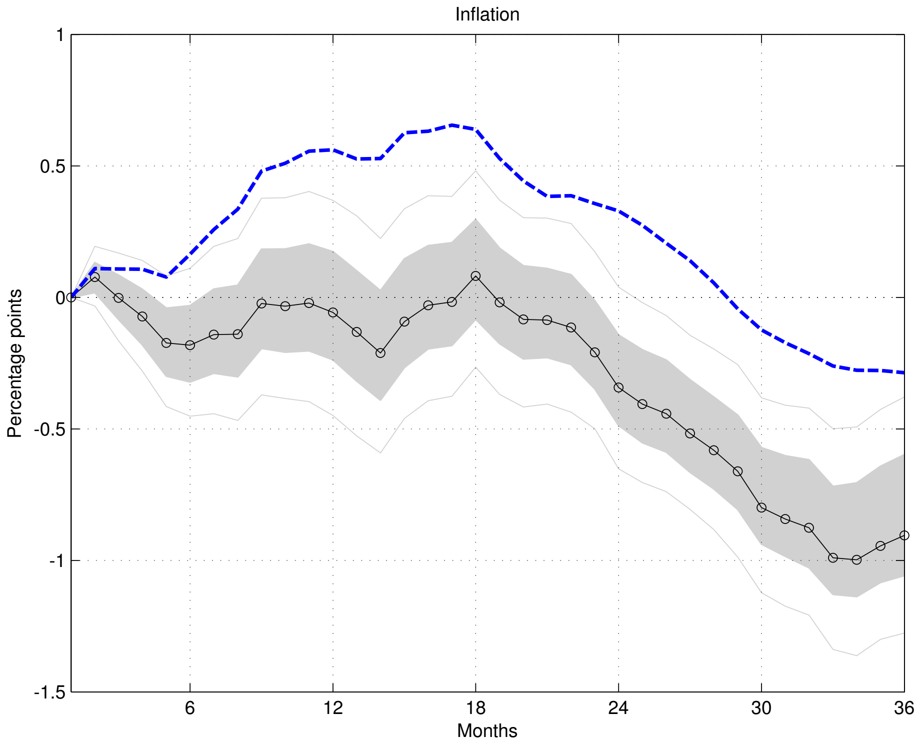
Notes: The results from previous studies listed in the table are from impulse responses displayed in these papers. We computed implied peak effects to a one percentage point increase in the interest rate. In brackets we report the specific output and price measure, where IP denotes industrial production. Coibion (2012) presents a range of exercises and magnitudes. These are taken from Coibion (2012) Table 2, reporting the baseline specification results using a VAR and ADL model. The US narrative results are for the Romer and Romer (2004) sample 1969-1996.

4.4.2. The price puzzle

Conventional VARs which employ observed interest rates and the recursive identification strategy of Christiano et al. (1996, 1999) often generate a substantial and persistent price puzzle — a monetary policy tightening is followed by an increase in the price level and/or inflation rate. This observation, first documented in Sims (1992) and dubbed the 'price puzzle' by Eichenbaum (1992), has raised doubts about the recursive identification scheme, being at odds with conventional intuition and theory. A large literature has proposed various methods to resolve this puzzle, such as expanding the VAR with oil prices and commodity prices or to use FAVARs. The motivation behind these approaches is that conventional VARs do not contain enough observables to capture the information actually available to policymakers and driving the changes in interest rates.

For the UK economy, we also find that a VAR with Bank Rate as the policy instrument (rather than our measure) and employing the recursive identification assumption produces a large and persistent price and inflation puzzle.[30] As a robustness check we add a variety of extra variables to this VAR including oil prices, unemployment, money supply and various exchange rate measures. However, adding these variables does not solve the UK price puzzle. Figure 7 shows the inflation response to a one percentage point increase in Bank Rate in our baseline VAR (dashed line) and compares it to the response based on our new series. Using the standard recursive method, the inflation response is positive for around two years and lies outside of the 95 per cent confidence intervals of our baseline results.[31]

Figure 7: Response of inflation in VAR with the new innovation measure vs. a conventional, recursive VAR with Bank Rate



Notes: Impulse responses to a one percentage point contractionary monetary policy shock. VAR with industrial production, inflation rate (RPIX12m), commodity prices and shock measure. P=24. Sample: 1975-2007. The circled line is the inflation response based on the new shock measure together with the respective confidence bands. The dashed line is the inflation response based on a conventional, recursive VAR with Bank Rate. Confidence bands indicate 68 and 95 per cent intervals.

Romer and Romer (2004) also document a large price puzzle for the US using the conventional recursive VAR methodology and show that their new shock measure solves this issue. It therefore seems a robust feature of both the US and UK that applying the narrative identification strategy resolves the puzzling results in conventional VAR studies.

[30] In our procedure, we replace Bank Rate in the VAR specification with our new monetary shock measure.
[31] Appendix B.6 shows the response of inflation in the recursive VAR, together with standard errors.

5. Robustness and extensions

5.1. Alternative timing assumptions

So far we have followed the previous literature (Christiano et al., 1996, 1999; Romer and Romer, 2004; Coibion, 2012) imposing that the policy change does not contemporaneously affect macroeconomic variables. We relax this assumption for the following reason. The regressors in the first stage regression capture the real-time information set of policymakers prior to the policy rate decision. As discussed, we carefully ensure that the forecasts do not include the consequences of the policy change. If we have correctly captured the information set that policymakers used to form their decision, our new measure m_t should be contemporaneously exogenous. Rather than assuming movements in policy do not contemporaneously affect other variables in the second stage VAR, we should, in principle, be able to relax this assumption.

We therefore estimate our baseline VAR with the new monetary policy measure ordered first in the recursive ordering. This implies that contemporaneous macroeconomic fluctuations do not affect the policy decision other than via the forecasts. This seems reasonable given the discussion above. We can now identify the contemporaneous effects of our monetary policy changes.

Panel A of Figure 8 presents the results based on this new identification assumption (blue dashed line). Our results are virtually identical, suggesting that the effects of monetary policy are indeed very protracted, building up slowly over time.

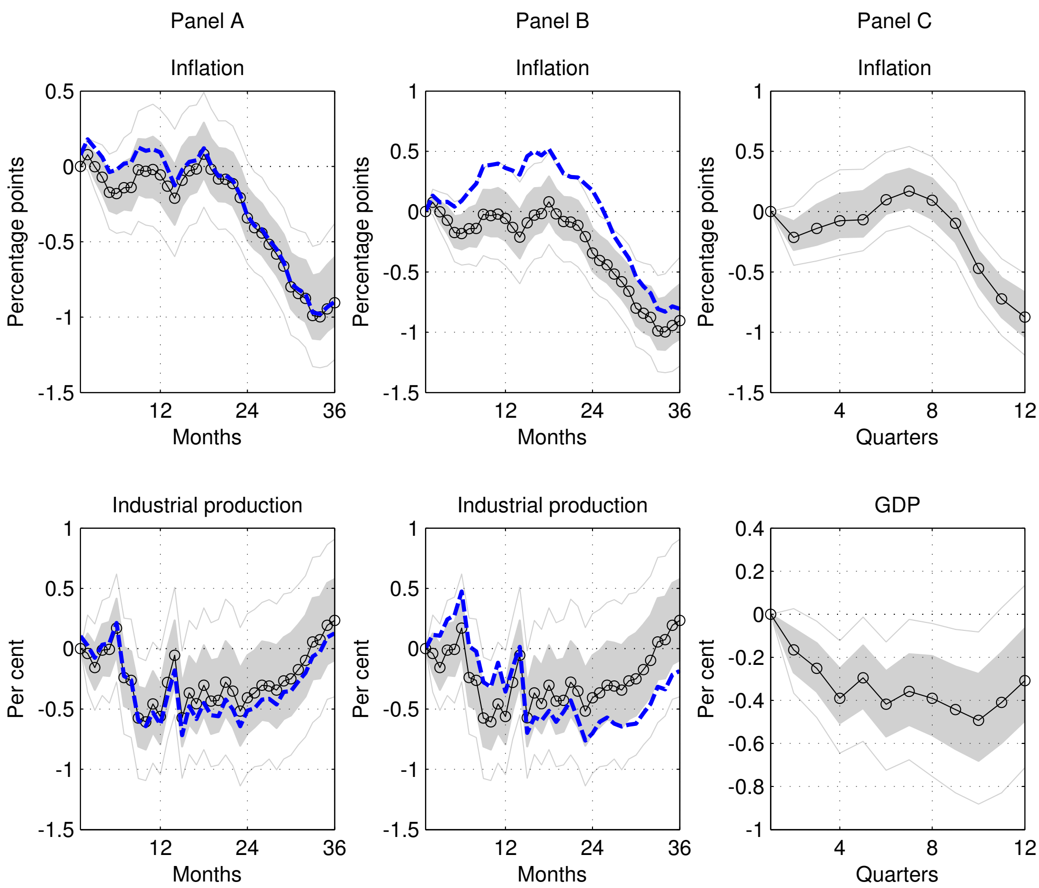
5.2. Do the forecasts matter?

Previously we argued that forecasts provide summary statistics of the policymakers' information set. Forecasts also allow us to control for policy reactions designed to offset future business cycle movements. If policy did not respond to forecasted conditions, or if the VAR already contains sufficient information to make their inclusion redundant, excluding the forecasts from our first stage regression would not alter our baseline results. To examine this possibility we estimate the first stage regression only including lagged real-time variables. Panel B in Figure 8 shows the results of this exercise. With forecasts excluded we find a substantial and pronounced price puzzle and the industrial production response is slightly stronger. These findings suggest that policymakers do respond to anticipated movements in the macroeconomy and that this information is not adequately summarised by conventional macroeconomic variables used in VARs.

As a further experiment, we estimate the first stage regression excluding real-time backdata and forecasts of the current period.[32] Interestingly, the dynamics are very similar to our baseline results in Section 4. It is therefore the inclusion of the forecasts that seems key for removing the price puzzle.

[32] In practise, we estimate equation (2) with the forecast horizon $i = 1, 2$ instead of $i = -1, 0, 1, 2$.

Figure 8: Robustness to timing assumptions, excluding forecasts and quarterly GDP data



Notes: Impulse responses to a one percentage point contractionary monetary policy shock (dashed line) of alternative specification compared to baseline specification (circled line) with corresponding 68 and 95 per cent confidence intervals. The baseline specification uses industrial production, RPIX12m inflation, commodity prices, and our shock measure. Panel A: non-recursive VAR allowing for contemporaneous effect (dashed line). Panel B: first stage regression with only lagged variables (dashed line). Panel C: quarterly VAR with GDP.

In a related contribution, Castelnuovo and Surico (2010) provide compelling evidence that the omission of expected inflation in a VAR can account for the price puzzle in indeterminate monetary regimes. In essence excluding forecasts causes omitted variable bias and the empirical evidence for the UK economy in this section is in line with their finding.

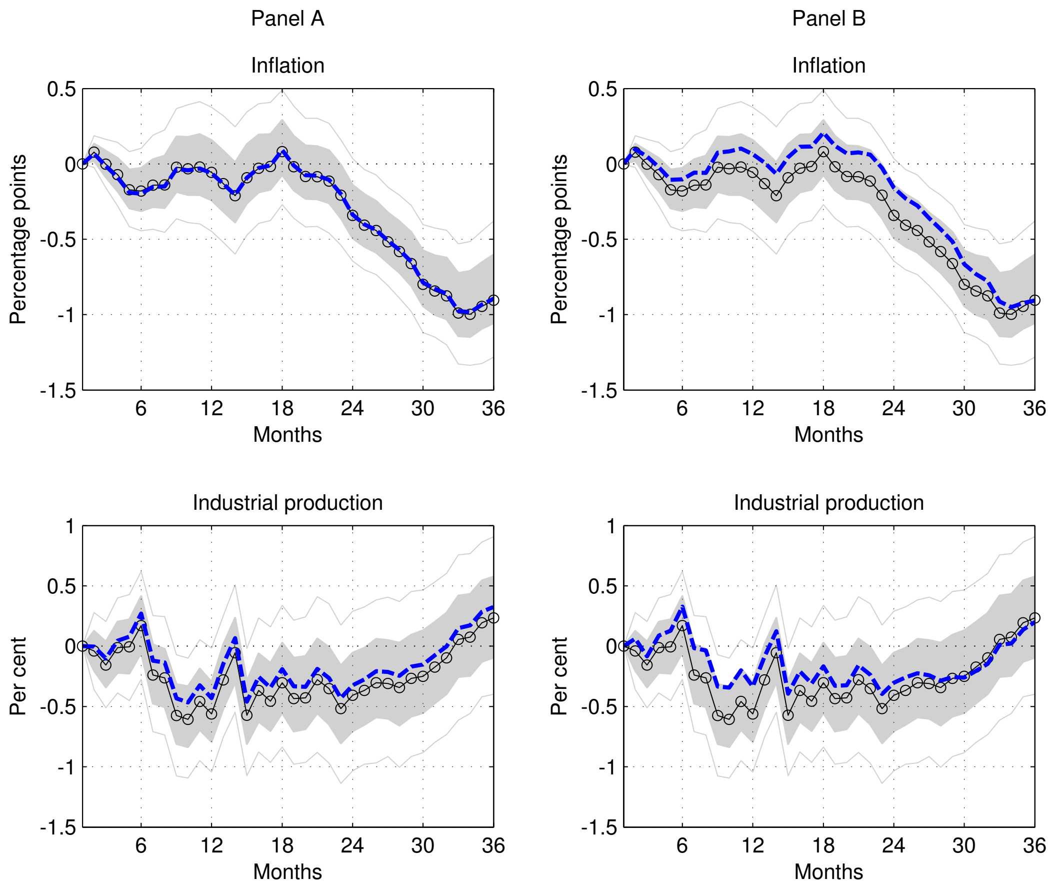
5.3. Quarterly VAR with GDP

In earlier sections we used industrial production as our measure of output. This is useful because it is available monthly and correlates strongly with GDP. To provide an estimate of how strongly monetary policy innovations affect the total economy, as measured by GDP, we estimate a quarterly VAR with National Accounts data.[33] In line with our baseline results the

[33] We include GDP, RPIX inflation, commodity prices and our new measure cumulated to a quarterly series.

peak decline in inflation is 0.88 percentage points (see Panel C in Figure 8). GDP significantly falls below zero to a minimum of -0.5 per cent, slightly smaller than the effect on industrial production found earlier. A smaller peak effect on GDP as compared to industrial production is in line with the UK result of Mumtaz et al. (2011). The GDP response is more clearly significant at 95 per cent than the industrial production results, although the standard errors remain wide. For completeness, Appendix B.2 shows the response of GDP using the single equation method.

Figure 9: Robustness to including extra first stage regressors and using NIESR forecasts



Notes: Impulse responses to a one percentage point contractionary monetary policy shock (dashed line) of alternative specification compared to baseline specification (circled line) with corresponding 68 and 95 per cent confidence intervals. The baseline specification uses industrial production, RPIX12m inflation, commodity prices, and our shock measure. Panel A: first stage regression includes lagged money supply M0, US Dollar-Sterling exchange rate, DM (Euro)-Sterling exchange rate (dashed line). Panel B: using only NIESR forecasts (dashed line) in first stage regression.

5.4. Expanding the first stage: money supply and exchange rates

Although inflation targeting has been the stable policy regime since 1993, there have been a number of other policy environments since 1975. Monetary targeting was emphasised in the early 1980s and stricter control of the money supply had begun in the late 1970s. In addition, during the latter half of the 1980s the UK began shadowing the Deutsche Mark as a forerunner to the UK joining the European Exchange Rate Mechanism, which it then was forced to leave in 1992.

Batini and Nelson (2009) argue that short-term interest rates have consistently been used as the policy instrument even throughout these earlier periods of UK monetary policy. Nonetheless, to examine whether these extra objectives affected the setting of the policy target rate, we expand the variables in the first stage regression to include lagged money supply (M0) as well as the US Dollar-Sterling exchange rate and the Deutsche Mark/Euro-Sterling exchange rate.[34] Panel A of Figure 9 shows that our baseline results are largely unaffected by the inclusions of these extra variables.

5.5. Private sector forecasts

A possible concern is whether NIESR forecasts (for periods where official forecasts were unavailable) are suitable substitutes for official forecasts. Ideally we would like to have used official forecasts for the full sample, but these were unavailable further back. Previously we noted that NIESR and Bank of England forecasts are highly correlated at short forecast horizons. Moreover, if private sector forecasts are a good proxy for official forecasts we should expect very similar results using NIESR forecasts in our first stage regression for the full sample. To investigate the validity of employing private forecasts, we therefore estimate the first stage regression using only NIESR data. Panel B in Figure 9 shows that the impulse responses based on NIESR data (in the blue dashed lines) for the full sample are almost identical and lie well within the 95 per cent confidence bands of our baseline results (solid line). The results are virtually unchanged suggesting that NIESR forecasts are indeed a useful econometric proxy for the policymakers' own forecasts.

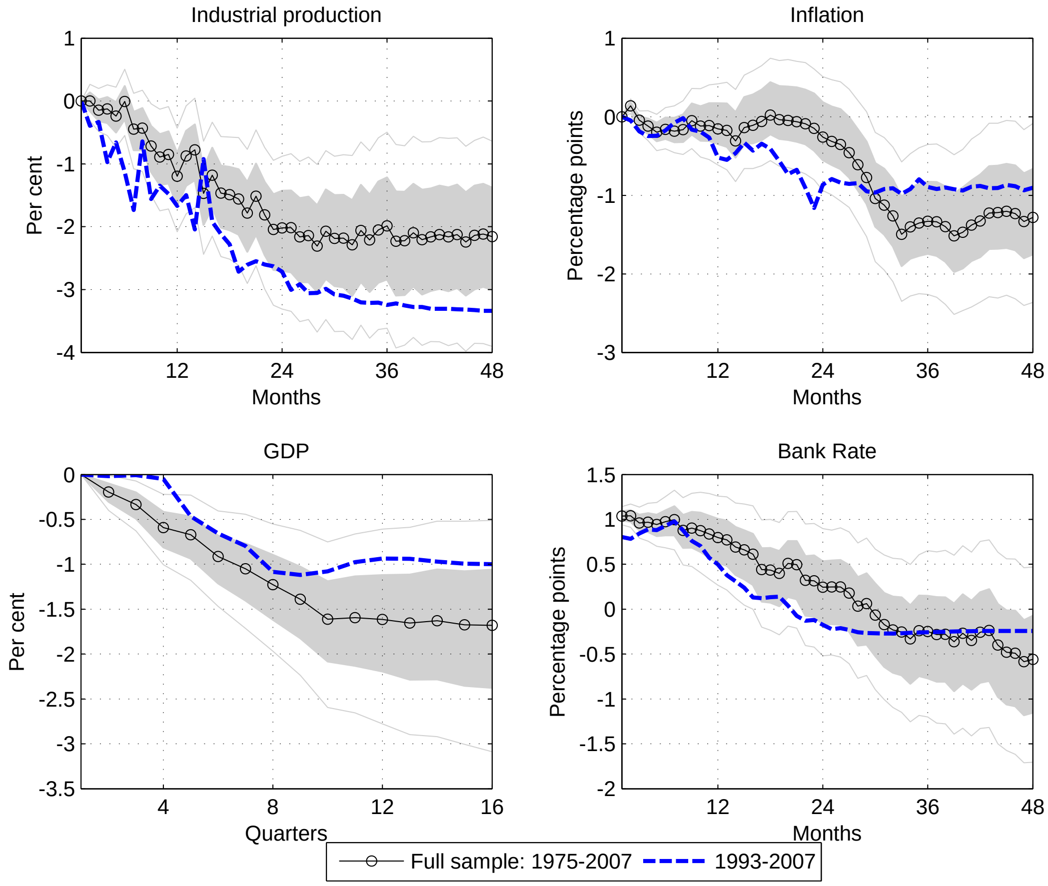
6. Effects of monetary policy under inflation targeting

After leaving the European Exchange Rate Mechanism in the autumn of 1992, the UK established an official inflation target. From 1992 until the recent crisis, the UK economy experienced low and stable inflation together with consistent positive output growth.[35] The inflation targeting period is also reflected in our monetary policy shock series: the volatility of the series clearly decreases after the early 1990s. An interesting question, therefore, is whether the effects of monetary policy after-1992 change markedly from the effects we find using the full sample.

[34] Clarida, Gali, and Gertler (1998) estimate policy rules for several countries, among these for the UK economy, and include the Sterling-Deutsche Mark exchange rate as a relevant regressor.

[35] In the US, this period of low aggregate volatility has been dubbed the Great Moderation in the literature (e.g. Benati and Surico, 2009; Boivin and Giannoni, 2006; Mavroeidis, 2010).

Figure 10: The effects of monetary policy under inflation targeting



Notes: Impulse responses to a permanent one percentage point monetary policy shock. Confidence bands indicate 68 and 95 per cent intervals. Samples: 1993-2007 and 1975-2007. Confidence bands indicate 68 and 95 per cent intervals.

To generate a specific post-1992 shock series, we re-estimate our first stage regression only on the post-inflation targeting period.[36] We then use this series in the second stage regressions employed in Section 4.[37]

Figure 10 shows the results of repeating the single equation regressions considered in Section 4.1.[38] The figure shows the original full sample estimates, together with the new post-1992 results in the dashed blue lines. As before, the GDP results come from a quarterly version of the regression. The inflation response is faster and has a slightly smaller peak effect by the

[36] Results of the predictability tests are shown in Appendix C.1. For the post-1992 sample our dataset also contains forecasts for output and inflation more than two quarters ahead. As the results do not change, to remain comparable with the previous literature we prefer our baseline specification employing up to two quarter ahead forecasts. Even when including up to six quarter ahead forecasts, the results are very similar.

[37] Because we have halved the sample size, we employ half the lags in the regressions in this second compared to the full sample.

[38] Results obtained using the VAR are shown in Appendix C.4. Again, the inflation response is faster and the industrial production reaction is slightly larger than in the full sample, although neither response is highly significant.

third year in the post-92 sample. However, this suggests the overall effect on the price level is similar across the two samples. The response of GDP is a bit smaller, at around 1 per cent rather than 1.5 per cent. However, the industrial production response is larger. Although the point estimates differ somewhat, all of these responses are within the 95 per cent confidence intervals of the full sample results. [39]

Given the change in the monetary regime, the response of the economy is likely to be affected by the conduct of monetary policy following the initial contraction. The fourth panel of Figure 10 shows this to be the case. After 1992 the policy rate decreases more quickly, suggesting that monetary policy acted more quickly to offset the contractionary effect of the initial innovation over time. This also suggests that conditional on the subsequent policy reaction the overall effect of a monetary policy contraction on prices and GDP is similar to the full sample results.

The paradox of more stabilising monetary policy is that, in reducing volatility, it may become harder to precisely identify the effects of monetary policy on the economy. Furthermore, any innovations would be more quickly offset, making it more challenging to identify the effects in our later sample period. Mirroring this logic, the results after 1992 are not very significant as shown in Appendix C.3. This partly reflects the smaller sample but, as noted above, it could also be driven by the diminished volatility of interest rates and policy surprises after 1992. However, this does not mean that monetary policy was ineffective post-1992, in fact quite the opposite.

Our points estimates — and the results in Mumtaz et al. (2011) — suggest GDP effects that are similar pre- and post-1992. That said, unlike in the full sample, the results for industrial production do not seem to provide a precise quantitative guide to the effect on GDP post-1992.[40] Turning to our results for inflation, although our peak inflation effect post-1992 is smaller than the results in Mumtaz et al. (2011), they also find that the response of inflation is faster in the more recent period. Furthermore, given the dynamics of inflation in Figure 10, the overall effect on the level of prices appears similar in both samples.

7. Conclusion

Identifying exogenous variation in monetary policy is challenging. This paper tackles this issue for the UK by applying the identification strategy of Romer and Romer (2004). While numerous studies employ more conventional VAR methodologies, to our knowledge, there has been no other application of this so-called narrative strategy to corroborate the large effects found for the US economy. Moreover, there is comparatively little evidence of the macroeco-

[39] As in the full sample, our new measure of monetary policy innovations ensures a negative response of inflation after 1992, contrary to the conventional VAR results shown in Appendix C.2. That said, while the inflation response is positive using a conventional VAR, this post-1992 price puzzle is insignificant.

[40] This may reflect the diminished contribution of industrial production to GDP in recent decades.

nomic effects of monetary policy for the UK economy.

The UK is an excellent country for this new study: the Bank of England's policy rate *is* the intended target rate and there is a wealth of UK real-time and forecast data available. We construct a new, extensive real-time forecast database and carefully match these data to relevant Bank Rate decision. We therefore reconstruct the policymakers' information set prior to the policy change, allowing us to identify monetary policy innovations from a first stage regression.

Armed with our new measure of monetary policy innovations we estimate the effects of monetary policy on the macroeconomy. In our baseline VAR, a one percentage point tightening leads to a maximum decline in output of 0.6 per cent and a fall in inflation of 1.0 percentage point after two to three years. Monetary policy changes have a protracted effect on the economy. Our results also suggest that GDP responds by a comparable magnitude as industrial production — around 0.5 per cent at the peak.

The Romer and Romer (2004) narrative results for the US generated considerable discussion given the large effects found. Also employing this narrative approach, we find similar effects of monetary policy for the UK and the US. Differences between our ADL and VAR results are also shown — at least for the UK — to result largely from different paths for the policy shock. Once we control for these effects we find our estimates are in line with the magnitudes reported in the wider VAR literature.

However, the VAR literature that relies on a commonly employed recursive ordering exhibits a large price puzzle in the UK. This occurs even after controlling for a range of other variables, including commodity prices. In keeping with RR, we are able to resolve the price puzzle for the UK and we show that the narrative approach employed here, in particular the use of forecast data, is crucial for this result.

The effect of changes in monetary policy continues to be keenly debated, both in academic and policy circles. At the Jackson Hole conference on 28 August 2010, Deputy Governor of the Bank of England Charles Bean argued that in times of financial stress asset purchases are a suitable last resort at the zero lower bound, but there are reasons to primarily rely on short-term interest rates in normal times (see Bean et al., 2010). It therefore seems likely that interest rates will remain a key tool of monetary policy in the future as economies recover from the Great Recession. Our new estimates therefore contribute to this ongoing debate. In doing so, we provide a rich new data set and a new monetary policy innovations measure for the UK. We hope both will provide exciting scope for future research.

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A. Data appendix

Table 5: Data sources

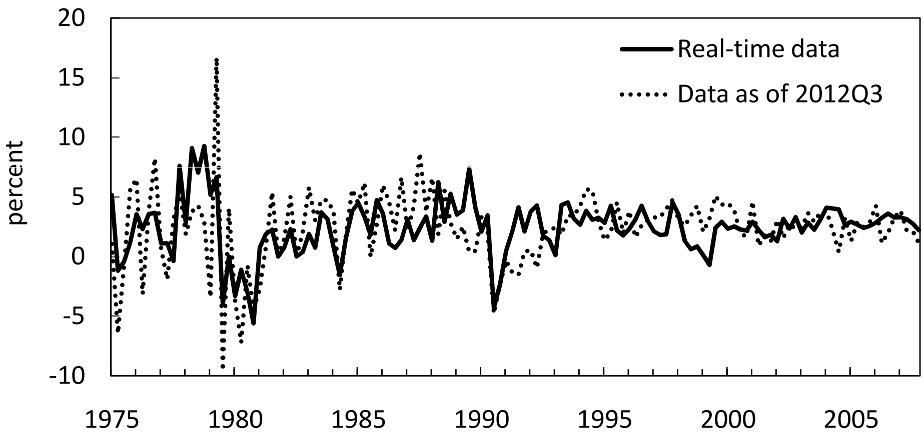
Variable	Source	Description	Series
Output	ONS	GDP seasonally adjusted (S.A.)	ABMI
Industrial production	ONS	Covers manufacturing, mining and quarrying and energy supply (S.A.)	CKYW
Inflation (RPIX)	ONS	Annual change in Retail Price Index excluding mortgage interest payments	CHMK
Inflation (RPI)	ONS	Annual change in Retail Price Index	CHAW
Inflation (CPI)	ONS	Annual change in Consumer Price Index	D7BT
Interest rates	Bank of England	Bank Rate / Minimum Lending Rate / Repo Rate / Official Bank Rate	"Official Bank Rate history"
Unemployment rate	ONS	Unemployment rate (Age 16 and over). Claimant count and ILO measure (S.A.)	MGSX
Money supply M0	Bank of England	Monthly average amount outstanding of total sterling notes and coin in circulation, excluding backing assets for commercial banknote issue in Scotland and Northern Ireland (S.A.)	LPMAVAB
Exchange rates Sterling/USD	Bank of England	Spot exchange rate, USD into Sterling (monthly average)	XUMAUSS
Exchange rates Sterling/Euro	Bundesbank	Spot exchange rate Euro into Sterling (monthly average)	BBK01.WT5627
Exchange rates Sterling/DM	Bundesbank	Spot exchange rate DM into Sterling (monthly average)	BBK01.WT5005
Effective exchange rates	Bank of England	IMF-based effective exchange rate index (1975-2006), thereafter effective exchange rate index. (monthly average, S.A.).	XUMABK82; XUMAGBG
Commodity price index	IMF	IMF Commodity price index converted to Sterling (S.A.)	

Table 6: Variables of real-time forecasts data set

Variable	Source	Description	Available period
Real GDP growth	IR	Annualised quarterly real GDP growth rates (S.A.)	1997-08
RPIX	IR	Annual RPIX inflation rate	1993-03
HCPI	IR	Annual HCPI inflation rate	2003-08
Real GDP growth	NIESR	Annualised quarterly real GDP growth rates (S.A.)	1975-08
RPI/RPIX	NIESR	Annual RPIX inflation rate	1987-08
HCPI	NIESR	Annual HCPI inflation rate	1999-08
GDP Deflator	NIESR	Annualised quarterly GDP deflator	1987-08
Consumer price defl.	NIESR	Annualised quarterly consumer price deflator	1975-89
Effective exchange rate	NIESR	Annualised quarterly exchange rate growth rate	1975-08
Unemployment rate	NIESR	Annual unemployment rate (ILO rate after 98Q3) (S.A.)	1987-08
Trade Balance/GDP	NIESR	Trade balance-GDP ratio (S.A.)	1992-08

Notes: If available we collected up to eight quarters forecasts and eight quarters backdata amounting to 17 observations for each variable including the real-time estimate of the contemporaneous quarter.

Figure 11: Real-time and revised data for annualised real GDP growth

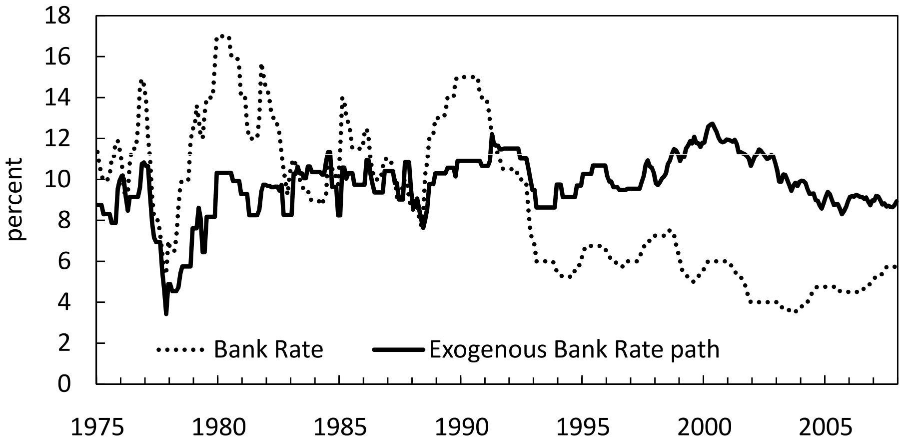


Notes: Real-time data is the nowcast based on NIESR (1975-1993) and Inflation Report (1993-2007).

B. Further results

B.1. A comparison with Bank Rate

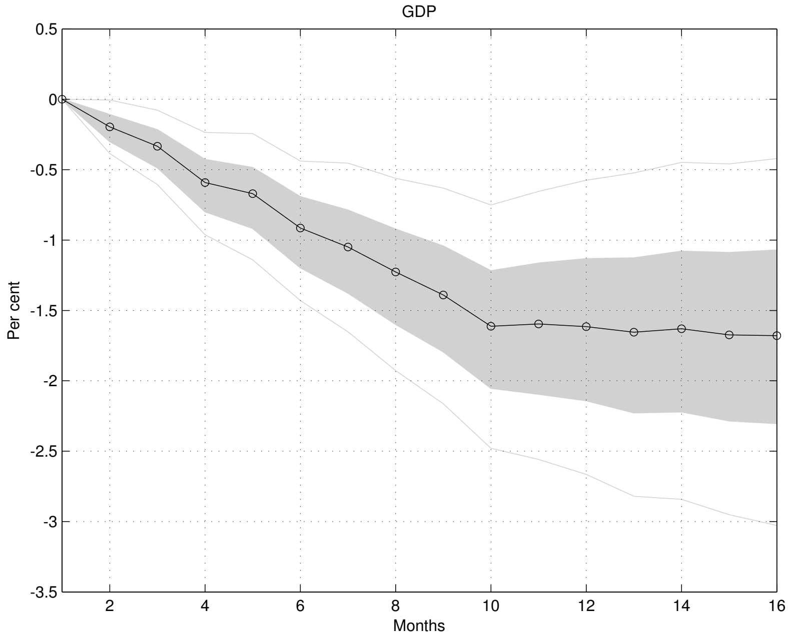
Figure 12: Cumulated shock series and actual Bank Rate



Notes: Exogenous Bank Rate path is the cumulated shock series adjusted for the average Bank Rate.

B.2. Quarterly single equation results

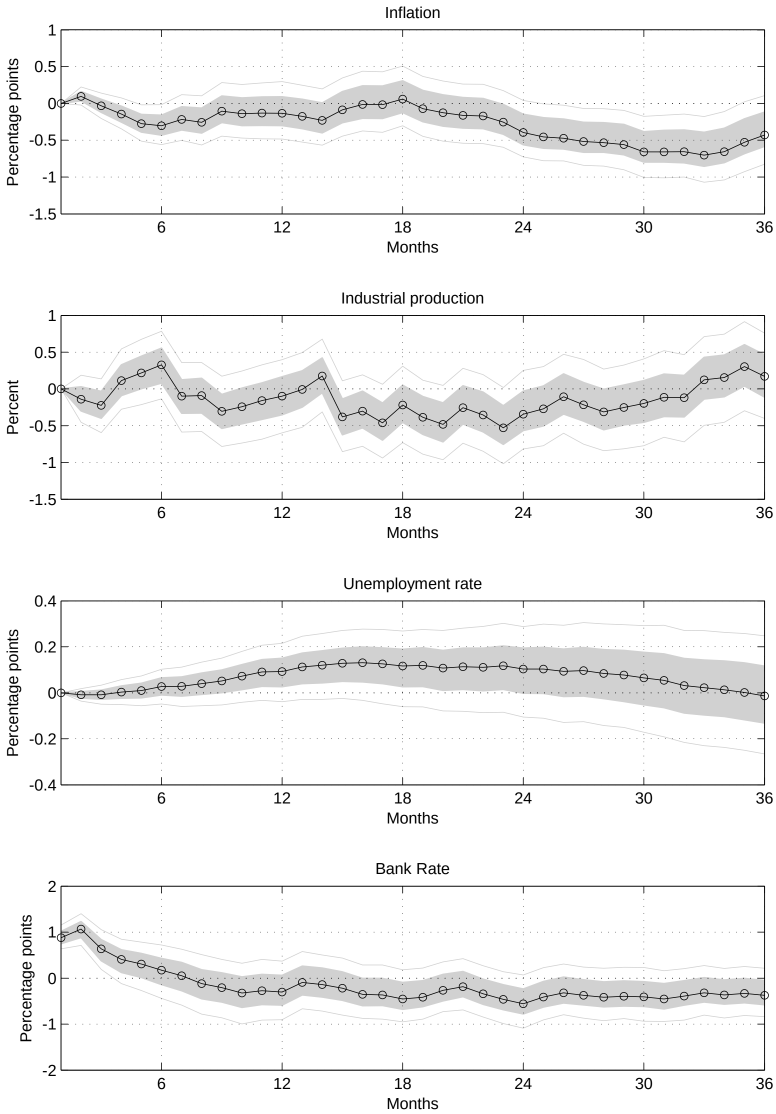
Figure 13: Single equation regression



Notes: Impulse responses to a permanent one percentage point contractionary monetary policy shock with corresponding 68 and 95 per cent confidence intervals. GDP series P=8, Q=12. Full sample 1975-2007.

B.3. Results from a larger VAR

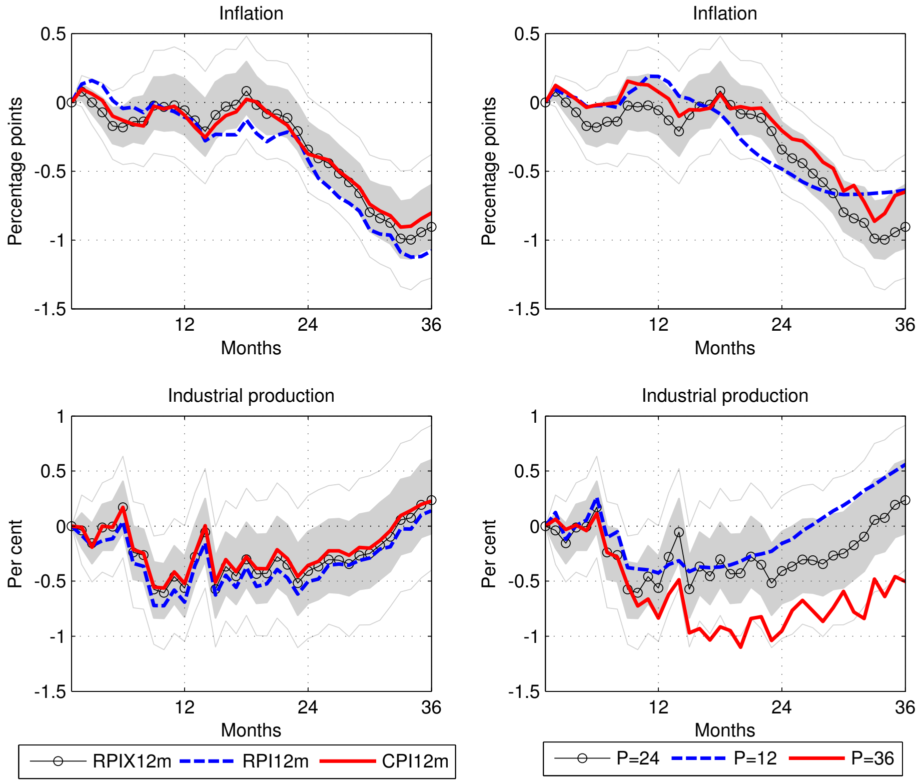
Figure 14: Large-scale VAR



Notes: Impulse responses to a one percentage point contractionary monetary policy shock with corresponding 68 and 95 per cent confidence intervals. The specification uses industrial production, RPIX12m inflation, unemployment rate, commodity prices, our new cumulated shock measure and Bank Rate.

B.4. Lag length sensitivity

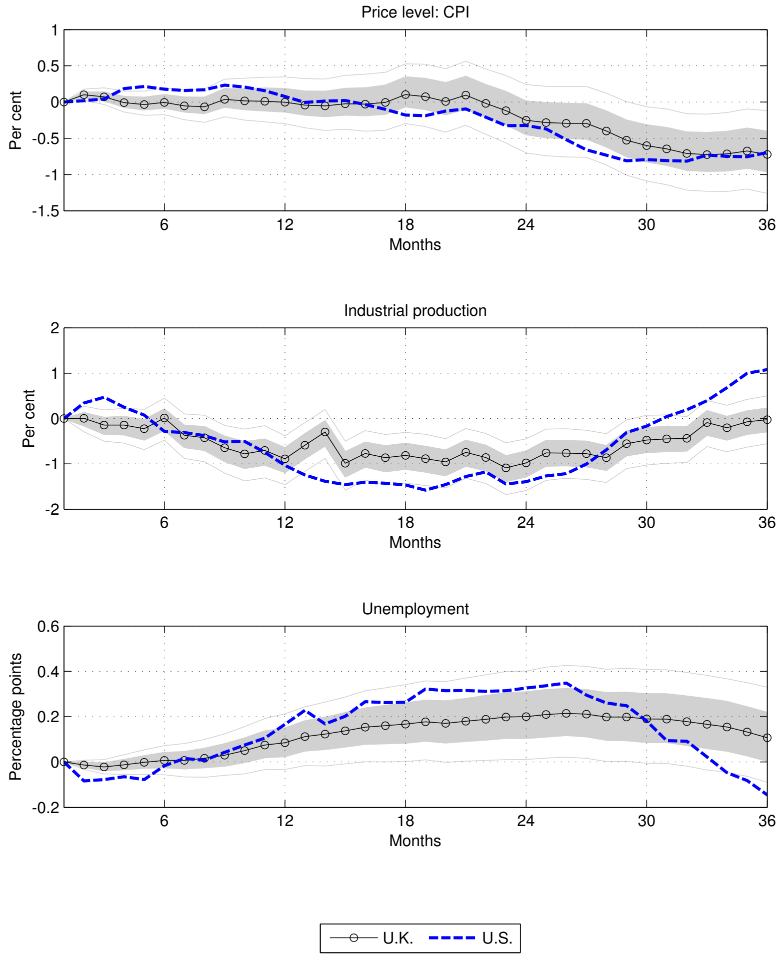
Figure 15: Robustness to alternative price measures and lag length



Notes: Impulse responses to a one percentage point contractionary monetary policy shock (dashed line) of alternative specification compared to baseline specification (circled line) with corresponding 68 and 95 per cent confidence intervals. The baseline specification uses industrial production, RPIX12m inflation, commodity prices, and our shock measure. Panel A compares the dynamics for various inflation measures (RPI and CPI) to the baseline VAR with RPIX. Panel B provides the baseline VAR results compared to using 12 and 36 lags.

B.5. Further comparison of the US and UK results

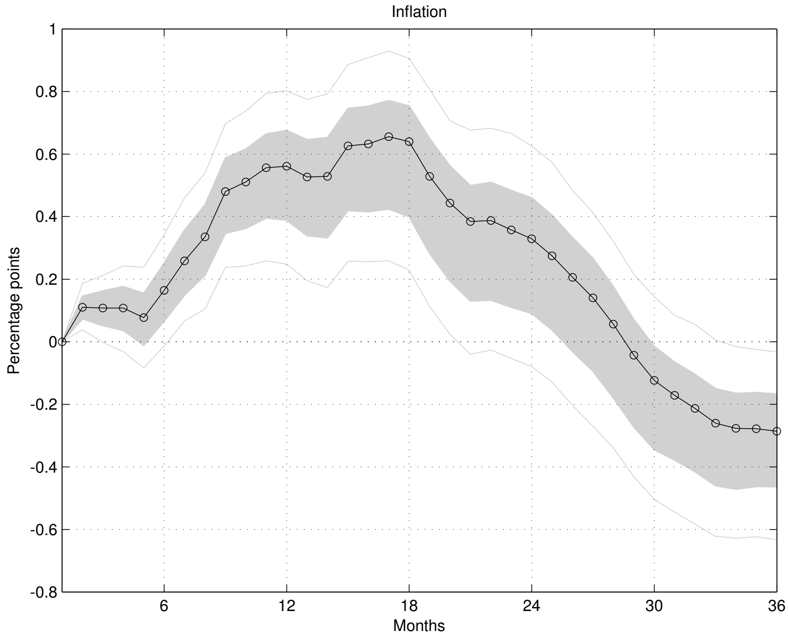
Figure 16: Single equation regression with hybrid UK VAR shock: UK vs. US



Notes: Impulse responses to series of policy target rate shocks implied by the hybrid VAR with corresponding 68 and 95 per cent confidence intervals. Single regression for industrial production, price level and unemployment.

B.6. The price puzzle

Figure 17: Baseline VAR using Bank Rate to measure monetary policy shocks



Notes: Impulse responses to a one percentage point increase in Bank Rate with corresponding 68 and 95 per cent confidence intervals. The specification uses industrial production, RPIX12m inflation, commodity prices, and Bank Rate. P=24, sample=1975-2007.

C. Further results for the post-1992 sample

C.1. Predictability tests for the post-1992 subsample

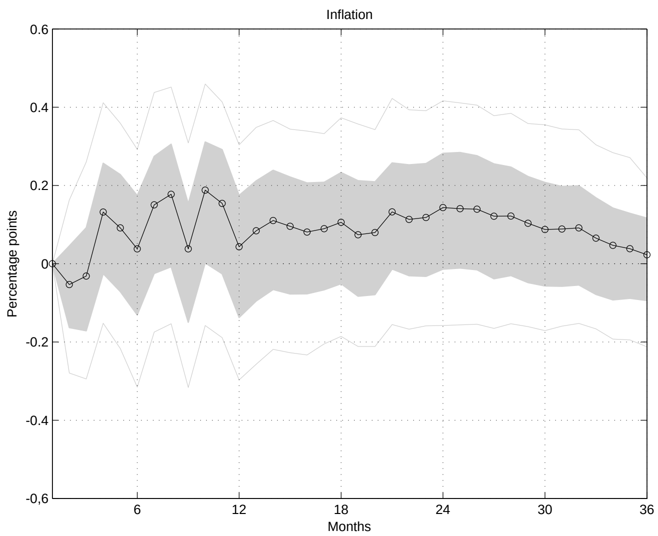
Table 7: Predictability of monetary policy innovations: 1993 to 2007

	I = 3 lags		I = 6 lags	
Variable	F-statistics	P-values	F-statistics	P-values
Change in industrial production	0.67	0.57	0.64	0.70
Monthly inflation	1.85	0.14	1.32	0.25
Unemployment rate	0.00	1.00	0.87	0.52
Money growth M4	0.62	0.60	0.41	0.87
Commodity price inflation	0.43	0.73	1.02	0.42
Change in FTSE	0.88	0.45	0.94	0.47

Notes: The table reports F-statistics and P-values for the null hypothesis that all coefficients β_i are equal to zero. The standard errors are corrected for the possible presence of serial correlation and heteroskedasticity using a Newey-West variance covariance matrix.

C.2. The inflation response in a conventional VAR after 1992

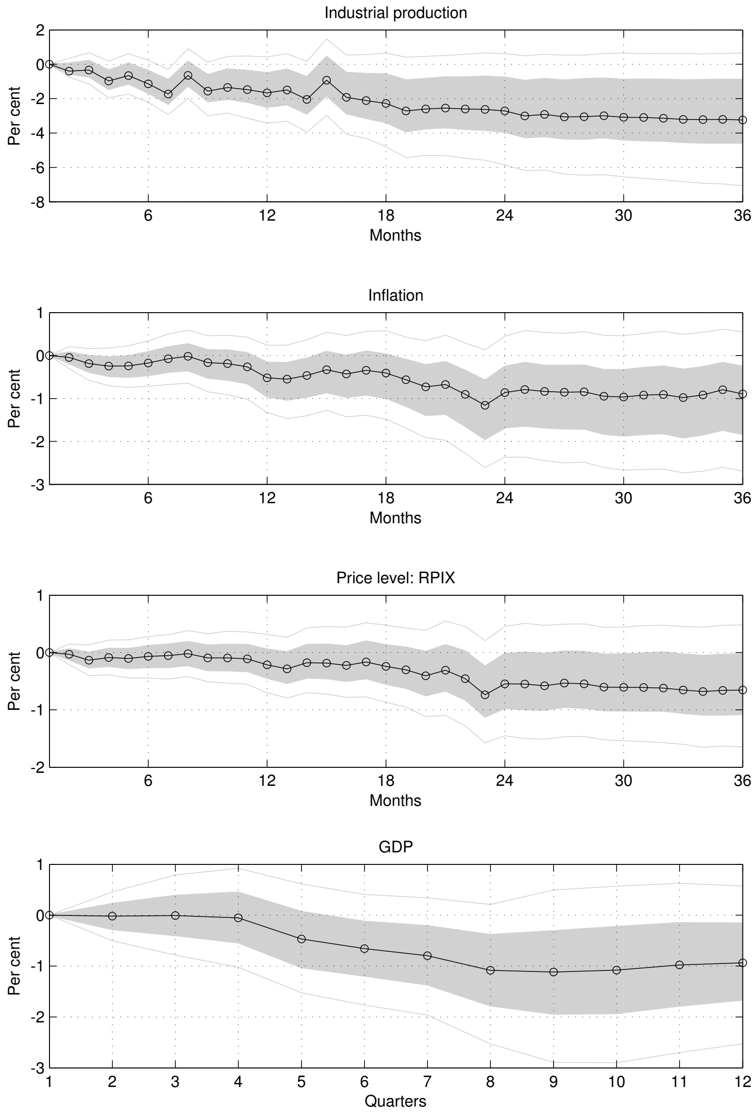
Figure 18: Small-scale VAR with Bank Rate



Notes: Impulse responses to a one percentage point contractionary monetary policy shock with corresponding 68 and 95 per cent confidence intervals. VAR with industrial production, RPIX12m inflation, commodity prices and Bank Rate. P=12.

C.3. Post-1992 single equation results

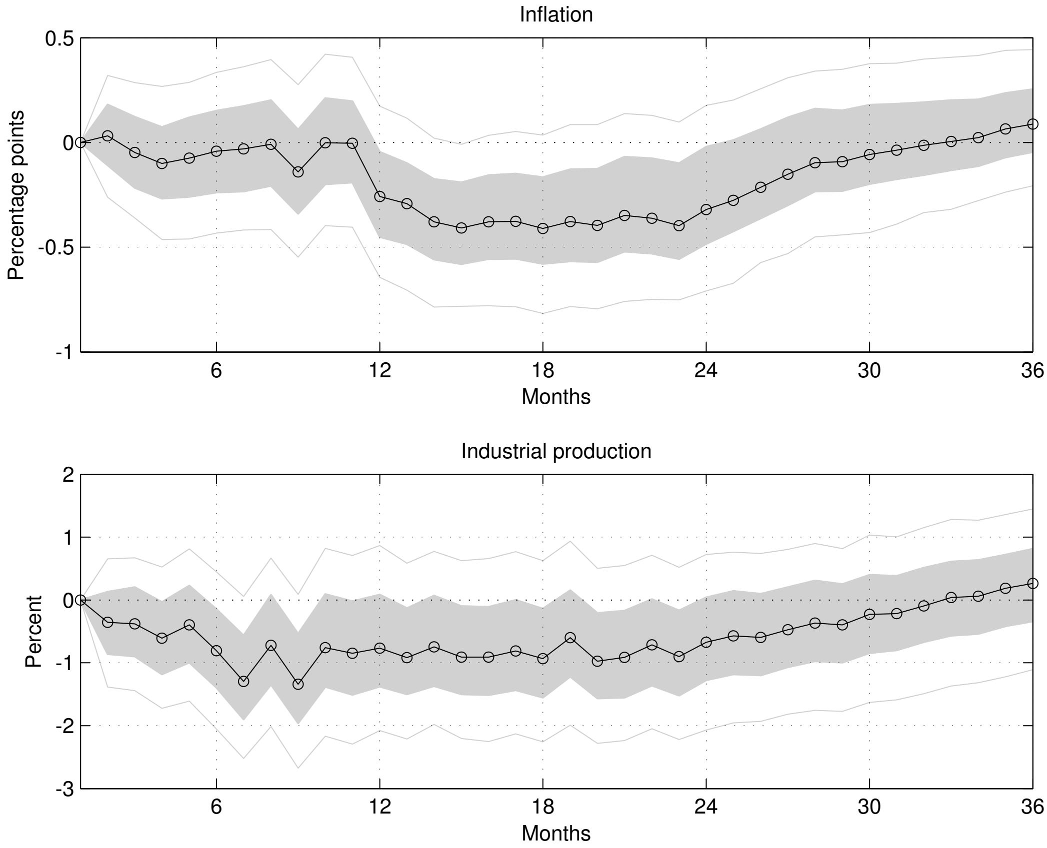
Figure 19: Post-1992 single equation results



Notes: Impulse responses to a permanent one percentage point monetary policy shock with corresponding 68 and 95 per cent confidence intervals. Single regression for industrial production (P=12, Q=18), RPIX12m inflation (P=12, Q=24), price level RPIX (P=12, Q=24) and GDP (P=4, Q=8).

C.4. Post-1992 VAR results

Figure 20: The effects of monetary policy under inflation targeting: VAR results



Notes: Impulse responses to a one percentage point monetary contraction. Hybrid VAR with industrial production, RPIX12m inflation, commodity prices and our new cumulated shock measure. P=12, sample: 1993-2007. Confidence bands indicate 68 and 95 per cent intervals.