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Real effects of Quantitative Easing at the Zero-Lower Bound: Structural VAR-based evidence from Japan

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Abstract

Using monthly post-1995 Japanese data we propose a new sign-restriction based approach to identify monetary policy shocks when the economy is at the zero-lower bound (ZLB). The identifying restrictions are thoroughly grounded in liquidity trap theory. Our results show that a quantitative easing shock leads to a significant but temporary rise in industrial production. The effect on the price level is significantly positive and permanent. Inflation does therefore temporarily rise but returns to zero subsequently. In addition, we show the shock has even stronger effects on these variables if stock prices react positively. Our results are robust to different specifications, in particular to the further identification of aggregate demand and supply shocks under liquidity trap conditions. Accordingly, our results imply that while the Japanese Quantitative Easing experiment was successful in stimulating economic activity and inflation in the shortrun, it did not lead to any permanent increase in the inflation rate. We believe these results are interesting not only for the Japanese economy, but also for other advanced economies where monetary policy is currently constrained by the ZLB.

JEL Classification: E43, E51, E52, E58

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1 Introduction

We study the real effects of Quantitative Easing (QE) in a structural VAR (SVAR) when the shortterm interest rate is constrained by the Zero-Lower-Bound (ZLB). Using monthly Japanese data since 1995 - a period during which the Bank of Japan's target rate, the overnight call rate, has been very close to zero - and sign restrictions based on liquidity trap theory, we find that an increase in reserves leads to a significant 0.5 percent rise in industrial production after around 10 months. This rise lasts for about two years. At the same time our results indicate that the same shock leads to a small, but significantly positive and permanent response to the price level. This implies that inflation temporarily rises after a QE-shock and subsequently returns to zero. In addition, our results show that the effects of QE are generally stronger if the policy leads to positive developments on the stock market. Thus our results provide mixed evidence on the successfulness of QE in Japan. Whilst real economic activity and inflation do seem to pick up temporarily after a QE-shock, this does not seem to affect inflation permanently in a way that Japan could exit its deflationary period through such a policy shock.

However, this conclusion strictly holds only under the usual caveat in SVAR- analysis that the monetary policy shock we consider must be a small one - one that is not allowed to change the policy regime or any other of the structural relations we estimate. Whilst we argue this is precisely the kind of shock that central banks currently inflict on our economies, we should be careful not to conclude that any more aggressive policy changes by central banks to escape the deflationary period of the liquidity trap¹ are doomed to fail.

Our study adds to the existing literature in various important ways. First, focusing specifically on post-1995 Japanese data where the policy rate of the Bank of Japan, the call rate, was virtually zero,² allows us to identify a monetary policy shock under liquidity trap conditions. We call such a shock unconventional monetary policy shock or QE-shock for short. Second, including standard macro variables in our VAR allows us to study the effects of such a QE-shock on a broader set of variables than usually studied in the literature on unconventional monetary policy effects. In particular, our approach allows us to study the effects of a QE-shock on real economic activity and on the inflation rate - the two variables of ultimate interest to the central bank. Third, using a sign-restriction approach to identify our QE-shock allows us to remain *agnostic* about whether, how, and when real activity and inflation respond to the QE-shock. Fourth, by including a longterm government bond yield in our estimation we can study the effect of a QE-

¹For instance along the lines of Krugman (1998) or Svensson (2003).

²See Figure 1 on p. 7.

shock on longterm yields - an issue that has received renewed interest in the current literature on quantitative easing. At the same time the sign restriction approach allows us to include stock prices in the analysis and thus to assess the importance of this variable for the transmission of our unconventional shock. Fifth, because our restrictions are firmly grounded in liquidity trap theory we believe they are *credible* in the sense of Sims (1980) and that what we measure in our SVAR is indeed the structural QE-shock we are aiming at. Finally, because shortterm policy rates in the US, the Euro Area, the UK and other economies around the world are currently very close to zero and therefore possibly constrained by the ZLB, our results shed light on the effects of the currently implemented nonstandard policy measures adopted by the leading central banks in the world.

The rest of the paper is organised as follows: The next section summarises the key findings in the literature on monetary policy effects at the Zero-Lower-Bound (ZLB). Section 3 then briefly discusses key features of the main monetary policy decisions implemented by the Bank of Japan since the stock and housing market crashes in the early 90s. Our key identification strategy using sign-restrictions based on liquidity trap theory is explained in Section 4. Data, results and robustness checks are then presented in Sections 5 and 6 respectively. Section 7 finally concludes.

2 Effects of monetary policy shocks under liquidity trap conditions

The effects of monetary policy shocks when monetary policy is *not* constrained by the Zero-Lower-Bound (ZLB) has been well documented in the literature. Of course, arguments are still ongoing as to how the monetary shock under normal times is best identified. But by and large there is a broad consensus that expansionary monetary policy, say by lowering the policy interest rate, affects inflation and output positively, but only very sluggishly and only temporarily.³ This of course is roughly in line with our macroeconomic theories on how monetary shocks, be they through changes in the interest rate or the monetary base, affect the real economy under normal times when the interest rate is not constrained by the ZLB.

It is somewhat surprising therefore that there is much less empirical evidence on the real effects of monetary policy shocks when monetary policy *is* in fact constrained by the ZLB. Notable exceptions are Baumeister and Benati (2010), Chung et al. (2011), Kamada and Sugo (2006),

³Compare Christiano et al. (1998). But note different identifying restrictions do in fact lead to slightly different results, compare Uhlig (2005) and Lanne and Lütkepohl (2008).

Lenza et al. (2010), and Peersman (2010).⁴ One obvious reason might be that most economies until very recently have not been in such a situation and that sample periods to use in estimation would thus be notoriously short. However, it is also true that at least since 2000, when the Fed was fast to lower the Federal Funds rate to very low levels in response to the bursting of the IT-bubble, there has been an important theoretical discussion amongst central bankers as how to avoid liquidity traps and how to escape them once an economy found itself in the trap.⁵ Unfortunately, with the above exceptions, the corresponding empirical evidence evaluating those theories has however not been forthcoming.

The recent financial crisis has led to renewed interest in the empirical effects of the so-called unconventional monetary policies implemented by the leading central banks. However, most of these studies focus on the effect unconventional policies have on various interest rates or interest rate spreads. They do not study the effects of those policies on other standard macro variables like output or inflation. But these variables of course are the key variables of interest to the central bank and the public and of course important for welfare considerations. Thus there is by now a growing body of literature that studies the effects of unconventional monetary policy on such financial market variables like interest rates, spreads or the entire yield curve. Recent examples include Bernanke et al. (2004), Gagnon et al. (2010), Hamilton and Wu (2010) and Stroebel and Taylor (2009) for the US, Meier (2009) for the UK, ECB (2010) for the Euro Area, and Oda and Ueda (2007) and Ueda (2010) for Japan. Broadly speaking, these studies do find negative effects on yield spreads of unconventional policies, or more precisely of announcements of such policies, in the sense that the yields of various assets do tend to decline thereby narrowing the spread to the corresponding riskless rate. However, these effects are generally found to be rather small. For instance, Hamilton and Wu (2010) find that a purchase of 400 billion US dollars in 10-year US Treasury Bonds would lead to a 14 basis points fall in the 10-year yield. Gagnon et al. (2010) find that the same policy measure would lower longterm yields by 20 basis points. Meier (2009) estimates that the Bank of England's QE-related asset purchases lowered gilt yields by around 40-100 basis points.

The recently announced additional round of monetary easing by the Fed on 3 November 2010 further stimulated this debate about the effectiveness of the unconventional monetary policy measures. The FOMC announced that it "intends to purchase a further 600 billion dollars of longer-term Treasury securities by the end of the second quarter of 2011, a pace of about 75

⁴We comment below on how our study differs from these.

⁵See e.g. Bernanke (2002), Bernanke and Reinhart (2004), Krugman (1998) or Svensson (2003).

billion dollar per month.”⁶

It is important to note that the theoretical impact of such a policy announcement on longterm yields is far from clear. Most theoretical studies (see e.g. Doh (2010)) refer to some kind of imperfect substitutability between assets and explain the expansionary effect of such a policy decision by arguing that the purchase of longterm bonds by the central bank will naturally lower longterm bond yields, because the central bank buys those bonds at a higher price than the market charges. This lower longterm yield on government bonds then feeds through - via portfolio shifts (Meltzer, 1995) - to other asset markets, like the corporate bond market and the stock market. Longterm financing for investment and durable goods becomes cheaper thereby stimulating aggregate demand. In other words, the central bank cuts through the traditional interest rate channel by directly lowering longterm yields. Being constrained by the ZLB the traditional interest channel which normally lowers longterm yields through the expectations hypothesis does not function anymore and the central bank circumvents this by directly intervening in the market for longterm bonds. This theoretical argument is partly supported by the empirical evidence of the above mentioned studies.

However, from a theoretical point it is not clear that longterm yields are indeed supposed to fall after such a policy announcement. Indeed, if market participants believe the Fed intervention is successful in stimulating the economy by increasing aggregate demand, inflation and real rates are likely to rise in the future. Thus inflationary expectations as of today should rise and longterm nominal yields should in fact rise. In other words, the effectiveness of such a policy move might instead be seen by *rising* longterm yields, not by falling yields. In fact, falling longterm rates would then be a sign that the Fed policy was not successful.⁷ And indeed, since Fed officials first announced the possibility of further monetary easing in October 2010 yields on nominal 10-year US Treasury bonds have risen by almost 130 basis points. But because real yields from TIPS have only risen by about 90 basis points, longterm inflation expectations in the US have risen by around 40 basis points since the first QE2-mentionings by Fed officials.

This remark allows us to finally discuss the ways in which our study differs from the above mentioned studies. First, our study differs from Baumeister and Benati (2010) mainly by using a different set of variables and corresponding sign restrictions. Because of the above remarks we prefer not to restrict any spreads or identify an expansionary monetary policy shock by a reduction in spreads. Instead we want to study precisely the effects of unconventional policy on

⁶See FOMC statement from 3 November 2010, <http://www.federalreserve.gov/newsevents/press/monetary/20101103a.htm>

⁷On this see e.g. Illing and Watzka (2010), Siegel (WSJ, 14 Dec 2010) or Wolf (FT, 14 Dec 2010).

longterm yields, inflation and real activity. Thus, we try to be as agnostic as possible and only restrict those variables which are either under direct control of the central bank or necessary to restrict to disentangle the QE-shock from other economic shocks. Thus, we restrict only the responses of the call rate, the current account holdings (or reserves) of banks at the Bank of Japan, and the real effective exchange rate.

Second, our results are in fact very similar to those obtained by Chung et al. (2011) in their recent study on the effect of the Fed's asset purchase programme on the unemployment rate, inflation, and the 10-year government bond yield. Chung et al. (2011) find that unemployment falls within two or three years, inflation rises temporarily, and the longterm yield initially falls but rises later. The authors use the large-scale Fed model (the FRB/US model) and simulate the model with estimated effects of the Fed's asset purchases impact on longterm yields. Our study differs by using Japanese data which allows us to properly estimate the effects and uncertainty around the effects of the QE-shock. Chung et al. (2011) must either rely on a notoriously short sample period or else use a sample period where the US economy was in fact not constrained by the ZLB. Whilst it is not entirely clear that the behaviour of the economy is necessarily different when at the ZLB, our method allows for different structural behaviour at the ZLB. Thus, we believe our method is less prone to changing parameters due to the Lucas critique.

Third, our study differs from Kamada and Sugo (2006) by not having to rely on an intermediate monetary indicator which is used to capture the monetary stance in their model. In our model monetary stance is fully determined by the level of current account holdings and an unchanged call rate. We believe this is more reliable because these variables are more directly under the control of the central bank than any intermediate variables.

Fourth, our study differs from Lenza et al. (2010) most obviously by considering a different country for which we have longer time series. We further differ from their study by carrying out traditional SVAR-impulse response analysis. Lenza et al. (2010) instead estimate their model and carry-out counterfactual policy analysis under the assumption that the remaining model remained unchanged. Our traditional method allows us to carry out policy analysis without such a strong assumption.⁸

Finally, our study differs from Peersman (2010) again by considering a different country. Peersman (2010) uses sign restrictions to study the effects of credit market shocks as well as uncon-

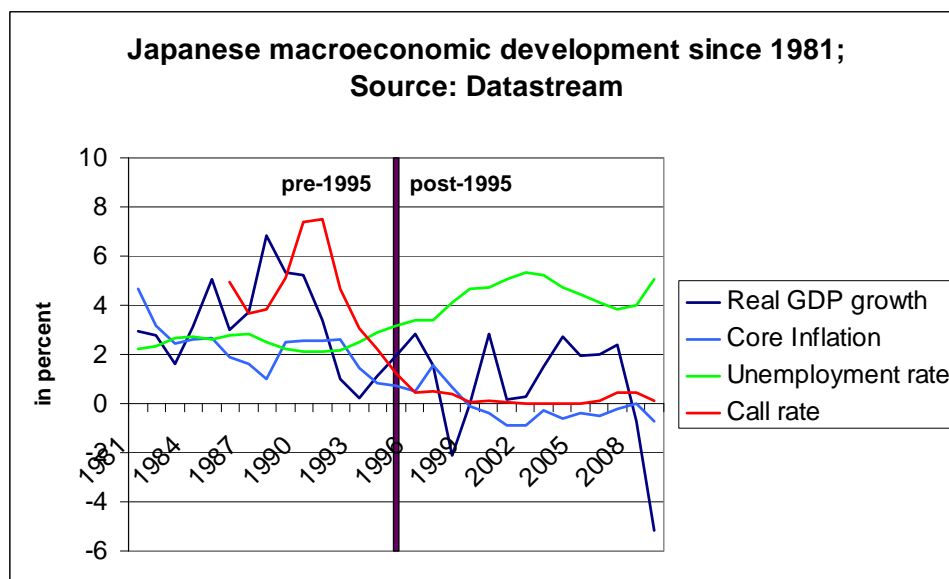
⁸As a matter of fact, SVAR-analysis is of course a key method of counterfactual analysis. But because we do not need to simulate our model we believe our method is less prone to omitting variable problems and the Lucas critique.

ventional monetary policy shocks for the Euro Area. Again, to study the impulse responses of unconventional monetary policy an in our opinion rather strong assumption on the bank lending interest rate is imposed. Our study thus differs from his by focusing on the QE-shock and by being as agnostic as possible in our identification scheme.

3 Monetary Policy in Japan since the late 1980s

This section briefly summarises key monetary policy developments in Japan since the late 1980s/early 1990s - in other words since the bursting of the Japanese stock and real estate bubbles. We only sketch key developments, for a thorough discussion please consult Mikitani and Posen (2000), Ugai (2007) and Ueda (2010). We divide this period into pre- and post-1995 based on the behaviour of the Bank of Japan's target interest rate, the call rate, which has been lowered by the Bank of Japan to virtually zero during 1995. Figure 1 shows key macroeconomic variables for Japan since 1981.

Figure 1: Key macroeconomic variables in Japan since 1981. The thick line indicates 1995.



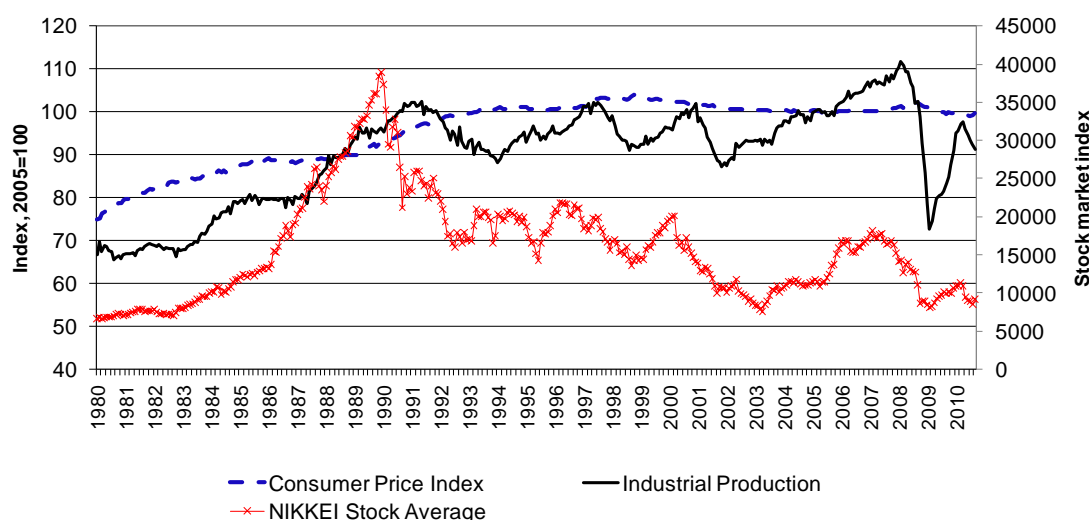
The figure reveals the widely documented behaviour of the dramatic fall in real GDP growth rates after the bursting of the asset prices bubbles in 1990/91. Whilst GDP grew in the pre-1991 period by an average rate of 3.9 percent per year, it slowed down to only 0.8 percent post-1991.

This of course is the numerical basis for the well-known label "Japan's lost decade." Meanwhile the notoriously low Japanese unemployment rate has more than doubled while the core inflation rate has steadily trended below zero since 2000. The following subsections give some more details to Japanese monetary policy pre- and post-1995.

3.1 The bursting of the bubbles and delayed monetary policy reaction

The bursting of the stock market bubble can be seen in Figure 2. The stock market was rising dramatically until around 1990. The figure shows that this went together with rapid increase in industrial production under fairly low and constant rates of inflation (compare also Figure 1).

Figure 2: Industrial production, Consumer Price Index and Nikkei Stock Index since 1980. The stock market bubble burst in 1990. Source: Datastream

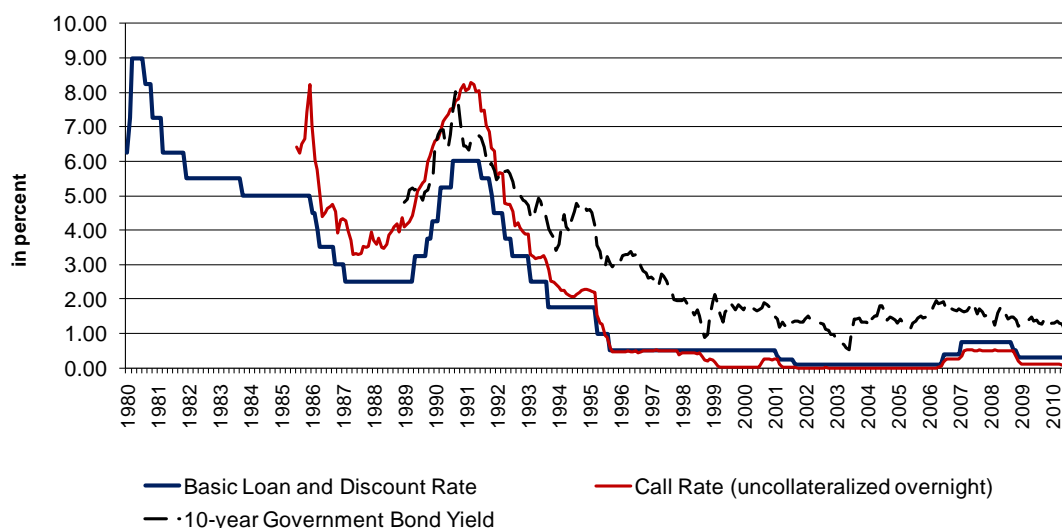


Realising that the elevated stock and land prices seemed out of touch with fundamentals the Bank of Japan did in fact continuously increase the call rate (compare again Figure 1). Optimism turned into pessimism around 1990/91 and both stock and land prices started falling rapidly. It is nowadays widely agreed (see e.g. Jinushi et al. (2000)) that the initial response of the Bank of Japan to the bursting of the asset price bubbles was too slow and not aggressive enough. In fact, Figure 1 shows that the call rate was high until 1992/3 and then only lowered very gradually until it reached 0.5 percent in the last quarter of 1995.

3.2 Post-1995

But even with its key policy rate at 0.5 percent and therewith close to zero, the Bank of Japan was very slow in implementing unconventional expansionary policy measures. In fact, only in 1999 did the Bank of Japan officially introduce its so-called zero interest rate policy (ZIRP) when it lowered the call rate to 0.03 percent (see Figure 3). It also tried to steer market expectations by adding commitments to its policy statements indicating that it would keep the call rate low for longer time.

Figure 3: Key Bank of Japan interest rates since 1980. The call rate has been the Bank of Japan's main policy rate between the mid-80s and early 2000. Source: Datastream

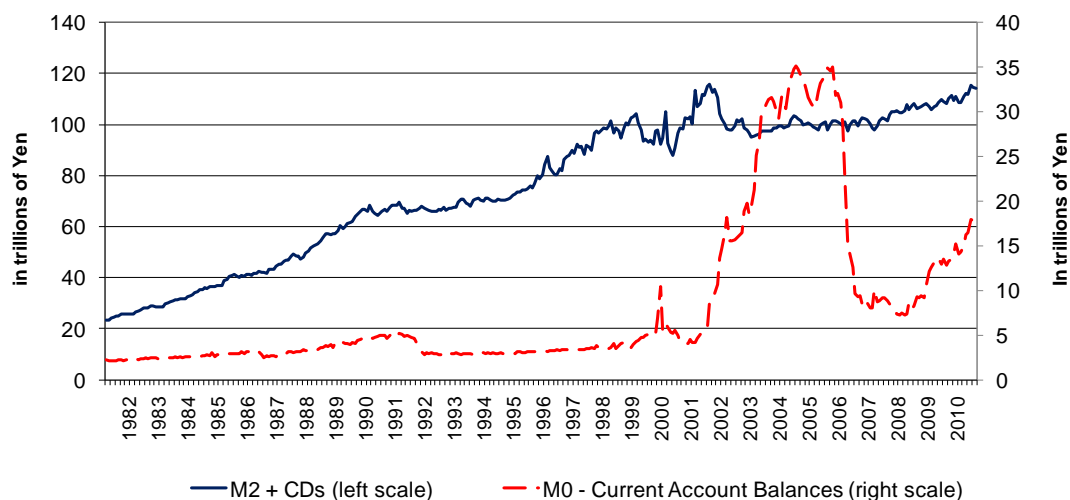


When the Japanese economy started to recover slightly in 2000 with real GDP growth of 2.8 percent, the call rate was raised to 0.25 percent and ZIRP was officially ended.

However, the worldwide economic recession following the bursting of stock market bubbles in response to the IT-bubble led to renewed macroeconomic problems in Japan. This time the Bank of Japan introduced a more aggressive policy programme. From March 2001 until March 2006 it implemented the so-called "Quantitative Easing Policy" (QEP) which consisted basically of three elements: (i) the operating target was changed from the call rate to the outstanding current account balances held by banks at the Bank of Japan, (ii) to commit itself to continue providing ample liquidity to banks until inflation stabilised at zero percent or a slight increase,

and (iii) to increase the amount of outright purchases of longterm Japanese government bonds.⁹

Figure 4: Monetary aggregates in Japan. Quantitative Easing was implemented between 2002 and 2006. Source: Datastream



The monetary development and the effect of the Bank of Japan’s QEP measures can be seen in Figure 4. We plot that part of the monetary base that is the current account holdings of banks at the Bank of Japan, in other words these are bank reserves held at the central bank. The figure clearly shows the enormous increase in reserves during the QEP period and later again when the recent financial crisis hit. At the same time we see that the growth rate of M2 and Certificates of Deposits (CDs) steadily slowed since 1980.

Having these macroeconomic and monetary developments in mind we next want to present our identification strategy based on the reasonable assumption that the Bank of Japan since 1995 did not conduct its monetary policy through the call rate anymore - which was constrained by the ZLB - but by changing the reserve holdings of banks at the Bank of Japan.

⁹See the authoritative survey by Ugai (2007) for more details.

4 Identification of structural shocks based on liquidity trap theory

This section discusses in detail how we use liquidity trap theory to derive our identifying restrictions used to study the effects of a QE-shock on real activity, the price level, and longterm government bond yields. We first discuss our benchmark identification scheme and subsequently extend the analysis.

4.1 Benchmark identification scheme

To analyse the effects of monetary policy on economic activity and the price level at the ZLB, the following reduced-form VAR model is estimated:

$$Y_t = A(L)Y_{t-1} + u_t, \quad (1)$$

where Y_t is a vector of endogenous variables, $A(L)$ is a matrix of autoregressive coefficients of the lagged values of Y_t and u_t is a vector of error terms. In our benchmark regression we include the following six variables in the system:

$$Y_t = [P_t, IP_t, EX_t, RES_t, R_t, LTY_t], \quad (2)$$

where P_t denotes the all-items consumer price index, IP_t Japanese industrial production, and EX_t the real effective exchange rate of the Yen against other currencies. Our monetary policy variables of interest are the bank reserves held at the Bank of Japan (RES_t)¹⁰ as well as the call rate (R_t). Finally, the 10-year yield of Japanese government bonds (LTY_t) is included in the set of regressors.¹¹

In the benchmark case, six lags of the endogenous variables are included in the estimation, which seems to be sufficient to capture the dynamics of the model.¹² Except for the call rate and the

¹⁰Specifically as measure of reserves we use the monthly average of current account balances held at the Bank of Japan which is a base money component and which was used as policy target by the Bank of Japan in its Quantitative Easing Policy from March 2001 through March 2006 replacing the call rate (see Ugai (2007)).

¹¹Following Uhlig (2005) and Kamada and Sugo (2006), we do not include a constant or a time trend in our VAR model. Including these terms would require an adjustment of the prior used in the Bayesian estimation (see Uhlig (1994)). A more thorough investigation of this issue will be provided in a follow-up paper specifically designed to study the effects of various choices of deterministic and appropriate prior information for our approach.

¹²While different lag length criteria lead to different suggestions concerning the number of lags to include, all

longterm yield, all variables are seasonally adjusted and included as log-levels¹³

Because a number of empirical studies conclude that the relationship between broader measures of money supply and economic activity or prices disappeared in the course of the 1990s (see e.g. Miyao (2005)) we do not include the variable measuring the broader money supply (M2 + CDs). Figure 4 above indeed shows that during the period of massive quantitative easing in the early 2000's M2 + CDs did in fact not increase with the monetary base. In other words the money multiplier was far from constant. Thus, the broader money stock is not likely to be an important variable with respect to the transmission of monetary policy during the 1990's and 2000's. A detailed description of the data is given in Section 5.

The VAR model is estimated by means of Bayesian methods using monthly data over the period January 1995 to September 2010. As in Uhlig (2005) we identify the monetary shock by imposing sign restrictions on the impulse response functions. In the baseline specification, restrictions are binding for twelve months.¹⁴ A summary of the restrictions considered in the benchmark case is provided in Table 1:

Table 1: Identifying sign restrictions

Variable	Response to QE-shock
CPI	
Ind. production	
Exchange rate	$\geq 0, \quad k = 0, \dots, 11$
Reserves	$\geq 0, \quad k = 0, \dots, 11$
Call rate	$-\epsilon \leq \cdot \leq \epsilon, \quad k = 0, \dots, 11$
Longterm yield	

In particular, the QE-shock is identified by restricting reserves not to decrease following the shock. Because we identify an expansionary shock, the call rate should not increase following the QE-shock. Moreover, since we estimate the model for a zero-lower bound situation, the

of them tend to propose shorter lag lengths. Our main results are, in fact, robust to varying the lag length (see our robustness section 6.4).

¹³According to Sims et al. (1990) classical estimation of VARs in levels leads to consistent estimates even in the presence of some unit roots. However, because correct classical inference depends crucially on the correct asymptotic distribution which is discontinuous at the unit root, we prefer to use Bayesian estimation instead. The posterior density in Bayesian VAR estimation behaves similar to the likelihood (assuming a flat prior) which is well-behaved even under the unit root (see Sims and Uhlig (1991)).

¹⁴Scholl and Uhlig (2005) use a similar restriction horizon.

nominal interest rate cannot fall further. Thus, our setup requires the call rate not to react at all as a response to the monetary disturbance. This is implemented by means of a “near-zero” restriction; in particular, we specify the response of the call rate to stay “reasonably close” to zero following the unconventional monetary shock. Thus $-\epsilon \leq r_k^{i, QE} \leq \epsilon$ where $r_k^{i, QE}$ denotes the impulse response of the call rate following a quantitative easing shock. For the baseline case we set $\epsilon = 0.005$.¹⁵

Finally, we restrict the effective exchange rate not to decrease following a QE-shock, implying our QE-shock causes a real depreciation of the Yen. This restriction follows from theoretical monetary arguments proposed by for instance Meltzer (1995, 2001) and Mishkin (2001) suggesting portfolio rebalancing effects after a monetary policy shock. In particular, the monetarist asset market equilibrium framework in Meltzer (1995) points to increased purchases of real capital and financial assets on the side of investors after a base money injection by the central bank, which drives up asset prices. In theory, this result also holds in a liquidity trap situation. While, following an increase in the monetary base, the interest rate does not move, increased asset purchases still take place due to the excess money supply in the economy leading to a rise in respective prices. To the extent that investors use a part of the additional liquidity to purchase assets denominated in foreign currency the exchange rate is likely to rise, i.e. depreciate, after an expansionary shock even if the interest rate does not react. Kamada and Sugo (2006) use a similar restriction on the exchange rate.

With respect to industrial production and consumer prices, the central question assessed in this paper is concerned with the effectiveness of unconventional monetary policy measures on economic activity and prices at the zero-lower bound, which is the ultimate concern of central banks. Thus, we leave these variables unrestricted. In addition, we abstain from restricting the 10-year government yield. As discussed in the last section, the effects of quantitative easing on longterm yields is theoretically not clear; observing rising yields following a base money expansion may be possible as a consequence of increasing inflation expectations or increasing risk premia. In this sense our identification scheme can be considered *agnostic* in that we let the data speak concerning the effects of an unconventional monetary shock on the real economy, the price level, and longterm interest rates.

¹⁵While varying ϵ does not change our main results, lower values of the parameter of course lead to a more restrictive specification and thus to an increased computational effort. In principle, we could also use an exact-zero identification scheme (see Mountford and Uhlig (2009)) for the call rate response to the QE-shock. We leave this alternative implementation method for future study.

Numerically, following e.g. Canova and DeNicolo (2002) or Uhlig (2005), the sign restriction approach is implemented by taking draws for the VAR parameters from the Normal-Wishart posterior,¹⁶ constructing an impulse vector for each draw and calculating the corresponding impulse responses for all variables over the specified horizon.¹⁷ If all these responses meet the sign restrictions the draw is kept, otherwise it is discarded. The impulse response functions for the respective variables are then calculated as the median of all "successful" draws. For the analysis at hand, the procedure is repeated until 1000 draws are found satisfying the restrictions. In contrast to other identification strategies the sign restriction approach offers some advantages. Compared to the traditional Cholesky ordering identification, the sign restriction approach allows for more explicit, transparent, and in particular model-based identification. Thus, zero-restrictions on contemporaneous interactions may not hold in reality (Faust, 1998). At the same time imposing zero restrictions on long-run impulse responses is avoided. (Faust and Leeper, 1997) show that long-run restrictions may be biased in small samples.

4.2 Identifying three shocks

In order to avoid other economic disturbances being captured by our one-shock identification strategy, we extend the above-explained setup and identify two more shocks. In particular, next to the QE-shock we additionally identify two more traditional shocks: a positive demand and a positive supply shock. To be able to distinguish between the responses to the respective shocks, we first require these disturbances to be orthogonal to the monetary shock.¹⁸ Using this specification we ensure that the expansionary monetary shock is not confused with other disturbances related to business cycle fluctuations. In identifying the additional shocks we explicitly stick with our ZLB assumption and base the restrictions on a simple AS-AD scheme adapted to a liquidity trap situation. The restrictions for the extended identification scheme are summarised in Table 2.

A positive aggregate demand shock leads to a non-negative response in consumer prices and

¹⁶Uhlig (1994) and Zellner (1971) offer detailed discussions on the Normal-Wishart prior. Uhlig's proposition 5 states that for the univariate case with nonexplosive roots, i.e. $|\rho| \leq 1$, using a flat Normal-Wishart prior is equivalent to using the *critics prior* of Phillips (1991) for all practical applications. While the Normal-Wishart prior puts equal weights on all values of ρ , the critics prior emphasizes larger values of ρ because the data provides more information on ρ when the true parameter is large.

¹⁷Estimation was performed by using Fabio Canova's Matlab codes `bvar.m`, `bvar_chol_impulse.m` and `bvar_sign_ident.m` which can be downloaded from his website <http://www.crei.cat/people/canova/>.

¹⁸Mountford and Uhlig (2009) show how the identification setup in Uhlig (2005) can be extended to control for additional shocks. Our estimation strategy closely follows their approach.

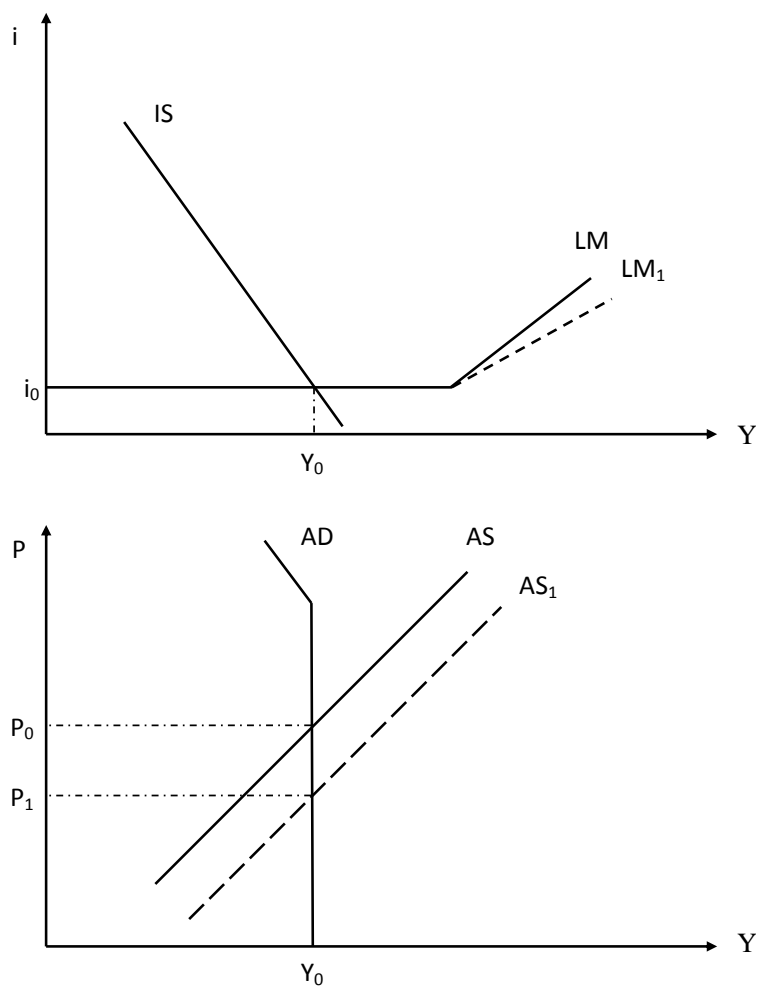
Table 2: Identifying sign restrictions - three shocks

Variable	Response to			Restriction horizon
	Demand shock	Supply shock	QE shock	
CPI	≥ 0	≤ 0		$k = 0, \dots, 11$
Ind. production	≥ 0	$-\epsilon \leq \cdot \leq \epsilon$		$k = 0, \dots, 11$
Exchange rate	≤ 0		≥ 0	$k = 0, \dots, 11$
Reserves			≥ 0	$k = 0, \dots, 11$
Call rate	≥ 0	$-\epsilon \leq \cdot \leq \epsilon$	$-\epsilon \leq \cdot \leq \epsilon$	$k = 0, \dots, 11$
Longterm yield				

industrial production. Moreover, the nominal interest rate is allowed to positively respond to the shock. This is a rather traditional set of restrictions that has been used by, for instance, Canova et al. (2007) and is valid both under “normal” circumstances as well as at the ZLB. Additionally we restrict the exchange rate to appreciate after a positive demand shock, which is reasonable in the case of a domestic demand disturbance. Having opposing sign restrictions to the response of the exchange rate to the QE-shock and the demand shock helps us to econometrically distinguish these two shocks in our estimation.

In the case of a positive supply shock the identification is somewhat complicated by the ZLB constraint and thus differs from a traditional specification. In particular, industrial production is demand determined and thus fixed in the liquidity trap case, which is reflected by the “near-zero” restriction shown in Table 2. Furthermore, the call rate is constrained not to fall below zero resulting in a similar restriction for this variable. The consumer price index is specified not to increase following a positive supply shock. The rationale for the restriction setup for the traditional shocks under liquidity trap conditions can be seen more clearly in the simple AS-AD framework shown in Figure 5. At the ZLB, characterized by the usual horizontal LM curve the AD-curve is vertical. Thus a positive supply shock that shifts the AS-curve to the right only results in a lower price level without changing output or interest rates. In Figure 5, a shift of the AS-curve leads to a new price level P_1 with $P_1 < P_0$, while output remains unchanged at Y_0 . Moreover, in the IS-LM diagram a lower price level due to the supply shock does not result in a shift of the LM-curve under liquidity trap conditions. Thus, the interest rate is fixed at i_0 , resulting in a corresponding “near-zero” restriction on the call rate as shown in Table 2.

Figure 5: Supply shock at the zero-lower bound



4.3 Varying the Identification Scheme: Including Stock Prices

We additionally estimate a further specification that augments the model given by equation (2) by adding the Nikkei stock price index, denoted by STP_t :

$$Y_t = [P_t, STP_t, IP_t, EX_t, RES_t, R_t, LTY_t]. \quad (3)$$

The inclusion of this variable may potentially lead to interesting insights concerning the transmission of our QE-shock. Earlier studies on the real effects of monetary policy shock in Japan point to the importance of stock prices in the monetary transmission process. For instance Miyao (2002) offers an econometric investigation of this issue. He includes stock prices in a VAR framework for Japan and finds a positive reaction of this variable to an expansionary monetary base shock for the pre-1995 period. Furthermore, Kamada and Sugo (2006) find that including stock prices in a VAR model leads to a faster increase in output following an expansionary monetary shock for different post-1995 sample periods. To analyse the importance of the stock market for the transmission of unconventional monetary policy we assess the responses of a second “tighter” QE-shock which is, in fact, identified by positively restricting the impulse responses of stock prices. This more narrowly identified “tighter” QE-shock allows us to compare the effects of unconventional monetary policy that, by construction, has an effect on stock prices to a less aggressive policy identified by the less tight QE-shock identified above.

The modified identification scheme used to identify this shock is summarised in Table 3. In particular, we specify stock prices not to decrease following an expansionary unconventional shock, while the remaining restrictions are equal to those explained in the last subsection. Thus, we intentionally take a stance on the importance of stock prices in the transmission of monetary policy when postulating this restriction, assuming an increased demand in and thus a rising price of these financial assets. This assumption is in line with the portfolio rebalancing argumentation of Meltzer (1995, 2001) and Mishkin (2001), which has already been outlined above. Moreover, Bernanke (1999) explicitly suggests a potentially important role of asset prices in the transmission of expansionary monetary policy in a zero-lower bound situation. For Japan the importance of stock prices for monetary policy has been documented by Oda and Okina (2001). In the case of outright purchases of long-term government bonds and equities as part of the QE-program conducted by the Bank of Japan, a certain share of the portfolios of banks and other institutional

investors is converted into base money.¹⁹ The consequent indirect reduction in portfolio risk offers new risk-taking possibilities in an attempt of utility maximizing investors to retain equilibrium. This may lead to an increased purchase of risky assets such as corporate bonds and equities. Of course, the outright purchase of bonds and equities by the Bank of Japan might also directly increase stock prices. The magnitude of this effect is conditional on, first, the quantity of long-term bonds and equities purchased by the Bank of Japan relative to the total asset supply, and second, the extent to which investors are willing to engage in increased risk-taking. Whilst the question concerning the effects of portfolio rebalancing is ultimately, of course, an empirical one, we want to highlight the exact effect a QE-shock might have that *does* in fact stimulate the stock market and thereby lead to an increase in stock prices.

Table 3: Identifying sign restrictions - three shocks and stock prices

Variable	Response to			Restriction horizon
	Demand shock	Supply shock	QE shock	
CPI	≥ 0	≤ 0		$k = 0, \dots, 11$
Stock prices			≥ 0	$k = 0, \dots, 11$
Ind. production	≥ 0	$-\epsilon \leq \cdot \leq \epsilon$		$k = 0, \dots, 11$
Exchange rate	≤ 0		≥ 0	$k = 0, \dots, 11$
Reserves			≥ 0	$k = 0, \dots, 11$
Call rate	≥ 0	$-\epsilon \leq \cdot \leq \epsilon$	$-\epsilon \leq \cdot \leq \epsilon$	$k = 0, \dots, 11$
Longterm yield				

¹⁹See Ueda (2010) for description of the amounts of longterm government bonds and equities bought by the Bank of Japan.

5 Data

In the benchmark case we include six variables reflecting the macroeconomic and monetary environment of the Japanese economy. These variables are the all-items CPI, an index of industrial production, the real effective exchange rate, the current account balances held by Japanese banks at the Bank of Japan, the call rate, as well as the 10-year government bond yield. We use monthly observations for the period of January 1995 to September 2010. The start of the sample period is motivated by the fact that the Bank of Japan first decreased nominal interest rates to below 1% during the course of 1995 and we are mainly interested in the effectiveness of unconventional monetary policy at near-zero interest rates.

As far as the monetary variables are concerned, we include the call rate as well as a measure of reserves. These two series have been obtained from the Bank of Japan's statistics website. The uncollateralized overnight call rate, which we include as monthly average, has been the traditional Bank of Japan's target rate and is available from July 1985 (Miyao, 2002). In 1995 the call rate was lowered from around 2% to 0.5%. Figure 3 above shows, however, that the call rate was not held constant entirely by the Bank of Japan over our sample period. Instead the Bank of Japan lowered the call rate to virtually 0% in 1999 under its official "Zero-Interest Rate Policy." In fact the call rate was slightly increased during 2000 when the Japanese economy seemed to recover somewhat. The call rate was subsequently lowered again when the worldwide recession caused by the bursting IT-bubble hit the economy soon afterwards in 2001.

Since then the Bank of Japan had implemented its official "Quantitative Easing Policy" whereby instead of targeting the call rate, the Bank of Japan has chosen as policy target the current account balances held as reserves by Japanese banks at the Bank of Japan. This is the kind of policy whose effects we study in this paper. In particular, to be able to identify the QE-shock we include the average outstanding current account balances held by financial institutions at the Bank of Japan. This is the part of the monetary base that can be referred to as reserves held at the central bank. Under the QE policy this variable has gained importance as the main operating target for the Bank of Japan.

In addition, we include a measure of the Japanese industrial production as a generally used indicator of economic activity as well as the all-items consumer price index. These variables are obtained from Datastream. Both indices have 2005 as base year. In our alternative specification, we additionally include stock prices. More specifically we use the Nikkei 225 stock price average which can be found at the statistics website of the Bank of Japan. All variables other than the

interest rates have been seasonally adjusted by X12-ARIMA.

6 Results

6.1 Benchmark case

In the benchmark case we only identify the QE-shock, which is our main focus of interest in this analysis. Figure 6 shows the impulse responses to this shock based on the restriction setup explained above. In the figure, the solid line denotes the median impulse responses from a Bayesian vector autoregression with 1000 draws, while the dotted lines indicate one-standard error confidence bands. The response of the current account component of the monetary base has been restricted not to decrease following the shock, so the immediate responses are not surprising by construction. In particular, reserves rise and stay above the zero line slightly longer than preset. As restricted, the call rate stays close to zero following the shock. After two years, however, it increases slightly by only about 0.008% approximately three years after the shock. Moreover, as specified, the exchange rate rises in response to the shock indicating a real depreciation of the Yen. The impulse response stays above the zero line somewhat longer than preset pointing to the validity of restricting this variable.

Importantly, as explained above, the variables of interest have been left unrestricted. Figure 6 shows that an expansionary shock leads to a significant increase of industrial production by about 0.5% after ten months. The effect of the shock lasts for about two years; after this period the response becomes insignificant. Moreover, the consumer price index shows a significant and positive response after about nine months. While the effect seems to be persistent, the response is rather weak reaching at most 0.15%. It is important to keep in mind that the permanent increase of the price level following the QE-shock does of course not imply a long-lasting response of inflation. Instead, the reaction points to a temporary increase in the rate of inflation that is followed by a return to its steady state. Finally, the longterm government bond yield has been left unrestricted. As can be seen in the figure, the longterm rate does not decrease following the unconventional shock but in fact rises significantly after about two months. First, this finding confirms the validity of our agnostic approach with respect to the longterm yield; identification of an unconventional shock by an explicit negative restriction on this variable may lead to misleading results. Second, the positive reaction of the longterm interest rate indicates that there may be other factors, such as increased inflation expectations or rising term premia,

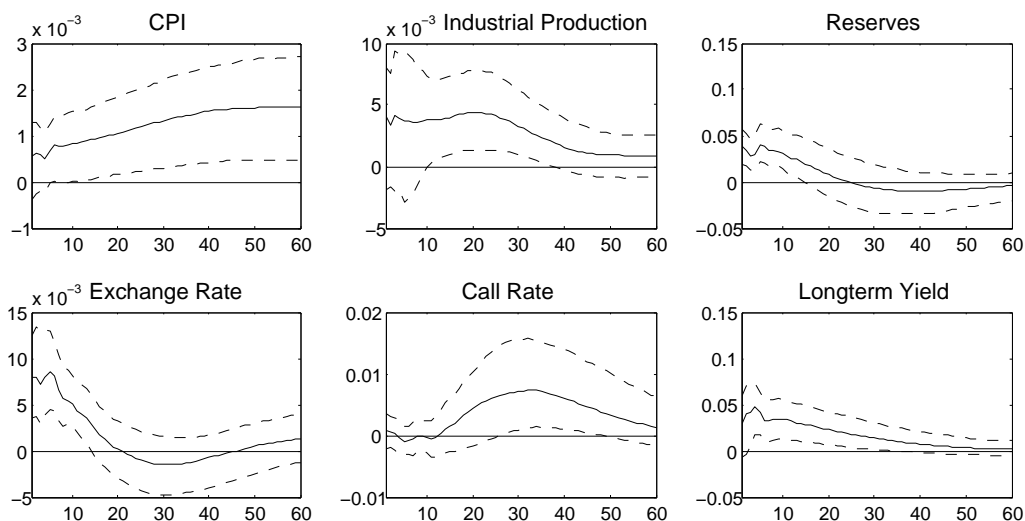


Figure 6: Impulse responses to a QE-shock

The figure displays responses to a QE-shock as identified in table 1. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 1000 draws, while the dotted lines indicate one-standard error confidence bands.

driving this variable in response to a QE-shock than changed expectations of future shortterm interest rates.

All in all, the results presented in Figure 6 suggest that the quantitative easing strategy adopted by the Bank of Japan in the early 2000's in a situation of near-zero interest rates has been somewhat successful in stimulating real economic activity, at least in the short run. However, while the price level rises following the shock, the Bank of Japan's second main goal motivating this policy, namely to permanently raise inflation and eventually to bring an end to Japan's deflationary episode, does not seem to have been achieved by the QE-policy.

6.2 Identifying three shocks

In order to prevent a confusion of the unconventional monetary shock with other disturbances related to business cycle fluctuations, our second identification scheme explained in the last section explicitly specifies two traditional shocks, a demand and a supply shock, next to the monetary shock. These shocks have been identified in line with liquidity trap theory in order to account for the zero-lower bound situation prevailing in Japan over our sample period. Figure 7 shows

the impulse responses to the first shock resulting from this identification scheme, the QE-shock. As can be seen in the figure, the qualitative results do not change after controlling for business cycle disturbances.²⁰ Industrial production still rises by up to 0.5%; however, error bands are somewhat wider. As in the benchmark case, the response of the consumer price index becomes significant after a while, however, the delay is somewhat longer. The responses of the other variables are very similar to those in the benchmark case. Thus, our extended identification scheme does not change our main conclusion that while production and prices could be increased temporarily by quantitative easing measures, the longterm inflation environment has not been affected by this policy. Moreover, the response of the longterm yield is robust to this extended specification confirming that longterm rates do in fact not fall after such an unconventional shock.

The second shock we identify is a positive demand shock. Since this shock is mainly identified for the purpose of controlling for demand disturbances and the reactions to it are not of particular interest, most variables have been restricted. In particular, we specify the CPI and industrial production not to decrease for one year following the shock. Moreover, the call rate increases after a positive demand disturbance, as suggested by simple economic theory. Impulse responses to this shock are shown in Figure 8. While the response of reserves is insignificant, the longterm yield shows a temporary positive reaction, which is in line with a positive demand shock. Similarly, the variables of interest have been restricted in order to identify the third shock, which is a positive supply disturbance. As specified, the CPI decreases following the shock. Industrial production and the call rate are restricted to remain close to their steady state values after the shock. In fact, Figure 9 shows that the impulse responses for these two variables stay close to zero and are insignificant over a much longer horizon than restricted. This points to the validity of our identification scheme based on liquidity trap theory.

²⁰As in the last subsection, the solid lines denote the median impulse responses from a Bayesian vector autoregression, while the dashed lines indicate one-standard error confidence bands. For the extended identification scheme we only use 500 draws, which seems to be sufficient for inference (Scholl and Uhlig, 2005).

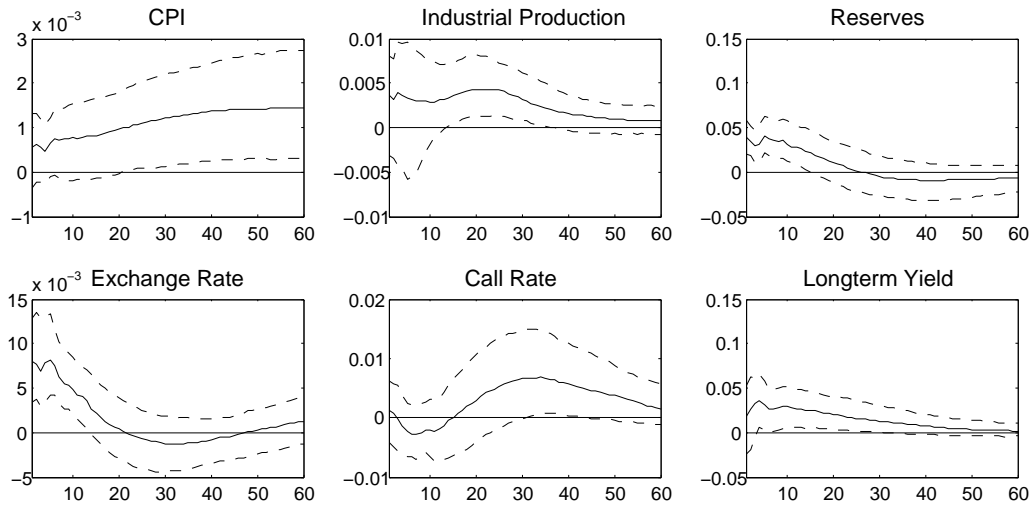


Figure 7: Three shocks - responses to a QE-shock

The figure displays responses to a QE-shock as identified in table 2. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

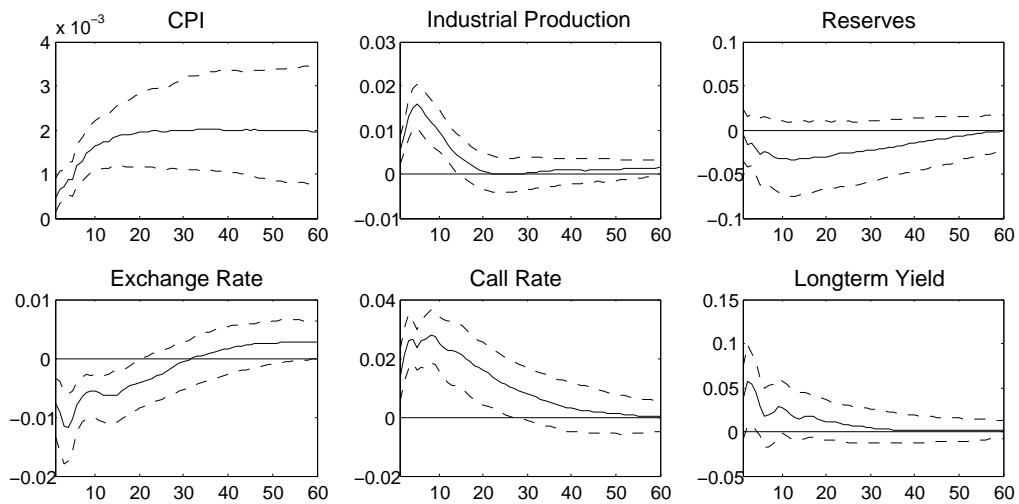


Figure 8: Three shocks - responses to a demand shock

The figure displays responses to a demand shock as identified in table 2. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

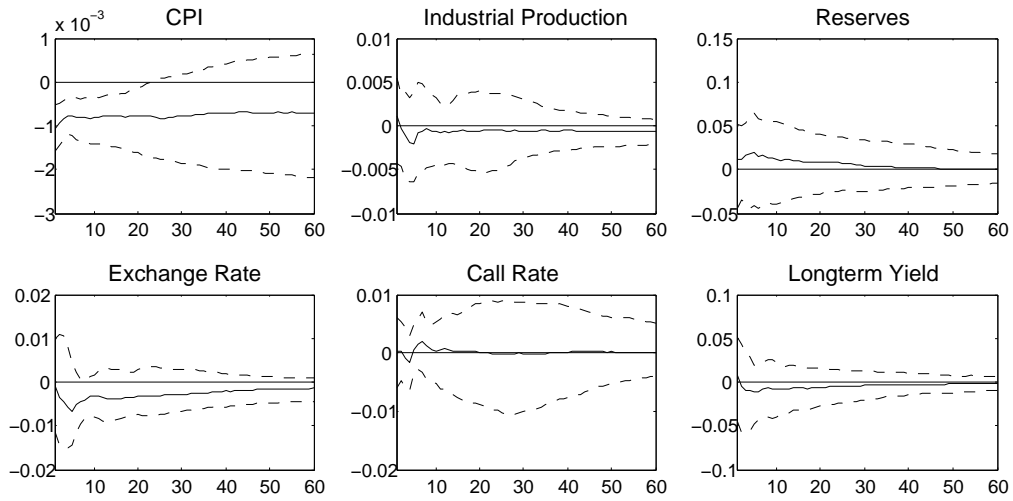


Figure 9: Three shocks - responses to a supply shock

The figure displays responses to a supply shock as identified in table 2. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

6.3 Including Stock Prices

Because the importance of stock prices in the transmission of monetary policy in Japan, at least during normal times, is well documented in the literature we additionally estimate a second specification including the Nikkei stock price index. In order to assess whether the development of stock prices is relevant for the transmission of unconventional monetary policy at the ZLB we identify a modified expansionary QE-shock which, by construction, has a positive impact on the stock price index. Figure 10 shows the impulse responses to such an unconventional shock.

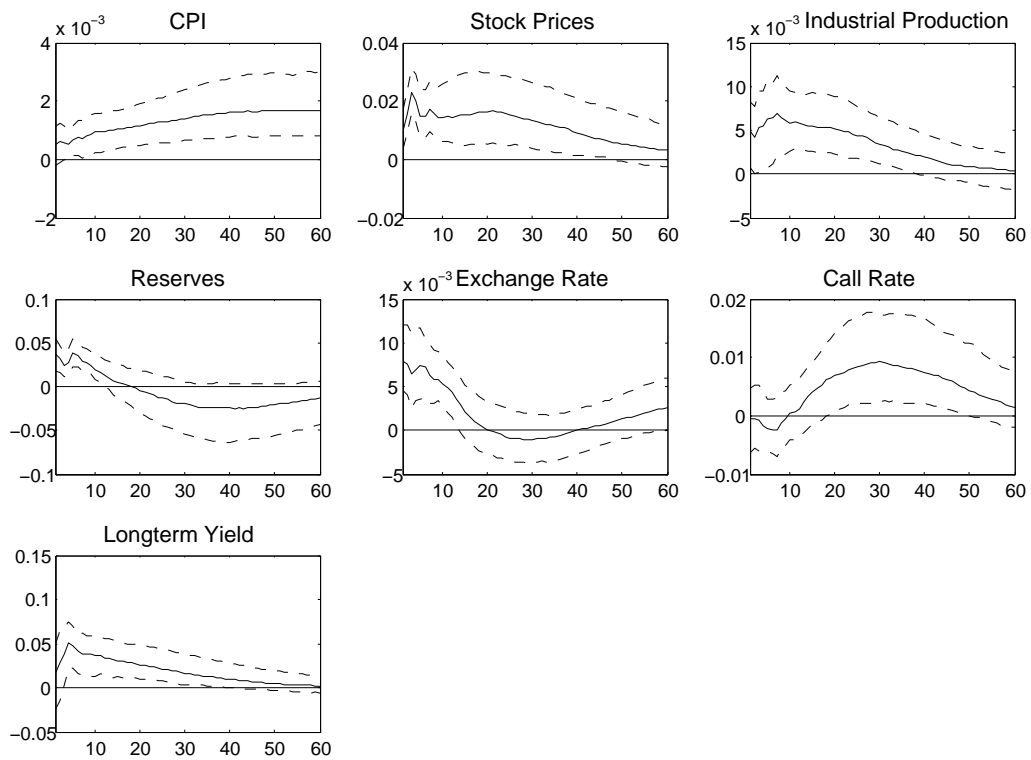


Figure 10: Three shocks - responses to a QE-shock with stock prices included in VAR. The figure displays responses to a QE-shock as identified in table 3. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

As preset, stock prices increase on impact and stay above the zero line for several years - considerably longer than restricted. Moreover, the response is rather strong amounting to over 2% in the first months following the shock. This suggests that stock prices indeed respond to a monetary base shock pointing to the validity of restricting this variable to increase. As expected, the responses of the other restricted variables are very similar to the results from the 3-shock scenario excluding stock prices shown in the last subsection. Moreover, the longterm yield shows a similar response to this modified QE-shock. Interestingly, however, the figure displays that our variables of interest, CPI and industrial production, show a more pronounced reaction to this unconventional disturbance. First, the reaction of the CPI is more immediate than for the more general QE-shock identified above. Second, industrial production increases already on impact and rises to 0.7% after several months. The effect lasts for about three years, which is considerably longer than for the benchmark QE-shock.

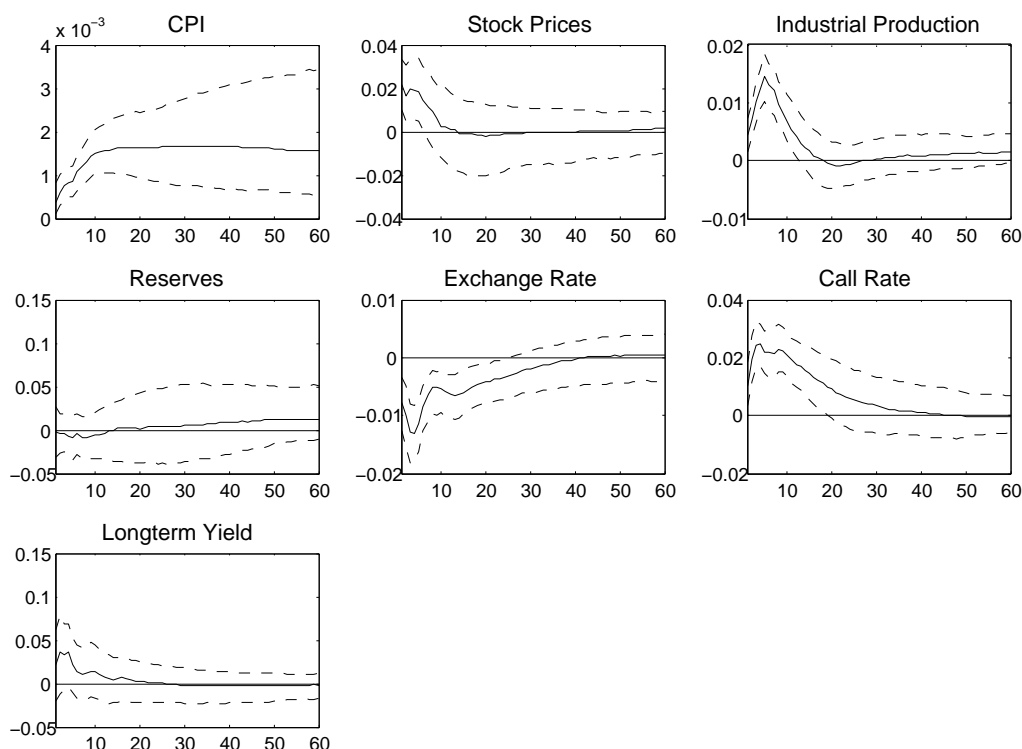


Figure 11: Three shocks - responses to a demand shock with stock prices included in VAR. The figure displays responses to a demand shock as identified in table 3. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

The identification setup of the traditional shocks have been left unaltered. Figures 11 and 12 show that the impulse responses to these business cycle disturbances are very similar for the specification including stock prices. As expected, the stock price index increases significantly following a positive demand shock. However, the reaction becomes insignificant after about six months. The positive supply shock does not lead to a significant effect on stock prices. This is in line with our identification strategy restricting industrial production not to react to the supply shock, which is consistent with a ZLB situation.

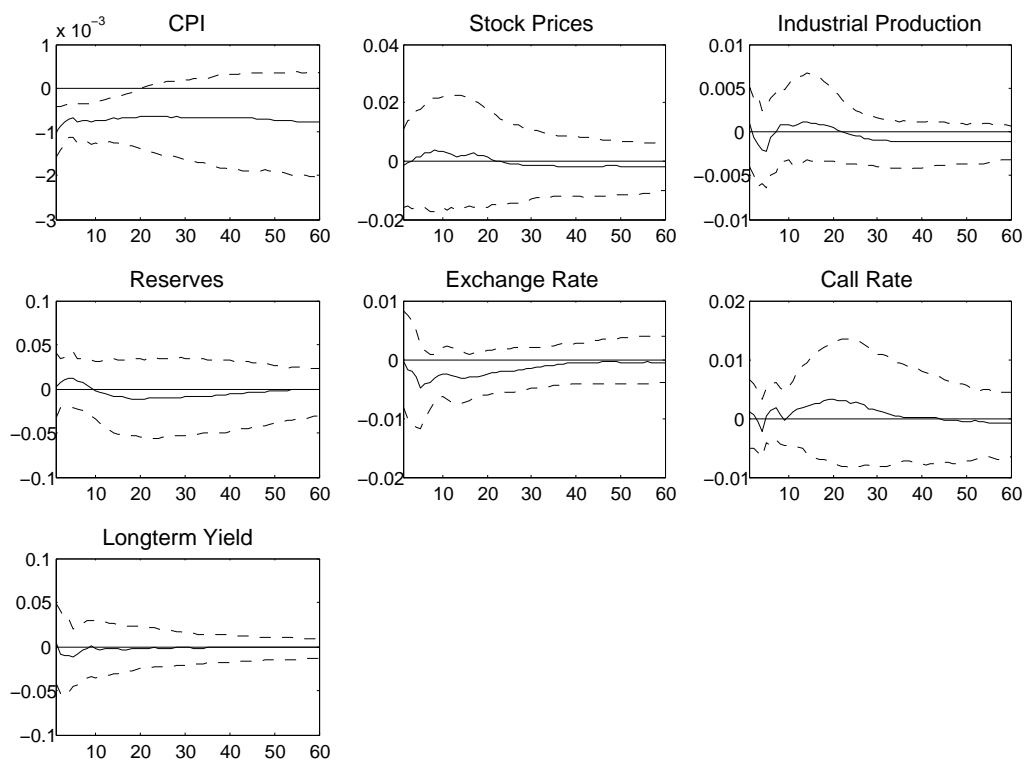


Figure 12: Three shocks - responses to a supply shock with stock prices included in VAR. The figure displays responses to a supply shock as identified in table 3. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 500 draws, while the dotted lines indicate one-standard error confidence bands.

6.4 Robustness

As noted by, for instance, Uhlig (2005) it is difficult to base the choice of the appropriate restriction horizon on economic theory resulting in some degree of arbitrariness in specifying this parameter. We therefore check sensitivity of our results to this choice by estimate the benchmark model (for the 1-shock case) for different restriction horizons. Figure 13 shows the impulse response functions for our variables of interest, CPI and industrial production, for lower restriction horizons compared to the benchmark model $k = 6$ and $k = 9$ (shown in the first and second row, respectively) and for longer horizons $k = 15$ and $k = 18$ (displayed in the third and fourth row, respectively). It can be seen in the figure that our main results are qualitatively insensitive to variations in k ; industrial production shows a significant and positive response at least over several months. However, the magnitude of this increase differs among the respective cases. While for $k = 6$, the positive impact on economic activity is significant only with a delay of about two years and vanishes rather fast following the shock, the response is stronger and lasts somewhat longer for $k = 9$. Compared to the benchmark case, $k = 12$, the response is somewhat stronger and lasts for a longer time period for longer restriction horizons. The response of the consumer price index seems to be slightly more sensitive with respect to the restriction horizon. For a less restrictive identification scheme with $k = 6$ the CPI does not react significantly, while it responds with a lag for $k = 9$.

A further robustness check concerns the number of lags of the endogenous variables included in the regressions. While different lag length criteria tend to suggest a shorter lag length, we include six lags in our benchmark case to be sure to sufficiently capture the dynamics of the model. To check robustness of these results, we estimate the benchmark model additionally with a lag length of two, four and eight, respectively. Being constraint by a relatively short sample period and the fact that we are estimating a rather large number of parameters, we do not try an even longer lag length. Results of this robustness check are given in Figure 14, which shows the impulse response functions for our variables of interest for the respective number of lags. The figure shows that our results are largely robust to this variations. In particular, while error bands are somewhat wider for the response of industrial production for lag length six and eight, the response is significant in all cases. However, for model including two lags the CPI shows an insignificant response indicating, again, that the effect of a QE-shock on this variable seems to be quite sensitive to variations in the econometric specification.

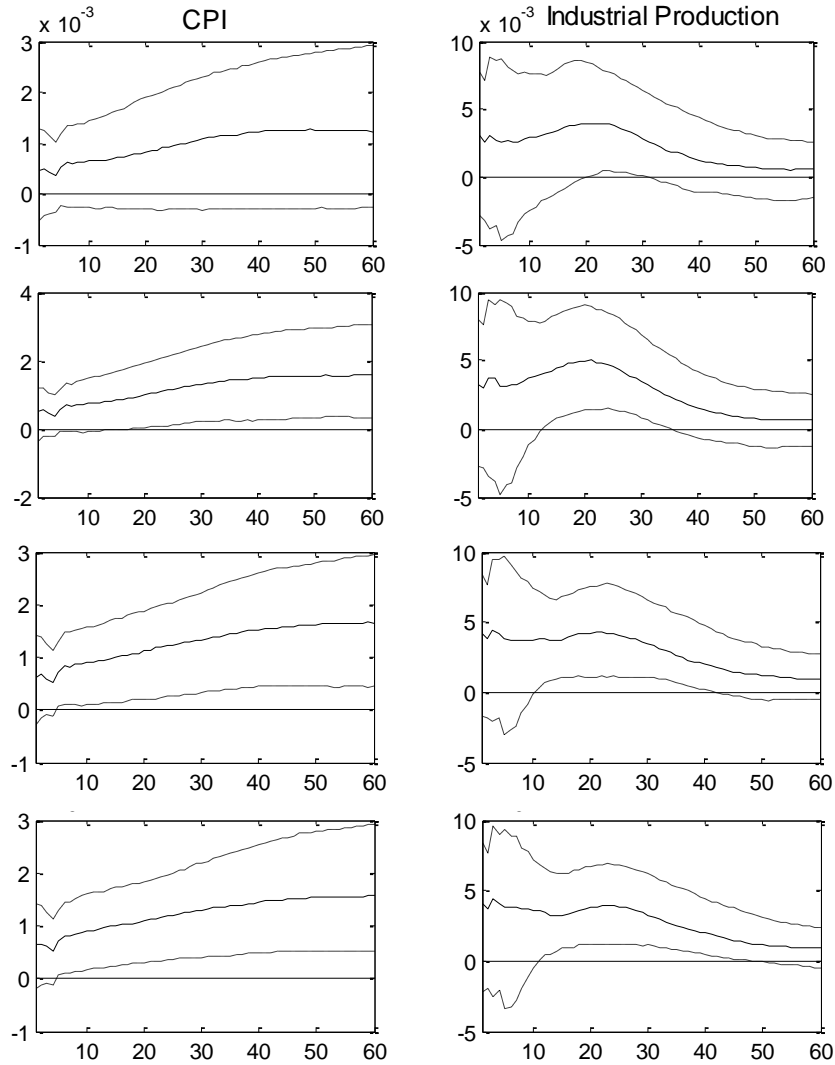


Figure 13: Impulse responses to a QE-shock - varying the restriction horizon
The figure displays responses of the CPI and industrial production to a QE-shock according to the identification scheme described in section 4.1. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 1000 draws, while the dotted lines indicate one-standard error confidence bands. The respective rows correspond to $k = 6$, $k = 9$, $k = 15$ and $k = 18$, respectively.

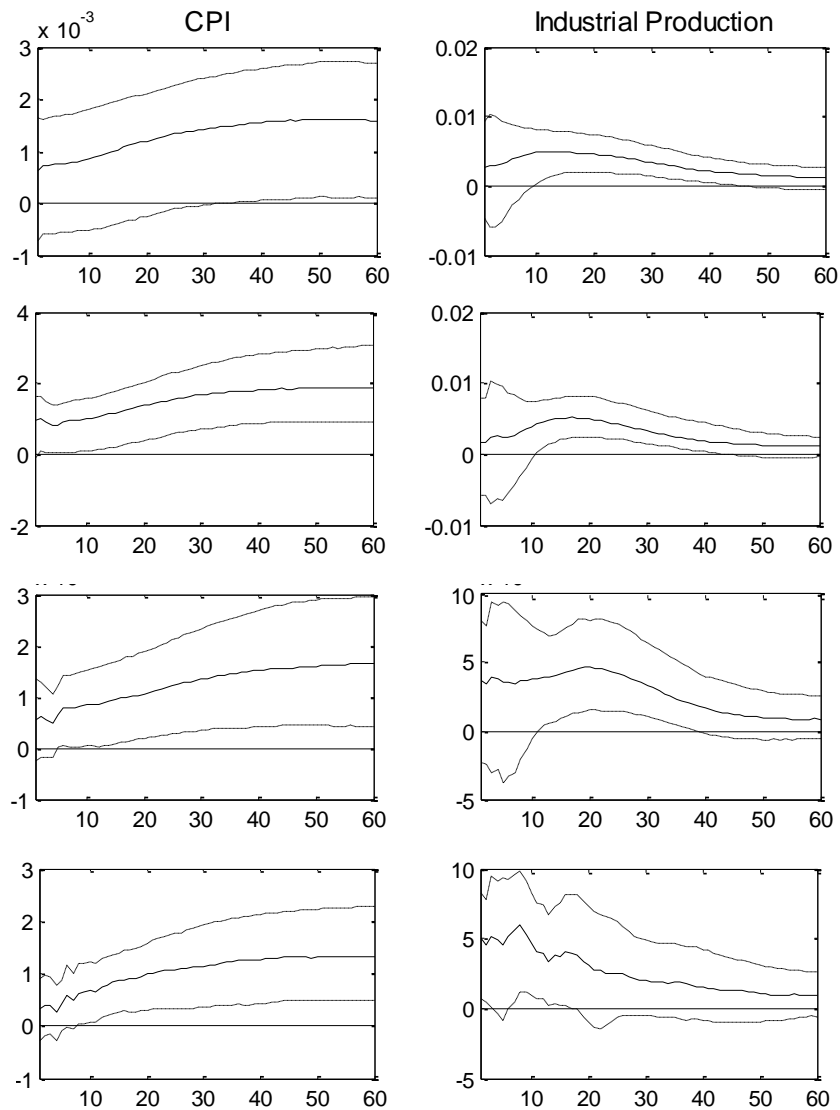


Figure 14: Impulse responses to a QE-shock - varying the lag length

The figure displays responses of the CPI and industrial production to a QE-shock according to the identification scheme described in section 4.1. The solid lines denote the median impulse responses from a Bayesian vector autoregression with 1000 draws, while the dotted lines indicate one-standard error confidence bands. The respective rows correspond to lag lengths of 2, 4, 6 and 8, respectively.

Finally, we note that our analysis is pretty robust with regard to different measures of macroeconomic variables and sample periods. Using for instance the core-CPI and a longer sample period from 1986M1 does not lead to contradictory results. In fact, whilst detailed results differ slightly the main message that a QE-shock leads to a significant but temporary increase in industrial production and a significant and permanent increase in the price level - though not inflation - remains.²¹

7 Discussion and Conclusion

The primary objective of this paper has been to agnostically assess the *real* effects of QE measures adopted by the Bank of Japan for a liquidity trap episode. Our empirical results show that unconventional monetary policy implemented by an increase of bank reserves can positively affect real economic activity and the price level - at least temporarily - even when the economy is in the liquidity trap. Moreover, this stimulating effect of unconventional monetary policy is even stronger when we account for an explicit reaction of stock prices. However the QE-shock we identify does not lead to a permanent increase in the rate of inflation. Thus, our results indicate some positive effects of the quantitative easing policy in Japan, but not the required rise of inflation that should lift the Japanese economy out of the liquidity trap. However, we need to repeat our caveat that the shock we consider is by its very nature a “small” shock, i.e. one that is econometrically not supposed to lead to parameter changes in our structural estimates. The economic implication is therefore that the shock we study is necessarily one where the economy is still in the liquidity trap after the shock. Given the situation and data of the Japanese economy we believe this is reasonable. Otherwise regime-changing models would need to be estimated, but our results so far do not provide any evidence of important structural changes.

Even though a detailed analysis of particular transmission channels of quantitative easing is beyond the scope of this study, our results suggest some tentative statements concerning the transmission of unconventional policy in Japan. Bernanke and Reinhart (2004) define three channels through which a base money expansion may potentially affect the economy. The first channel involves portfolio rebalancing effects a la Meltzer (1995) that have been discussed above. If money and other assets in the economy are imperfect substitutes, a base money injection induces investors to shift part of the additionally liquidity into other asset investments reducing

²¹We have carried out robustness tests with alternative variables like core-CPI or the Tokyo stock index, as well as varied the beginning of our sample from 1995 to 1986 and 1990. Whilst detailed results differ slightly, the message of our paper is robust to these changes. Results are available from the authors upon request.

the corresponding yields. Lower yields on these (longterm) assets may in turn stimulate private investment and thus economic activity. Second, QE measure may change expectations concerning future shortterm interest rates. A commitment to a permanent high level of reserves may even be more credible and thus more effective than an announcement of permanently low interest rates because it is more visible. Theoretically, via the expectations hypothesis, lower future shortterm rates may lead to decreasing current longterm rates, which again may have stimulating effects. Finally, a base money expansion can also have expansionary fiscal effects, again under the assumption that the public expects the measures to be relatively long-lasting. Since the central bank replaces publicly held interest-bearing government debt with currency on its balance sheet, the public may expect a lower effective tax burden. This channel is analyzed in Auerbach and Obstfeld (2005) by means of a DSGE model for Japan. A further channel, mentioned for instance by Oda and Okina (2001) also refers to portfolio balancing effects but postulated rather direct effect. Liquidity injections by the central bank lead to a reduction in portfolio risk, which offers new risk-taking possibilities in an attempt of utility maximizing investors to retain equilibrium. This may, in turn, lead to an increased purchase of risky assets such as corporate bonds and equities. Our empirical analysis shows that the longterm government bond yield does in fact not fall; instead it rises slightly. Therefore, our results suggest only minor importance to the classical portfolio rebalancing channel and the expectations channel in Japan. Instead our results imply a more direct portfolio shift by investors towards riskier assets such as, most notably, equities. Finally, inasfar as one believes other advanced economies are currently in a similar situation to Japan, we argue that our results are interesting not only for the Japanese economy, but also for those other economies where monetary policy is currently constrained by the ZLB.

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