Quantitative Easing in Japan and the UK An Econometric Evaluation of the Impacts of Unconventional Monetary Policy on the Returns of Aggregate Output and Price Levels

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Abstract

The research finds that the actions of the BoJ were more successful in raising aggregate levels of output and price than those of the BoE. In Japan, all financial variables analysed were found to transmit the benefits of QME, whilst in the UK the effect only occurs through the stock market and bank lending. The overall results however, are found to be small.

To analyse the effects of the most recent policies of QME by the Bank of Japan (BoJ) and the Bank of England (BoE) on aggregate levels of output and prices in Japan and the UK, We perform two-step VAR and VEC analysis to first identify the effects of QMEP before determining the financial transmission mechanism by which these effects take place.

This analysis aims to make contribution to the research surrounding the effects of QMEP. It is wholly reasonable to presume that both the Japanese and UK economies may experience similar economic difficulties in the future and further understanding of the effects of QMEP will enable more targeted policy decisions to be implemented to effectively protect stable inflation levels and stimulate future economic growth.

Key Words: Quantitative Easing, Monetary Policy, Bank of Japan, Bank of England, Vector Auto-Regression, Vector Error Correction.

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1. Introduction

Traditionally, central banks have used interest rate policy to achieve targets for economic growth, with wide agreement that it is economically advantageous for a country to experience a small amount of positive inflation.[3] A high inflation rate can reduce the public's ability to make accurate long term financial and economic decisions [Federal Reserve 2015] while conversely, a lower rate of inflation increases the probability that an economy can fall into deflation under weakening economic conditions. The economic utopia of price stability and optimal employment levels, which is sought under optimal inflation, is often referred to as a 'Goldilocks Economy' [Gordon 1998: 2].

When weakening economic expectations lead to a decrease in lending by financial institutions, central banks reduce the overnight call rate to induce these institutions to increase lending again. Conversely if high lending begins to cause an increase in inflation, rates can be increased, which in turn leads to a fall in lending due to the increased cost [The Economist 2015].

Over the last two decades, owing to changing economic conditions, a number of central banks around the world experienced a situation whereby reducing interest rates has not proven sufficient to stave-off an economic downturn. Many of these institutions have instead purchased a variety of financial assets through a policy known as Quantitative Monetary Easing (QME) in attempts to stimulate economic recovery and growth. The earliest attempt at QME came in Japan in March 2001, two years after the Bank of Japan (BoJ) had adopted a zero interest rate policy (ZIRP) in February 1999 [Honda, Kuroki and Tachibana: 2007].

In the late 1980's, the Japanese economy was booming. Success of its automotive and consumer electronics industries was the engine behind remarkable levels of growth in the 20th Century following World War II. Japanese real estate and stock prices soared with the Nikkei 225 stock average reaching an all-time high in 1989. But the economy overheated, and the asset price bubble burst, causing the Nikkei to lose 60% of its value in less than three years [BubbleBubble 2013]. Even by the end of the 20th century, the Nikkei 225 index was still less than half of its 1989 peak [Economic Research: St Louis Fed 2015], leading to this era being called Japan's 'lost decade.'

[3] In macroeconomics, the Taylor rule links the interest rate to deviations of inflation from its target and the output gap (deviations of output from its potential) [Taylor: 1993], effectively stipulating the amount a central bank should change nominal interest rates in response to changes in inflation, output and other economic factors [Hofmann and Bogdanova: 2012].

For almost 30 years the Japanese economy had grown at an astounding average of 6.37% per annum but between 1991 and 2002, annual real GDP growth registered a paltry 1.00% on average [Oda and Ueda 2007].

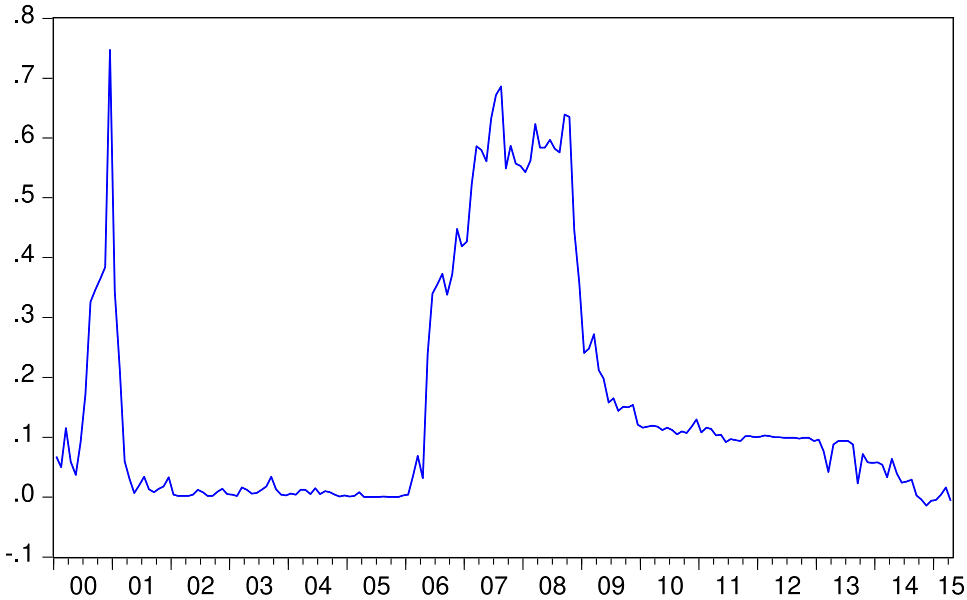
In an attempt to halt the deflationary spiral, the BoJ steadily lowered interest rates to zero but its actions failed to reignite Japanese economic growth [Girardin and Moussa 2008: 2]. In 1999 the BoJ faced the Zero Lower-Bound (ZLB) on interest rates leaving it with no further scope to cut rates to encourage consumption and stop deflation.[4] Then, with the Japanese economy beginning to show signs of improvement, the ZIRP was lifted in August 2000 (Figure 1). This recovery however was not sustained and in March 2001 the BoJ became the first central bank to introduce a programme of QME (QMEP), switching it's major target for monetary operations from the overnight call interest rate to the 'outstanding balance of current accounts held by Japanese commercial banks at the BoJ' [FRBSF 2006].[5] The overall objective was to achieve price stability and sustainable growth [Honda, Kuroki and Tachibana: 2007].

The policy of QME (QMEP) executed by the BoJ was constructed with three pillars: (a) to publicly commit to maintain accommodative monetary policy until inflation rates stabilised; (b) to set a quantitative target for BoJ current account balances (CABs) in order to increase the monetary base; (c) to support this quantitative objective by purchasing Japanese Government Bonds (JGBs) [Girardin and Moussa 2008: 2]. The aim was to tackle persistent deflationary pressure. In February 2001 the actual size of CABs held by the BoJ was less than the target amount [Kimura et al 2002]. This QMEP continued until March 2006 when, with the Japanese economy showing signs of recovery, the policy was largely reversed [Andolfatto and Li 2014]. The BoJ once again began to target short-term interest rates.

[4] Japan's liquidity trap has been heavily documented by a number of authors including Krugman, Dominque and Rogoff (1998) and Imawura, Kudo and Watanabe (2006).

[5] This should not be misunderstood to mean the current account of the balance of payments. Rather in this context, the term 'CAB' refers to the balance sheet of the central bank. This terminology is used to remain consistent with other published works, namely that of Honda, Kuroki and Tachibana, which is the main inspiration for this research.

Figure 1: Nominal Interest Rate (%) 2000 – 2015 (Japan)



Source: Bank of Japan

It is inherently difficult to isolate the specific effects of a QMEP on an economy; a statement proven by the many conflicting conclusions that have been the result of much economic and financial research. There appears to be general agreement that QME can have a positive economic effect (evidenced in part by its continued use in major economies today), but the exact nature of these effects is the subject of much debate [Klyuev, de Imus and Srinivasan: 2009].

Since the BoJ's initial QMEP, similar policies have been adopted by a number of central institutions including the US Federal Reserve, the Bank of England (BoE) and most recently the European Central Bank [BBC 2015]. In addition, the BoJ itself has embarked upon further purchases of a variety of financial assets in an attempt to stimulate economic growth following the 2007 global economic crisis.

In October 2010, faced with a slowing recovery and an appreciating yen, the BoJ announced a new asset purchase programme, under a policy of Comprehensive Monetary Easing (CME). CME differs from QME through the purchase of not only risk-free assets such as government securities, but also risky assets. In the case of Japan in 2010, this included the purchase of commercial paper; corporate bonds; real estate investment trusts (REITs) and exchange-traded funds (ETFs) [Lam 2011]. This policy contrasts with the monetary easing policies of other central banks, which focus solely on the purchase of risk-free assets [Lam 2011].

The devastating 2011 Great East Japan earthquake in Tōhoku led the BoJ to pump ¥15tn (£114bn) into the Japanese economy in a bid to stabilise markets following the surge in credit risk [Bloomberg 2011]. In addition, the Bank doubled the size of its asset purchases to ¥10tn and offered to buy ¥3tn (£23bn) worth of government bonds from lenders via repurchase agreements, in an attempt to protect these assets.

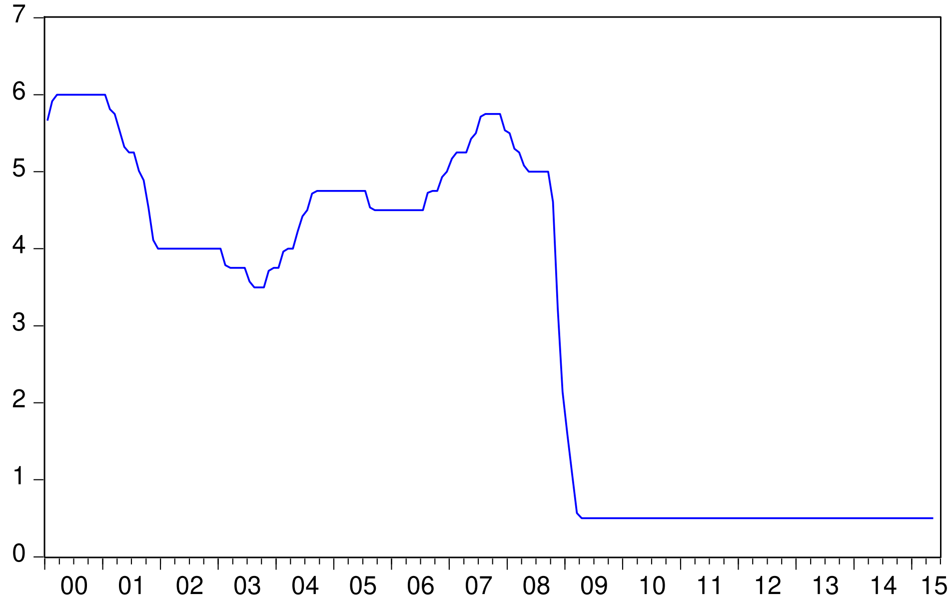
In April 2013, the BoJ announced a further QMEP to expand Japan's monetary base to ¥270tn (£1.876tn) in just two years (double the then current figure of ¥135tn (£938bn)). The Bank announced measures to increase purchases of long-term JGBs, focussing on those with longer maturity dates (up to 40 years) and also to remain active in the stock market through further purchases of REITs and ETFs [Forbes 2013].

Most recently, in October 2014, the BoJ announced an unexpected expansion of its QMEP, committing to increase Japan's monetary base by ¥80tn (£445bn) per year in an attempt to induce inflation following a dampening effect caused by an increase in consumption tax earlier that year. The policy appears to have had a positive effect on a number of areas, with the Nikkei stock index reaching new highs and a fall in the value of the yen leading to 'imported' inflation, although the BoJ has not yet achieved it's 2% target [The Economist: 2014]. A comprehensive timeline of monetary policy activity by the BoJ for the period 2007-2014 can be found in Appendix 1.

In the UK, the BoE has also implemented a policy of QME in recent years, following its first venture in this direction in March 2009, largely as a result of the impacts of the 2007 financial crisis. The BoE responded rapidly to swift tightening of credit conditions by quickly lowering the Bank Rate in an attempt to regain market confidence. Although conventional monetary policy in the UK had been successful in achieving low and stable inflation, it had not stopped the occurrence of asset market bubbles and there was concern that nominal spending levels were too low to achieve the inflation target. [Joyce et al 2012]. The reasoning behind this policy was clearly subtly different to the motivations of the BoJ.

At this time, the UK interest rate registered at 0.5% (Figure 2) and the UK Monetary Policy Committee (MPC) determined that a reduction in rates below this level would not be practical [Bank of England 2015]. The Taylor rule would endorse negative interest rates and so similarly to Japan, the UK was facing the ZLB whereby economic agents would prefer to hold cash than face negative rates. Secondly, large losses incurred during the financial crisis called into question the solvency of a number of financial institutions, damaging the generally dependable link between changes in the policy rate and those of the market.[6] To combat these challenges, the BoE began to buy UK government bonds (UKGBs) from the private sector (non-bank) in an attempt to impact yields on a range of financial assets, particularly "bonds issued to finance lending to companies and households" [Joyce et al 2012]. By January 2010 the BoE had bought assets totalling £200bn[7] (largely UKGBs), reporting that this action boosted the UK's annual economic output by as much as 2% [Bridges and Thomas 2012].

Figure 2: Nominal Interest Rate (%) 2000 - 2015 (UK)



Source: Bank of England

In October 2011, the MPC announced a further £75bn of gilt purchases, taking its total to £275bn. Gilts purchased were of the same class as under the BoE's previous QMEP and purchases were made over the course of four months. With a falling inflation level, a further £50bn of purchases was announced in February 2012 and again in July 2012, taking the total value of bonds bought between March 2009 and October 2012 to £375bn [Bank of England 2015] in a further attempt to achieve the 2% inflation target. The BoE has stated it will not commence unwinding of this QMEP "at least until interest rates have increased to a level from which they can be cut materially" [House of Commons Report – Quantitative Easing 2014], which is interpreted as a time when conventional monetary policy can again be used to achieve desired levels of inflation. A full account of BoE QMEP activity can be found in Appendix 2.

6 It should be noted that asset purchases by the BoE were not designed to solve liquidity problems within the banking system but actually to affect the yields on a range of assets [Joyce et al 2012].

7 This figure represented around 14% of UK GDP [Kapetanios et al 2012].

It is clear then, that both the BoJ and the BoE have implemented numerous rounds of QME with varying mechanisms. The purpose of this research is to analyse the most recent implementations of QME in Japan and the UK to determine whether use of the policy can be justified as a means for combating deflation and stimulating economic growth. This will also allow inferences and predictions to be made of the success of Japan's most recent QMEP, announced last year. Additionally, this work will attempt to understand the transmission mechanisms by which these varied policies of QME influenced both aggregate price levels and output. It is wholly reasonable to presume that both the Japanese and UK economies may experience similar economic difficulties in the future and further understanding of the effects of QMEP will enable more targeted policy decisions to be implemented to effectively protect stable inflation levels and stimulate future economic growth.

The remainder of the paper is therefore structured as follows. Section 2 offers a comprehensive literature review covering previous research into QME. Section 3 provides description of the macro fundamental data to be used in this analysis with relevance to the potential transmission mechanisms by which QMEP affects both aggregate price levels and output. Section 4 outlines the methodology adopted to analyse the data, and initial analysis of the impact of QME on output and price levels. Section 5 discusses transmission mechanisms for QME, and results of econometric models together with their interpretation. Section 6 concludes, providing comment on extensions of the current research and future analysis of the impacts of QME.

2. Literature Review

The existing literature has largely aimed to provide insight in two areas, evaluating the impact of monetary policy on a broad range of macroeconomic or financial indices and analysing the transmission mechanisms by which these effects take place. Since the seminal work by Sims (1980)[8], a majority of studies on the effectiveness of monetary policy choose to employ vector autoregressive (VAR) techniques, with early VAR analysis focussing on the macroeconomic effects of monetary policy. The work of Miyao (2002) focussing on traditional monetary policy techniques has served as a benchmark for future research surrounding QME. Miyao's research uses a simple VAR model including the first differences of interest rates, money, stock prices and output to analyse the effects of monetary policy on real output from 1975 – 1998. Miyao found

[8] Sims argued that traditional macroeconomic models provide implausible identifications, particularly when analysing monetary transmission. This widely cited argument (the "Sims critique"), has led to publication of swathes of research using varied identification methods.

monetary policy shocks to have persistent effects on real output, particularly during the turbulent period surrounding Japan's "bubble" in the late 1980's.

Two important works by Fujiwara (2003, 2004) use quarterly and monthly data on a number of macroeconomic variables to determine the structure and transmission channels of monetary easing across subsets of a larger time series spanning over 20 years from 1980 to 2003. First, Fujiwara (2003) analyses the consumption and investment channels as transmission mechanisms for monetary policy using VAR analysis. The findings suggest that the investment channel is more important[9] and the result is confirmed through the estimation of Dynamic Stochastic General Equilibrium (DSGE) models which are employed to determine if the impulse responses estimated by the VAR can be considered theoretically realistic. More detailed information surrounding the transmission channels of unconventional monetary policy will be provided in Section 3 of the paper, while a useful diagram used in Joyce et al (2003) can be found in Appendix 3.

Secondly Fujiwara (2004) employs a Markov switching (MS) model to determine structural breaks within the time series. The Markov model identifies regime shifts within data sets by allowing intercepts, coefficients and variance-covariance matrices to switch according to a hidden Markov chain. Under the initial assumptions of the regimes overlying the data, the method outputs probabilities of each regime for all time periods can be interpreted as structural breaks. Fujiwara combines the MS methodology with a VAR approach, incorporating variables for output, the price level, commodity prices, interest rates and money stock, to determine the transmission of monetary policy through the interest rate channel.[10] The paper concludes that a structural break exists during the 1990's, around the time the BoJ resumed the ZIRP and that monetary expansion had some slightly positive effects on overall economic output and the price level, but that it was weaker after this structural break.

Honda, Kuroki and Tachibana (2007) (HKT) construct a number of VAR models using prices, output and the monetary policy instrument, enabling initial assessment of the effect of QME on these fundamental macroeconomic variables. The research finds that a QME shock creates a persistent increase in output but that the response of prices

[9] The investment channel specifically relates to a mechanism whereby an increase in interest rates causes a reduction in the cost of capital thereby causing an increase in investment [Fujiwara 2003].

[10] Fujiwara follows popular convention by using the Cholesky decomposition to identify the ordering of macroeconomic explanatory variables within the VAR framework. The non-diagonal properties of the covariance matrix underlying the VAR model make it impossible to shock one variable whilst keeping the others fixed. The recursive Cholesky method imposes a downwards causal structure beginning from the upper-most variable, but not from the bottom up [Lin: 2006].

(measured by core CPI) is not statistically significant for the period tested. In addition, the authors perform further VAR analysis to determine the transmission mechanism through which these impacts occur. By re-estimating the model including a number of financial variables in isolation from each other, HKT find that a QME shock causes a persistent increase in stock prices, indicating this to be the transmission mechanism through which the QMEP was effective.

Using monthly observations between 1995 and 2010, Schenkelberg and Watzka (2011) construct Structural VAR (SVAR) models including prices (CPI and Industrial Production Index (IPT)), reserves and the 10-year yield of JGBs as regressors to analyse the impact of Japanese QME at the ZLB on real economic activity. By imposing on the regressors, a particular set of sign restrictions based on predictions of DSGE models, the authors are able to more accurately isolate the effects of the QMEP. Their results suggest that the BoJ's QMEP stimulated economic activity in the short run, but did not result in an increase in inflation.

Clearly the inclusion of interdependent macroeconomic variables can be problematic when making inferences following econometric modelling. Yamasawa (2006) attempts to overcome this, by employing the Generalised Method of Moments (GMM) procedure to avoid the burden of imposing various unwanted assumptions. Using this methodology, Yamasawa finds the BoJ's QMEP in 2001 to have a negative impact on GDP as the initial decline in interest rates was not matched by the increase in the monetary base.

Bowman et al (2011) also use a GMM procedure to overcome endogeneity biases in their study of the impact of QMEP on bank lending in Japan between 2000 and 2009, but they revert to the use of OLS techniques, judging the benefits of the GMM method to be slim. Although GMM is asymptotically consistent, its generality means its statistical power suffers under smaller samples. Wooldridge (2001) comments that robustness techniques to account for issues such as heteroskedasticity and serial correlation tend to minimise the actual benefits of using GMM techniques.

Many researchers have also investigated the possible existence of structural breaks which Moussa (2011) argues can 'characterize the monetary transmission mechanisms." Popular studies such as those of Jinushi et al (2000) and Miyao (2000) determine these breaks exogenously using dummy variables and subsample analysis. Although this can often be considered a crude measure of determining differing structures within the data, in the case of central bank policies when the timings of both announcement and implementation are well known it has become widely acceptable to use this method.

Nonetheless, alternative methods treat structural breaks as endogenous. As mentioned, the work of Fujiwara (2004) uses an MSVAR framework to estimate a structural break within the effectiveness of Japanese monetary policy, allowing endogenous determination of both the timing and length of the pre- and post-monetary policy periods. The Markov model first proposed by Hamilton (1989) is frequently used to determine expansionary and recessionary periods within macroeconomic time series data and works by expressing structural breaks in terms of Markov regime shifts, which are a product of the estimation process.

In addition to the plethora of research surrounding the Japanese QMEP, since the implementation of similar policies in the UK in 2009, a number of researchers have endeavoured to reproduce and enhance previous analysis, adapted to model impacts of QME by the BoE.

Joyce et al (2011) construct both VAR and multivariate GARCH (GARCH-M) models to examine the impact of the BoE's QMEP on UK asset prices. The baseline VAR model uses a vector of endogenous factors as the dependent variable, comprising of shares of total wealth held in assets and their monthly excess returns (for sterling-grade investment corporate bonds, gilts, M4 and UK equities). This is regressed upon a vector of exogenous variables to capture the state of the economy such as the slope of the yield curve and RPI inflation. The results indicate that QME had a large impact on equity prices; however the authors note that the robustness of a VAR model in this analysis may be poor, due to its assumption of constant covariance.

Joyce et al (2011) then estimate a GARCH-M model[11] to capture the dynamic nature of asset returns implied within empirical literature. The model is estimated over a longer period (to the end of 2009), with results indicating the intensity of the financial crisis in late 2008 through large movements in the covariance between gilts, equities and corporate bonds. Overall, the authors find that the impact of the BoE's QMEP led to gilt yields being almost 100 points lower than in the absence of this policy, which is roughly in line with alternative literature. It is suggested that the transmission mechanism is that of portfolio rebalancing whereby QME purchases increase gilt and other asset prices,

[11] Joyce et al use a covariance structure based on the BEKK model of Engle and Kroner (1995) although alternative studies have used a Dynamic Conditional Correlation (DCC) GARCH approach, such as that of Makiel (2015) who employs this approach to estimate the impact of various stages of US QMEP on relationships between assets within the oil and mining industries.

lowering borrowing costs and stimulating demand through wealth effects [Kapetanios et al: 2012]. GARCH analysis however, presents a number of issues when analysing data in the context of financial markets. Francq and ZakoÏan (2004) discuss common violations of the asymptotic properties of the Quasi Maximum Likelihood Estimation (QMLE) underlying the model while Billio and Caporin (2005) also comment on the unnecessary complexities introduced through use of this technique.[12]

Breedon, Chadha and Waters (2012) also argue the case of portfolio rebalancing as a transmission mechanism for QMEP. The authors measure the impact of the UK's initial QMEP of 2009/10 on bonds and other assets using a macro-finance term structure model assuming that both the level and slope of the yield curve follow a first-order VAR process. Macroeconomic variables are determined based on maximum likelihood (ML). The findings indicate that the policy reduced government bond yields by around 50 points.

Finally, Kapetanios et al (2012) model the UK QMEP over the same period, estimating three VAR models (Bayesian, Markov-switching structural and time-varying) and find that QMEP by the BoE increased the level of GDP by around 1.5% and the level of CPI inflation by around 1.25%, although the estimates vary across each specified model so the authors caveat that these results should be interpreted with caution.

In this paper, we aim to build upon the work of HKT to construct a series of VAR models to determine the impact of the most recent QMEPs of both the BoJ and the BoE. The limitations of the constant covariance assumption highlighted by Joyce et al (2011) will be overcome through the inclusion of structural breaks, identified based on econometric techniques and the timings of the implementation of QMEP in both Japan and the UK. Estimating multiple VAR equations will also enable determination of the transmission mechanism of QMEP in the Japanese and UK economies.

3. Data

The initial data proposed follows the work of Honda, Kuroki and Tachibana (2007), using the production index as a proxy for output, prices and the monetary policy instrument to estimate a base model for analysis. We also use financial variables to model stock prices, nominal interest rates, bank lending and foreign exchange rates. The periods modelled surround the more recent implementations of QMEP in both Japan and the UK, covering the period Jan-06 to Dec-14 in order to capture the

[12] Further information on the complexities of GARCH analysis can be found in Zivot (2008) and Conrad and Mammem (2015).

dynamics of the time series resulting from both the financial crisis and implementation of QMEPs. Data used is sourced from the BoJ, BoE and the World Bank. The frequency is monthly, comprising 108 observations.

Figure 3 shows the indices of output and prices for Japan over the period analysed, constructed with a 2006 base year.[13] The standard deviation for the production index is relatively high, at 8.56, indicating that the change in output levels over the period is quite large. This is evident from the difference between the maximum and minimum values, which is around 40% of the mean. Examining the median value of 91.91 in relation to the tail values indicates that the series does not follow a normal distribution. This is supported by the skewness value of -0.16 and a kurtosis value of 2.74, which indicates a platykurtic distribution.[14] The Jarque-Bera (JB) statistic of 0.75 however, does not allow us to reject the null hypothesis of a normal distribution.[15]

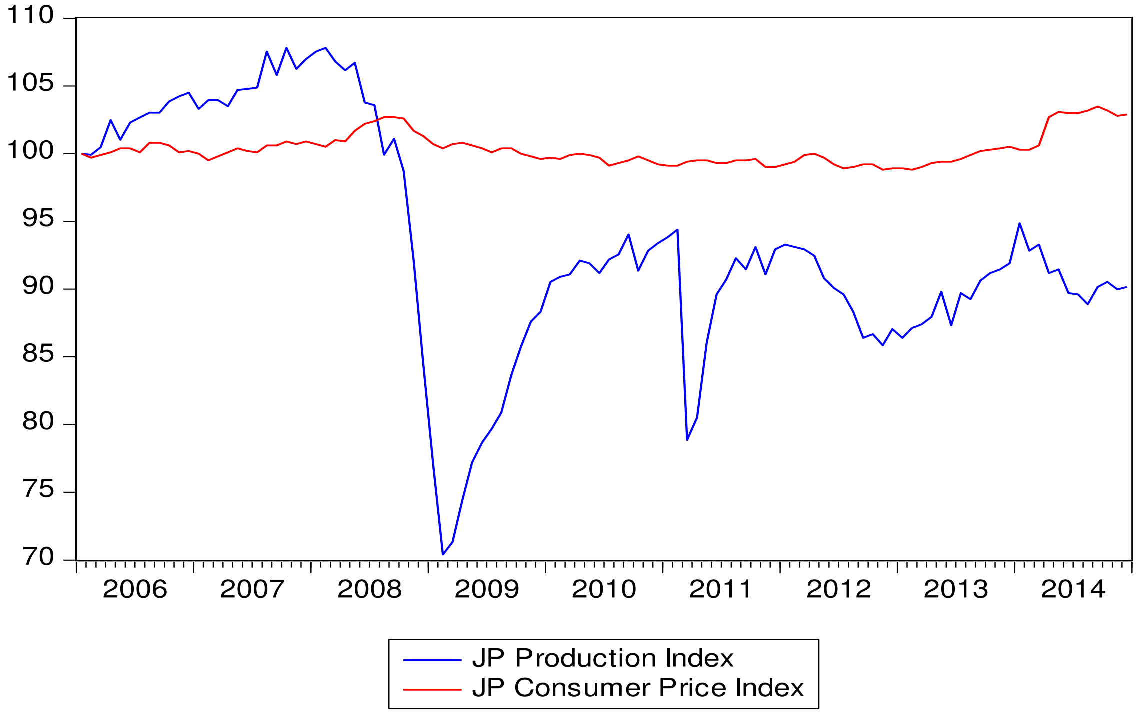
Japan has for a long time suffered stagnant or negative levels of inflation. Figure 3 shows this has been the case in recent years, although levels have been increasing since 2013. The standard deviation (Table 1) is relatively low but the mean value is skewed slightly towards the left, supported by the skewness of 1.16. The kurtosis of 3.60 indicates a leptokurtic distribution. Here, the JB statistic of 26.08 confirms we are able to reject the null hypothesis of a normal distribution.

[13] In other words, January 2006 values are normalised to 100.

[14] A platykurtic distribution has a lower peak and fatter tails than the normal distribution [Investopedia 2015].

[15] Jarque-Bera statistics are measured against critical values of the X^2 distribution with two degrees of freedom (one for skewness and the other for kurtosis). Values are 0.75 for the Production Index and 26.08 for the Consumer Price Index. Therefore we reject the null hypothesis of normality at the 1% level for the inflation series only.

Figure 3: Production Index and Consumer Price Index over Time (Japan)



Source: OECD and Ministry of Economy, Trade and Industry

Table 1: Descriptive Statistics of Key Japanese Macroeconomic Variables

Statistic	JP Production Index	JP CPI Index
Mean	93.35852	100.3126
Median	91.91176	100.0996
Maximum	107.8125	103.4861
Minimum	70.40441	98.80478
Std. Dev.	8.556794	1.165247
Skewness	-0.159433	1.165523
Kurtosis	2.746839	3.601506
Jarque-Bera	0.745949	26.08012
Probability	0.688683	0.000002
Sum	10082.72	10833.76
Sum Sq. Dev.	7834.403	145.2846
Observations	108	108

Source: Author's calculations.

Although the price index for Japan appears relatively stable, the production index shows a possible trend, masked by its higher volatility. We use the Augmented Dickey Fuller (ADF) test to determine the existence (or not) of a unit root within the data series'. This test has greater statistical power than the Dickey Fuller (DF) test as the problem of autocorrelation is reduced through the use of lags of the dependent variable as explanatory variables. Following the conventional approach, we reduce data to its logarithmic form.[16] This decreases the persistence of heteroskedasticity, which can cause numerous unwanted complications for analysis of financial and macroeconomic data [Fama (1963), French, Schwert and Stambaugh (1987)]. The results of unit root tests are then more robust, under reduced volatility.

The results of the ADF tests indicate unit roots within the levels of both series but the ADF statistics are beyond the critical values at the 1% level for the first differences and second differences of the production and output series respectively. Therefore we are able to reject the null hypothesis of a non-stationary series on this basis.[17] For confirmation, we also conduct the non-parametric Phillips-Perron (PP) test[18] on the levels and first differences of each series with slightly different results. For both the price and output indices we cannot reject the null hypothesis of the existence of a unit root at 10% significance when examining levels, but we can reject the null at the 1% significance level when analysing first differences. We therefore determine that each series is integrated to order one (I(1)) so on this basis, analysis in this paper will be performed using the first differences of these series'.

The graphed data also indicates the possible existence of a structural break within the data for Japanese output. The downward spike visible in 2008 matches to the start of the financial crisis, whilst the drop in early 2011 corresponds with the announcement of the introduction of a policy of QME in October 2010. The existence of a structural break (or multiple breaks) will be tested in the methodology outlined in Section 4.

Figure 4 shows the equivalent indices of output and prices for the UK. Summary statistics of these series are shown in Table 2. The standard deviations of each series meet expectations, with the figure for the output series (4.85) being slightly lower than the corresponding figure for the price index (8.90). Both series are skewed slightly away from the normal distribution with kurtosis values indicating platykurtic distributions (i.e. flatter than the normal distribution).[19] JB statistics confirm that we reject the null hypothesis of normal distribution for the both series, determined by the Chi-squared values.

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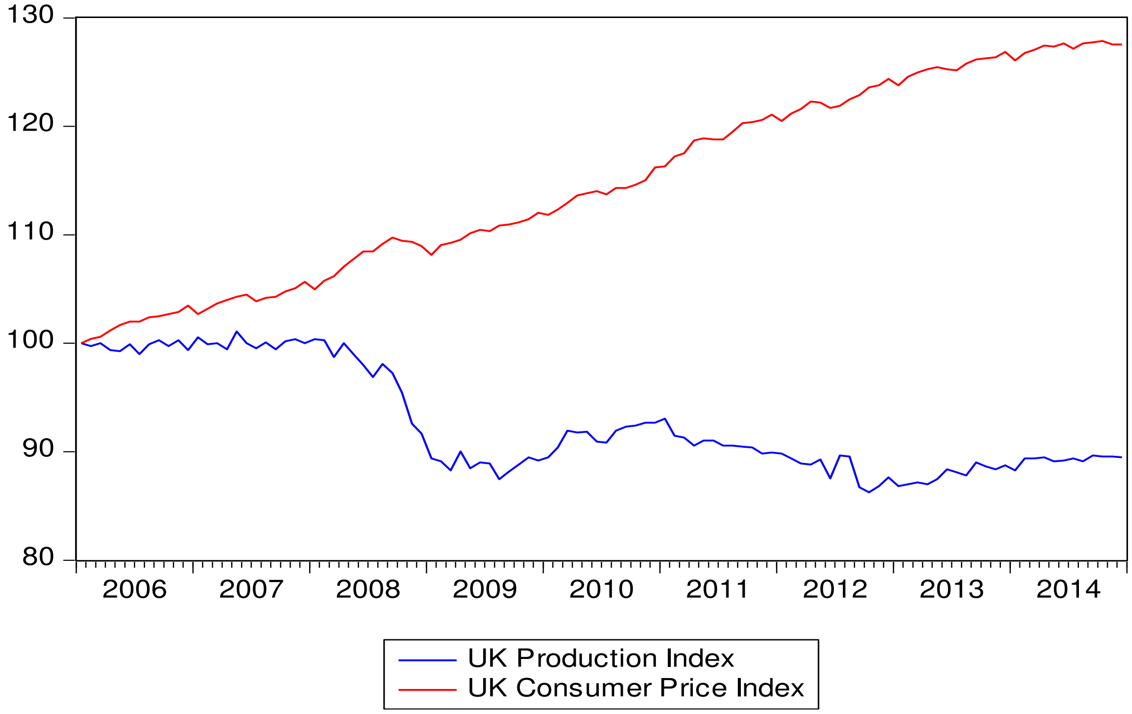
[16] For all variables except the nominal interest rates series which contains negative values. This follows the approach taken by Honda, Kuroki and Tachibana (2007).

[17] Test statistics are -2.583 and -11.226 for the levels and first differences of the output series and 0.959, 1.441 and -7.012 for the levels and first and second differences of the price series. Although we can reject the null hypothesis for the levels of the output series at the 10% significance level, results of analysis will be more robust using the first differences of this series. Results of these tests are available upon request.

[18] The main advantage of the PP test over the ADF test is that it is not necessary to select the level of serial correlation before running the calculations. A weakness of the PP test however, is that its statistical power comes asymptotically. These tests are therefore carried out on a longer data set, ranging from January 2000 to April 2015 to ensure robustness of the test.

[19] Kurtosis for the normal distribution is 3, so excess kurtosis refers to cases when kurtosis ≠ 3.

Figure 4: Production Index and Consumer Price Index over Time (UK)



Source: ONS

Table 2: Descriptive Statistics of Key UK Macroeconomic Variables

Statistic	UK Production Index	UK CPI
Mean	92.66467	114.7043
Median	90.52198	113.9303
Maximum	101.0989	127.8607
Minimum	86.26374	100.0000
Std. Dev.	4.854988	8.901170
Skewness	0.612911	0.008265
Kurtosis	1.712971	1.600684
Jarque-Bera	14.21586	8.812608
Probability	0.000819	0.012200
Sum	10007.78	12388.06
Sum Sq. Dev.	2522.088	8477.698
Observations	108	108

Source: Author's calculations.

The UK has experienced positive inflation during the period analysed so there is an obvious upwards trend in CPI inflation, indicating the series might be non-stationary. This assumption is confirmed by the results of the ADF test which generate values of -3.851 and -12.222 for the logarithms and first differences of the logarithmic data respectively. This indicates that a unit root does not exist within the data as the null hypothesis can be rejected with 99% confidence for both recurrences of the test. This is reinforced by the PP test, which supports rejection of the null at the 1% significance level.

For completeness, we also conduct ADF and PP tests on the output index. These tests indicate the existence of a unit root within the series, but we can reject the null hypothesis with 99% confidence when examining the first differences of the data. We therefore proceed with analysis on this basis.

Next, it is important to provide justification of the financial variables selected to be included in the four-variable VAR models which will be constructed to determine the transmission mechanism(s) by which QMEP takes effect. In this paper, we focus on the financial transmission mechanisms which are thought to enable QMEP to influence the aggregate levels of output and prices within the Japanese and UK economies. The two most prominent effects are the portfolio rebalancing effect, and the signalling effect.

The portfolio rebalancing effect assumes that a number of financial assets are imperfect substitutes for each other. When a zero short-term interest rate aligns money and short-term securities, money may still be an imperfect substitute for other financial assets. The injection into the monetary base causes investors to alter their portfolios, which raises prices (or reduces yields) and stimulates economic activity. Under the signalling effect, when an increase in monetary supply is announced, it can strengthen the signal of the intentions of the central bank to maintain short-term interest rates at zero. The stabilisation of expectations of the trajectory of short-term rates can cause long-term interest rates to fall [Honda, Kuroki and Tachibana 2007].

Through each of these effects, implementation of a policy of QME could raise stock prices, depreciate the value of the domestic currency or lower nominal interest rates, all of which would have a stimulating effect on economic activity. Finally, the additional money obtained from the central bank in open market operations may cause commercial banks to increase lending. Therefore, these financial variables are adopted as possible mechanisms to transmit the effects of QME.

4. Methodology and Results

Building on the initial work by Miyao (2002) and following the work of HKT, this paper will adopt a VAR methodology to analyse the effects of the Japanese and British QMEPs on price levels and aggregate output. The reduced benefits of GMM procedures and statistical complexities and limitations of GARCH models make VAR the most appropriate technique for this analysis. Additionally, its wide use enables comparisons to be drawn with the results of existing research. The base models will be estimated first, and then re-estimated to include each financial variable in turn to determine the transmission mechanisms of QMEPs within Japan and the UK. The necessary robustness checks will be performed to ensure the accuracy of econometric analysis. The analysis will be performed using both unrestricted and restricted VAR models.

As mentioned, there are a number of different techniques which could be used to determine the existence of structural breaks within time series data. Due to the nature of the implementation of these monetary policy techniques, the MS techniques of Fujiwara (2004) are not considered to be necessary[20] and so we first examine the existence of structural breaks by conducting Bai-Perron tests, which are used when searching for multiple unknown break points. This method endogenises structural breaks within the model, which allows for more significant statistical analysis.

First then, we estimate an Ordinary Least Squares (OLS) regression using the output and price indices and the current account balance. All variables are first differences of the logarithmic series, which are stationary according to the results of the Phillips-Perron tests performed earlier. The equation using the Japanese data is then:

$$d(JP\_PRODUCTION\_INDEX) = \beta_1 d(BOJ\_CAB_B) + \beta_2 d(JP\_CPI\_INDEX_F)$$

Here, the d prefix denotes the first difference of the following variable and the B and F subscripts denote breaking and fixed regressors. The aim is to determine whether there is a structural break within the BOJ_CAB time series which has an effect on its relationship with output. We estimate a similar equation where the price series is the dependent variable and the output series is a fixed regressor:

$$d(JP\_CPI\_INDEX) = \beta_1 d(BOJ\_CAB_B) + \beta_2 d(JP\_PRODUCTION\_INDEX_F)$$

The results of the Bai-Perron test in each case indicate that there are no structural breaks within the time series which influence the relationship between the BoJ CAB and the output or price series[21]. This is somewhat counter-intuitive. The start of the time series (2006) represents the end of the initial policy of QME by the BoJ, following which, the Bank quickly unwound its positions in financial markets resulting from the policy. It is more logical to predict that a structural break would exist within the time

[20] MS modelling can be used to indicate multiple regime switches within a data set. Here, we have 72 observations over a period of six years and monetary policy activities are implemented with some degree of rigidity and so alternative identification techniques for structural breaks are judged to be more appropriate.

[21] Results are available upon request.

series around the time that the BoJ announced new monetary measures in October 2010. Repeating the Bai-Perron test on a smaller subset of the data confirms this, indicating a break in September 2010.[22]

We strengthen this result by performing a Chow breakpoint test around this observation, using the same OLS models. The Chow test compares the coefficients of the two linear regressions which result from the data subsets, split at the specified point. We perform the test in multiple specifications around September 2010. The subsamples tested are shown in table 3. Results of these tests indicate a structural break in October 2010, based on generated F-statistics and log-likelihood ratios.[23]

The VAR analysis performed in this paper will therefore evaluate the impact of QMEP on output and prices by comparing each subset of data (before and after the implementation of the QMEP. This is a logical approach to take, as subsequent programmes of QME implemented by the BoJ in 2013 and 2014 can be viewed as extensions of the 2010 policy which was a new programme as the BoJ had largely unwound the positions it took between 2001 and 2006. Additionally, the number of observations in each data subset is sufficient to provide robust statistical analysis.

Table 3: Breaks Determined by Bai-Perron / Chow Tests (Japan)

From	To	No. Observations
Feb 2006	Sep 2010	56
Oct 2010	Dec 2014	51

The base VAR model is estimated using the production index, the consumer price index and the current account balances held by the central bank, resulting from QMEP. Lag selection criteria indicate a single lag order leading to estimation of the following equations:[24]

$$JP\_PROD\_INDEX_T = C + \beta_1 JP\_PROD\_INDEX_{T-1} + \beta_2 JP\_CPI_{T-1} + \beta_3 BOJ\_CAB_{T-1}$$
$$JP\_CPI_T = C + \beta_4 JP\_PROD\_INDEX_{T-1} + \beta_5 JP\_CPI_{T-1} + \beta_6 BOJ\_CAB_{T-1}$$
$$BOJ\_CAB_T = C + \beta_7 JP\_PROD\_INDEX_{T-1} + \beta_8 JP\_CPI_{T-1} + \beta_9 BOJ\_CAB_{T-1}$$

These equations follow those constructed by HKT, using the Cholesky decomposition to order the variables. This method gives consideration to the relative exogeneity of each input, assuming a unidirectional causal relationship. The logic behind the ordering

[22] This may be because the announcement of new monetary measures was anticipated, and so the impact was felt slightly before the official announcement was made.
[23] Results are available upon request.
[24] Variables are in first differences of logarithms. The t subscript indicates the time period; β coefficients represent responsiveness of dependent variable to the independent variables.

assumes that when a central bank makes a monetary policy decision, it observes current levels of output and prices.[25]

Results of the three-variable VAR are striking; the most significant equation uses the production index as the dependent variable. It is highly influenced by its own lagged values and the lagged values of the inflation index but the relationship with CABs held by the BoJ is substantially smaller[26]. This estimation is significant in explaining levels of the production index, as evidenced by the F-statistic of 11.03.

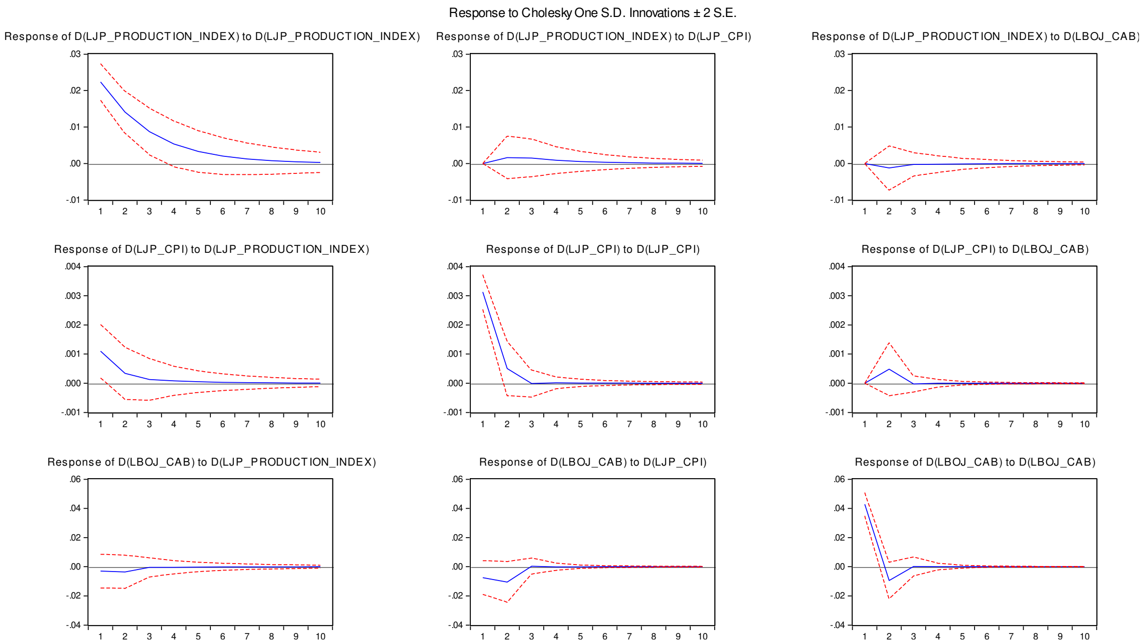
Impulse response functions (IRFs) are shown in Figures 5 and 6. Each solid line represents point estimates of an IRF. We use 100 repetitions of the Monte Carlo simulation to generate the outer, dotted lines which denote two standard error bands away from the point estimates in either direction. In both periods, output reacts negatively to a QME shock, although this decrease only lasts for one month before output returns back to its original level. The results however, lack statistical significance. This lack of impact and persistence is contrary to the findings of HKT but also to the intentions of the BoJ, which aimed to achieve sustainable growth and price stability. The reaction of inflation to the monetary policy shock is also minimal and not persistent, although it is positive, which matches expectations and the findings of HKT. Japan's failure to escape deflation has been widely documented and the statistical results derived from our VAR model do little to prove otherwise. Results of some previous literature have found QME to have a positive and sustained (more than a few months) impact on output and price levels but our results indicate that more recent QME is perhaps less effective.

Finally, we examine the reaction of CABs held by the BoJ, in response to shocks to output and price levels. In the first period, the CAB reacts negatively to shocks in both variables, with a greater impact caused by a shock to core CPI. This implies that at the time, the BoJ placed a greater emphasis on prices than it did on output and matches the findings of Honda, Kuroki and Tachibana. Additionally, the BoJ stated in the past that the termination condition for QMEP relates to levels of current and expected inflation, and not real economic activity. In the second period of our analysis, the reaction of CABs is positive, although in each case the impact is felt only briefly and does not appear to persist beyond a few months.

[25] This ordering is common in related literature, placing variables in order of macroeconomic indicators, monetary policy measures and financial variables (See Christiano et al (1996) or Thorbecke (1997)).

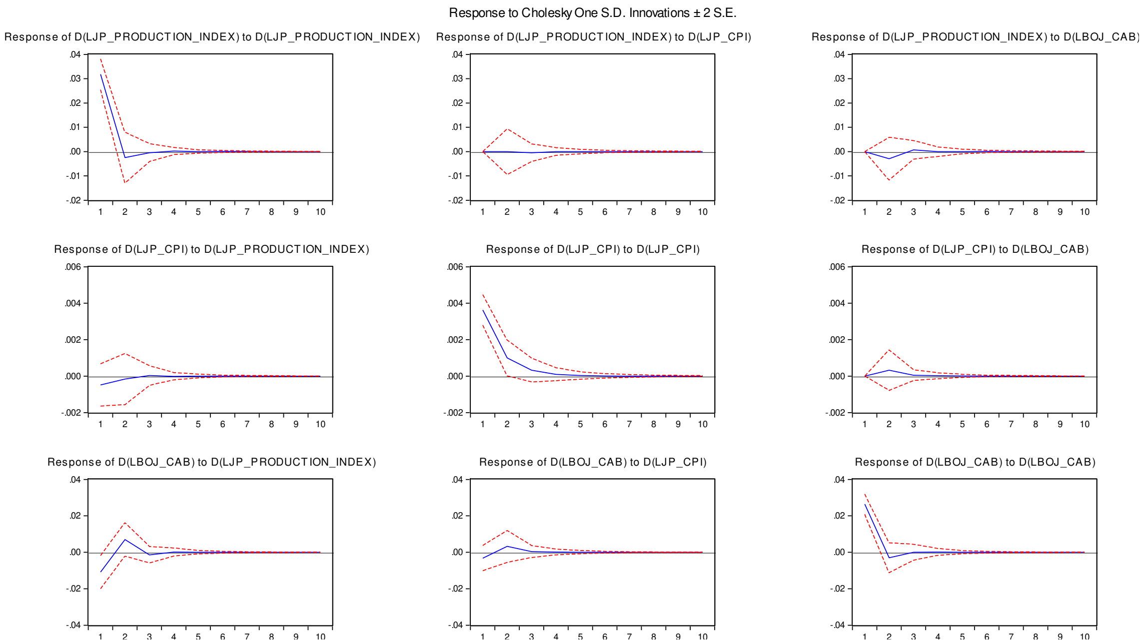
[26] Results are available upon request.

Figure 5: Impulse Response Functions Feb 2006 – Sep 2010 (Japan)



Source: Author's calculations

Figure 6: Impulse Response Functions Oct 2010 – Dec 2014 (Japan)



Source: Author's calculations

As the results of our VAR analysis are less than convincing, it is necessary to consider other options for analysis. A prevalent issue with using differenced data within a VAR system is the potential loss of long-run information or introduction of distortion within the multivariate model (someone said that). A useful alternative to conventional VAR analysis is the Vector Error Correction (VEC) Model, which replaces this lost information with an error correction term.[27] VEC models are commonly used when variables are non-stationary in levels, but stationary in their differences, as is the case here. The VEC model provides an alternative representation of a cointegrated VAR model, based on Engle and Granger's representation theorem [Engle and Granger 1987].[28]

First, we must determine the existence and number of cointegrating relationships using the Johansen Cointegration test [Johansen 1991, 1995]. Cointegration among macroeconomic variables is common and widely documented, particularly in the context of price and output levels [Caproale and Skare 2011]. The test determines the existence of cointegrating vectors in two ways. First, it uses the LR statistic based on the maximum eigenvalue. Asymptotically, the LR test statistic does not follow the typical X^2 distribution and so assumptions are required about trends underlying the data.[29] Separate tests are performed on each eigenvalue under the null hypothesis of r cointegrating vectors against the alternative $r+1$ cointegrating vectors. Secondly, the trace statistic of the stochastic matrix underlying the model is calculated and the rank of this long-run coefficient matrix is examined to determine the number of cointegrating vectors [Hjalmarsson and Österholm 2007]. A joint test is performed, under the null hypothesis that the number of cointegrating vectors is less than or equal to r against the alternative hypothesis that there are more than r cointegrating vectors. Lag intervals for the test are determined by the information criteria of VAR estimations and so we conduct Johansen's test using a single lag. Critical values are calculated using MacKinnon-Haug-Michelis (1999) p-values. The test itself is then quite straightforward, iteratively testing the existence of r cointegrating equations against the existence of k cointegrating equations.

In the case of Japan, for the first period the Johansen test indicates the existence of two cointegrating equations at the 5% level, based on the trace statistic[30]. With this knowledge, we can then estimate a VEC model.

The results of the IRFs estimated here (Figure 7) are clearer than those estimated previously under the unrestricted VAR framework. Outputs from the VEC model are

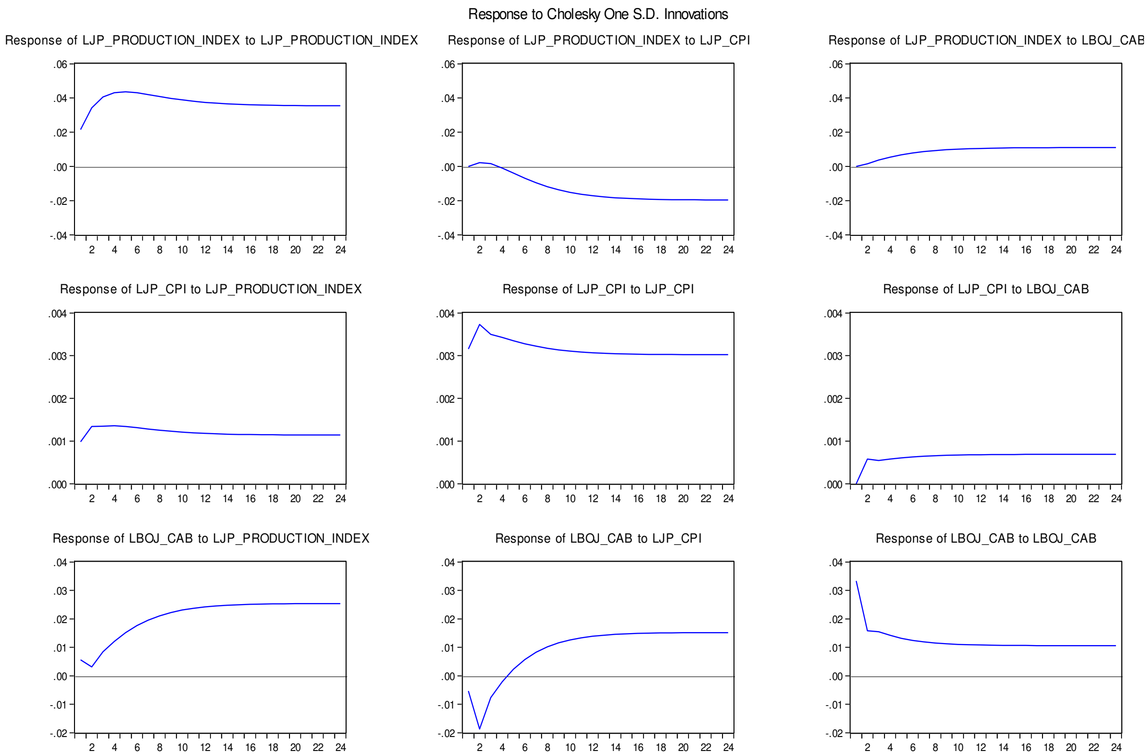
[27] Essentially, this can be viewed as a restricted VAR model.
[28] The theorem states the existence of $k \times r$ matrices of rank r for a coefficient matrix with rank $r < k$. where r is the number of cointegrating relations and k is the number of endogenous variables. Essentially, the elements of these matrices are used as adjustment parameters within the VEC model. The Johansen method estimates the coefficient matrix from the unrestricted VAR model and determines whether the restrictions implied by the reduced rank of the coefficient matrix, can be rejected.
[29] Specifically, we observe that series' exhibit non-zero means and deterministic trends.
[30] Results are available upon request.

more robust and take into account longer-term relationships which are lost when differencing non-stationary data for population of the VAR model. Production levels react positively to a QME shock. The increase lasts for 12 months and the effect persists. Similarly, price levels also react positively to a monetary policy shock but to a lesser degree. The shock has a relatively large impact in the first two months, but a minimal positive effect thereafter. Nonetheless, the effect persists and these results are similar to those obtained by HKT. The small and statistically insignificant reaction of CPI means there appears to be little evidence that the BoJ was successful in escaping deflation as a result of its' QME operations. Finally, BoJ CABs first react negatively to shocks in both output and price levels. This negative reaction is short-lived with the IRFs indicating a sustained positive reaction from the second month in both cases, with persisting effects.

Notably however, we do not compute confidence intervals for analysis of the IRFs attached to the VEC models. The presence of error correction terms negates the possibility of calculating uniform bands for the IRFs although it would be possible to compute bootstrapped confidence intervals individually using alternative software, such as JMulTi[31]. Looking at Figure 7, responses to shocks are notably small and so calculating the confidence intervals for each graph would likely not add to the analysis in this paper.

[31] JMulTi is an econometrics software programme specifically designed for univariate and multivariate time series analysis [JMulTi 2009].

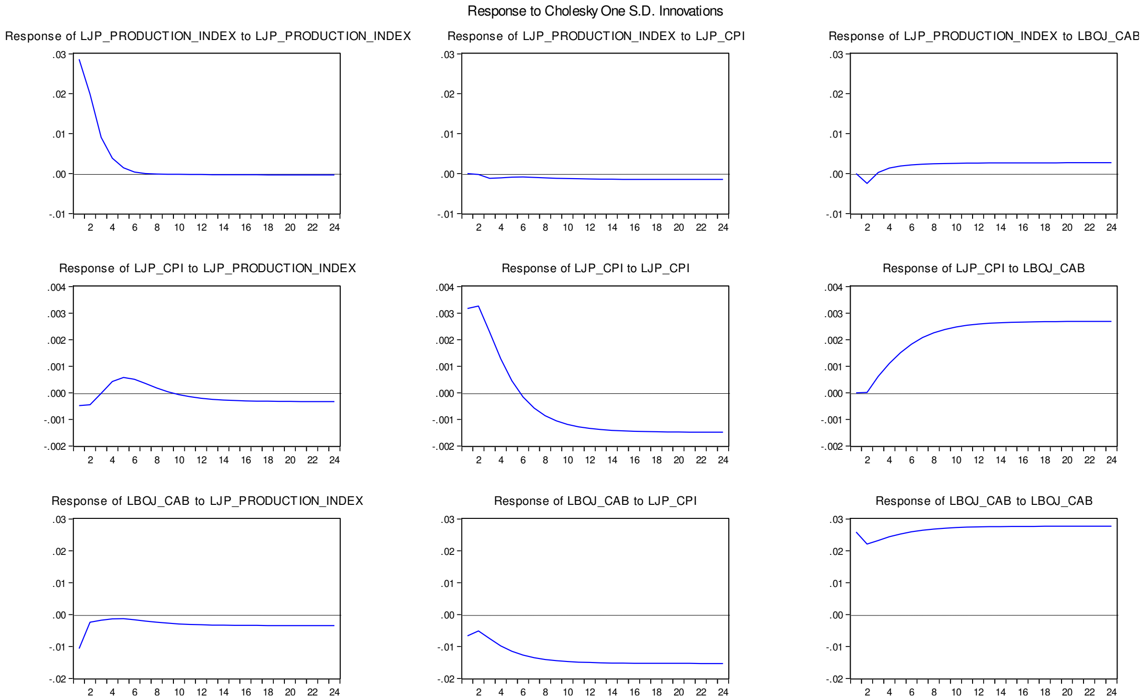
Figure 7: Impulse Response Function (Japan Feb 2006 – Sep 2010)



Source: Author's calculations

Examining the second period, results of the Johansen test indicate there to be two cointegrating relationships amongst the variables. This time the equation using the price index as the dependent variable is most significant, indicating it has a strong relationship with lags of output and the BoJ CAB. Analysing the IRFs generated from the estimated VEC model (Figure 8), we can see that the impact of a monetary policy shock on prices and output is subtly different than in the first period. Again, both reactions are positive but the reaction of output is weaker than before and the reaction of price levels is stronger. Output levels fall in the first two months following the shock, before recovering and seeing a slight increase, which persists. Price levels see a positive reaction starting in the second month, which continues until month 14. These results indicate an increased effectiveness of QME over time, meeting the BoJ's price level target, based on its' stated commitment to unwind QME positions only once inflation is positive and stable.

Figure 8: Impulse Response Function (Japan Oct 2010 – Dec 2014)



Source: Author's calculations

Next, we turn attentions to the UK. The OLS structural break test is performed on a subset of the data, commencing in February 2009 when the BoE formally announced a new programme of QME. Before this time, BoE CABs resulting from QMEP were zero.[32] When examining the logarithmic data, the Bai-Perron tests indicate possible structural breaks in February 2011 and September 2012, suggesting the existence of three regimes within the BOE_CAB time series. However, the test finds no structural breaks when analysing the first differences in logarithmic form. Throughout each programme of QME, the BoE bought financial assets at a steady pace, but there are clear periods when purchases were stopped and balances were maintained at consistent levels. The equations underlying the OLS model[33] used in estimation of the Bai-Perron procedure are:

$$d(UK\_PRODUCTION\_INDEX) = \beta_1 d(BOE\_CAB_B) + \beta_2 d(UK\_CPI\_INDEX_F)$$

$$d(UK\_CPI\_INDEX) = \beta_1 d(BOE\_CAB_B) + \beta_2 d(UK\_PRODUCTION\_INDEX_F)$$

Investigating further, we perform Chow tests around the observations indicated to be breakpoints by the first Bai-Perron test undertaken. Results of these tests show no break point in 2011 but do confirm the existence of a structural break in September

[32] Due to the nature of the dataset, the Bai-Perron test automatically determines to start analysis at the first non-zero value of the CAB, which occurs in February 2009. Therefore we decide against use of data before this date.

[33] These are logarithms of the original data series, using first differences to ensure stationarity of the data.

2012, as shown in table 4.[34] As with the policies of the BoJ, subsequent bouts of QME instigated by the BoE are considered as additional stages of QME, rather than new programmes in their own right. After September 2012, the BoE ceased actions to increase its balance sheets, purchasing financial assets only to offset falls caused by maturity of some holdings.

Table 4: Breaks Determined by Bai-Perron / Chow Tests (UK)

From	To	No. Observations
Feb 2009	Sep 2012	44
Oct 2012	Dec 2014	27

The base VAR model is constructed using a single lag for the first period, as determined by the information criteria and ML ratio. In the second period, selection criteria indicate no lag. Economically however, it is difficult to justify the position that output and prices move simultaneously with current account balances, even if it can be argued that markets are fully informed of policy decisions in advance of their implementation. In financial markets, it may be the case that asset prices adjust immediately but in more localised markets this is likely not the case. Therefore we also conduct VAR analysis for the second period, also using a single lag.

The model for the UK is constructed in an identical fashion as that based on the Japanese data. All variables are first differences of the logarithmic series. The three variable model is estimated as:

$$
\begin{aligned}
UK\_PROD\_INDEX_T &= C + UK\_PROD\_INDEX_{T-1} + UK\_CPI_{T-1} + BOE\_CAB_{T-1} \\
UK\_CPI_T &= C + UK\_PROD\_INDEX_{T-1} + UK\_CPI_{T-1} + BOE\_CAB_{T-1} \\
BOE\_CAB_T &= C + UK\_PROD\_INDEX_{T-1} + UK\_CPI_{T-1} + BOE\_CAB_{T-1}
\end{aligned}
$$

Again, the four-variable models are estimated using the lag structure of the base model. Variables are ordered based on the Cholesky decomposition for the reasons previously justified.

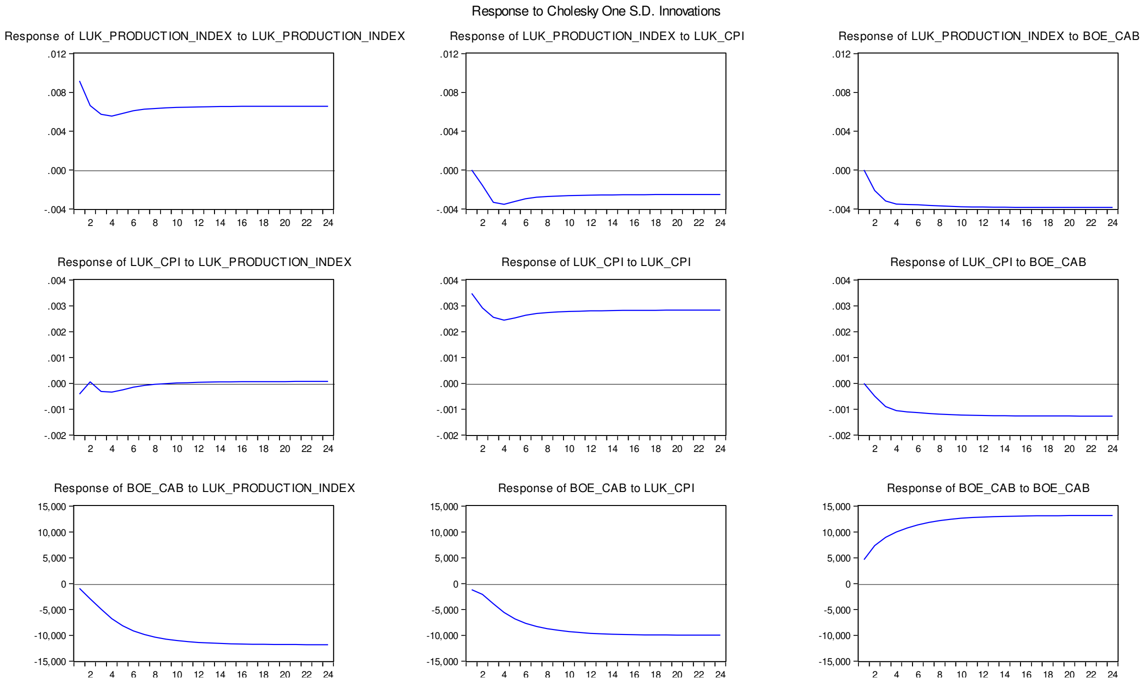
IRFs estimates indicate almost no movement in either output or price levels resulting from a monetary policy shock in either time period. This seems highly implausible and likely results from misspecification of the econometric model. Again, we can check for cointegration among the variables and estimate restricted VAR models (VEC models) to gain more accurate and robust results.

Results of the Johansen cointegration tests for the first period indicate one cointegrating relationship among the variables, which is sufficient to justify estimation of

[34] The Chow test generates an F-statistic of 5.09 which is beyond the critical value of 4.94 at 99% confidence.

a VEC model. The IRFs for the first period are displayed below in Figure 9. Here, we can see that output reacts negatively to a QME shock. The majority of the impact is seen within the first four months, with the decrease persisting. Similarly, price levels also fall following the shock, although not to the same degree. Both reactions are relatively small in magnitude. This lack of response could be a factor contributing to the additional purchases of financial assets made by the BoE over the last three years. Had prices and output reacted strongly to the monetary policy shock, the BoE would be less justified in swelling its balance sheets further. Therefore we might also assume there to be little impact on the financial variables when estimating the extended model shortly.

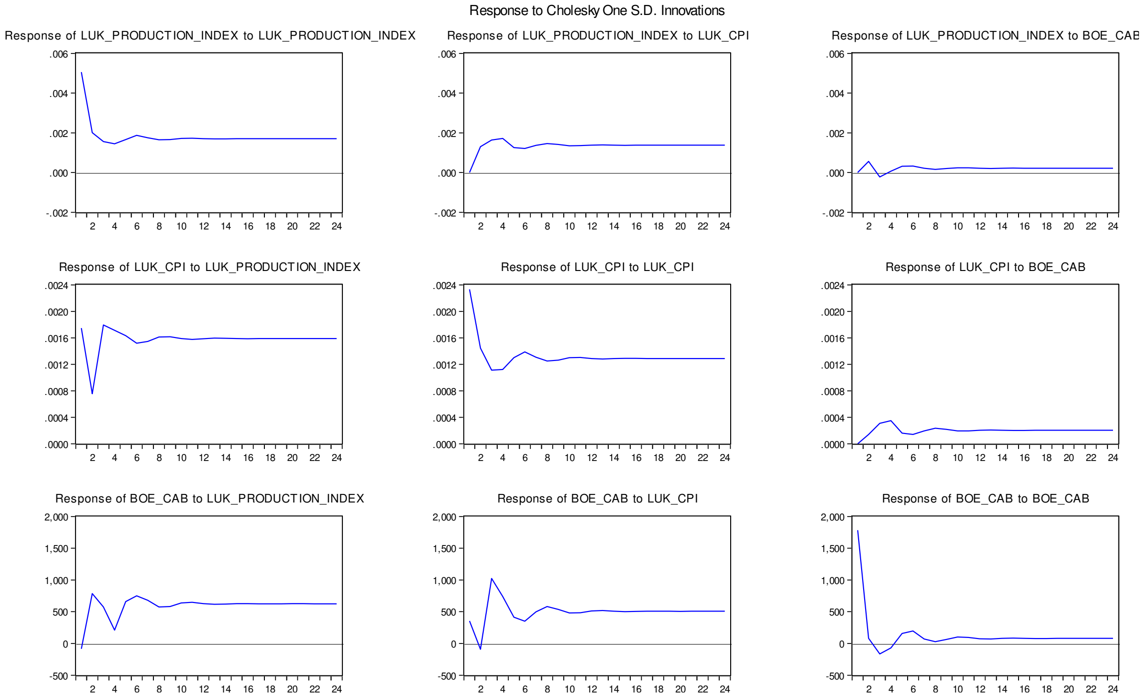
Figure 9: Impulse Response Functions (UK Feb 2009 – Sep 2012)



Source: Author's calculations

Turning to the second time period, we estimate a VEC model with two cointegrating relationships. Although the Johansen test indicates the possible existence of three cointegrating equations at the 5% level, the VEC model can only be constructed with a maximum of two (one less than the total number of variables included in the estimation). The IRFs shown below in Figure 10 indicate that the policy of QME implemented by the BoE did indeed begin to take effect, with a monetary policy shock now having a positive and persistent effect on both the production and price indexes. Nonetheless these effects are still very small indicating that the BoE’s monetary efforts in recent years have not been effective in raising either price or output levels. This contradicts the findings of some existing research such as Bridges and Thomas (2012) and Kapetanios (2012) although these research papers were funded by the BoE and so their positive findings should be met with caution.

Figure 10: Impulse Response Functions (UK Oct 2012 – Dec 2014)



Source: Author's calculations

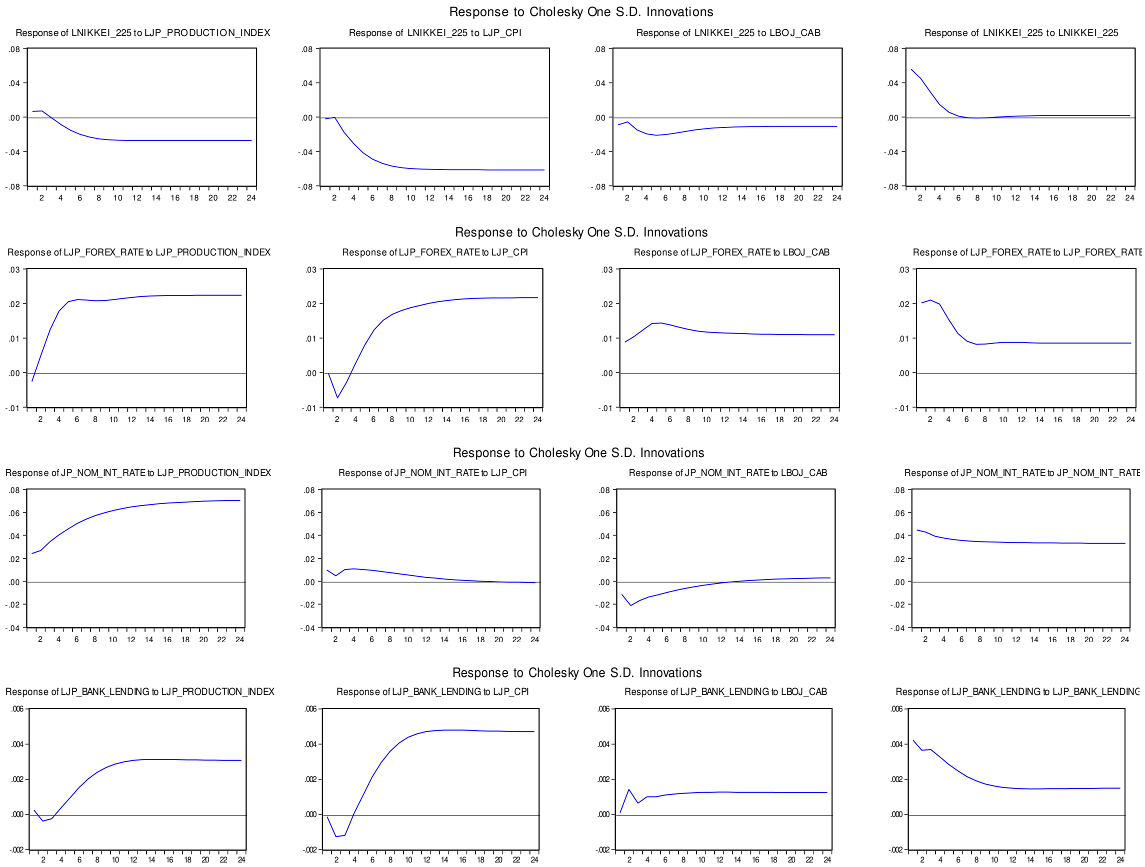
5. Transmission Mechanisms

Next we turn our attention to analysis of the transmission mechanism by which QMEP takes effect. In order to do this, we construct a series of VEC models to include each financial variable in turn. By comparing these models we are able to determine which financial variables react strongly to a QME shock. The number of lags and cointegrating variables is determined by those of the base model, in order to maintain consistency across all estimations. In each model, the financial variable is ordered last as it is assumed that financial markets respond to policy shocks with no lag.[35/36] A summary of the IRFs is shown below in Figure 11.

[35] This is in line with extensive research into the efficiency of financial markets following the seminal work of Fama (1970). More recently, the work of Malkiel (2003) is particularly applicable. This approach follows that taken by Honda, Kuroki and Tachibana (2007).

[36] Results are available upon request.

Figure 11: IRFs for Transmission Variables (Japan Feb 2006 – Sep 2010)

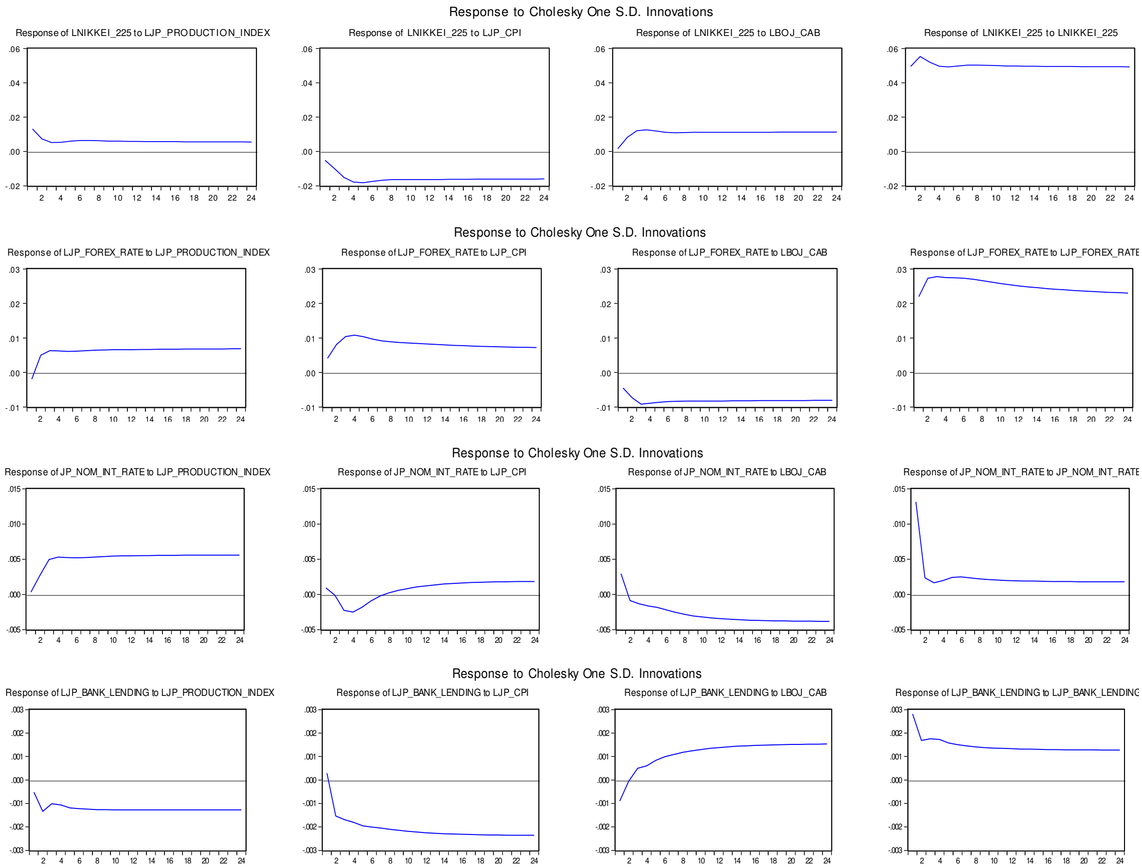


Source: Author's calculations

The reaction of the Nikkei index is negative and persistent while the responses of the forex rate and bank lending are positive, although neither to any great magnitude. The most notable reaction is that of the nominal rate of interest, which decreases in the wake of a monetary policy shock. This matches the intentions of the BoJ, to reduce the long-term interest rate through the signalling effect, whereby the actions and stated intentions of the central bank stabilise interest rate expectations, causing longer term rates to fall. 14 months following the shock, rates return to their original level, increasing slightly to balance the artificial fall caused by QME. This would appear to explain why the BoJ has continued to increase its financial asset holdings, in order to keep the nominal interest rate low until such a time when price and output levels have recovered.

Analysing the second period, based on two cointegrating vectors we see different reactions of each variable to the QME shock (Figure 12). First, the reaction of the Nikkei 225 is now positive, maintaining a persistent increase in the months following the shock. The reaction of the real effective exchange rate sees a short term fall which persists over time, indicating depreciation in the value of the yen[37]. Again, interest rates fall in reaction to the QME shock, although the position is not as dramatic as in the first period. This matches our expectations since interest rates in Japan by this time were already close to zero, following the BoJ actions to reduce the rate using both traditional and unconventional monetary policy. Finally, bank lending increases slightly in reaction to the shock, over a period of 24 months, which is in line with expectations.

Figure 12: IRFs for Transmission Variables (Japan Oct 2010 – Dec 2014)



Source: Author's calculations

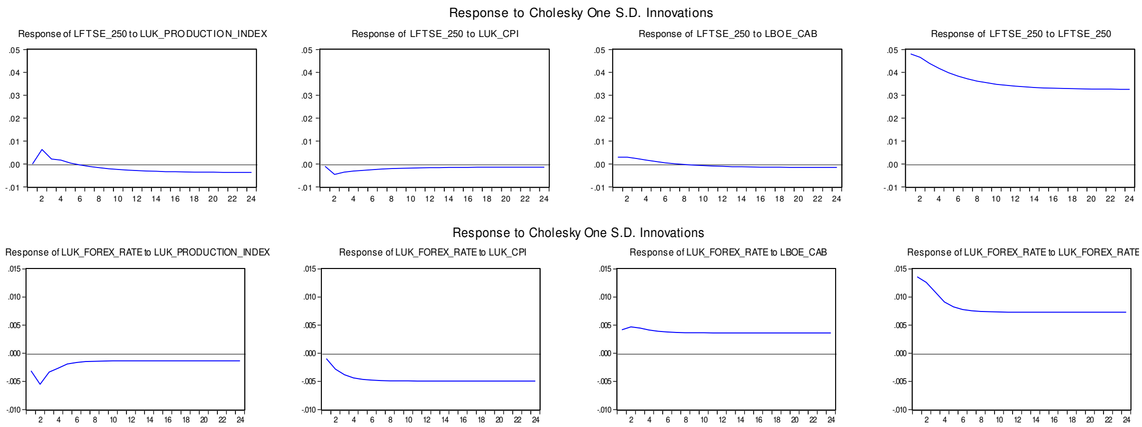
Summarising these results, from this evidence we can conclude that the interest rate channel was a strong channel through which QME was able to take effect in Japan over the period analysed. The differing or negligible reactions of the other financial variables indicate that they were not perhaps as strong in transmitting QME to have a significant impact on output and price levels within the Japanese economy. Economically, this is attributed to the infancy of the policy in the first period. Although the Japanese economy had previously experienced QME, it is highly likely that markets and agents reacted to the new policy with imperfect information which might explain why the interest rate channel was a prevalent transmission mechanism in the first

[37] We Analyse this result with some cautious, where the drop in the REER might also reflect a drop in the relative inflation ratio between Japan and its trading partners.

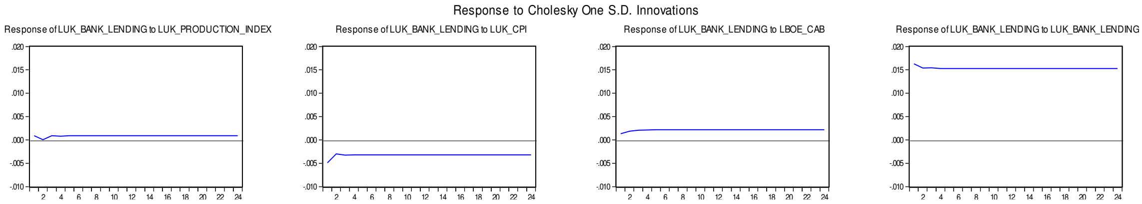
period. In the second period, in addition to a fall in interest rates, the QME shock depreciates the yen and raises stock prices and bank lending, all of which have a stimulating effect on economic activity. This indicates the presence of a small portfolio rebalancing effect, through the stock market channel. Financial institutions use the money they have gained from the sale of financial assets to increase the equity component of their portfolios, and decrease the weightings of interest-bearing assets. The fall in the nominal rate of interest is an indicator of a reduction in bond yields[38] which makes holding such assets less profitable. The resulting reduction in the return on domestic financial assets, could lead to a shift in investors' preferences towards foreign assets, explaining the fall in the value of the yen.

Turning focus back to the UK economy (Figure 13), in the first period there appears to be very little reaction from any indicator to a QME shock. The FTSE reacts positively in the first six months, before experiencing a slight but persistent decrease. The FOREX rate increases following the shock, but the result is not significant and opposes economic expectations, which would predict depreciation of the yen (and thus a fall in the rate of FOREX). The increase in bank lending is expected, but nonetheless is relatively small. Finally, the reaction of the nominal rate of interest could not be modelled effectively using the VEC framework.[39] The BoE recently announced that the nominal rate of interest would remain at 0.5% for the 77th consecutive month [BBC 2015]. Thus in the entire period analysed in this paper, the nominal rate of interest in the UK has remained unchanged. Clearly then, we can say that a shock to current account balances would have no impact on the interest rate, without the need for VEC analysis.

Figure 3: IRFs for Transmission Variables (UK Feb 2009 – Sep 2012)



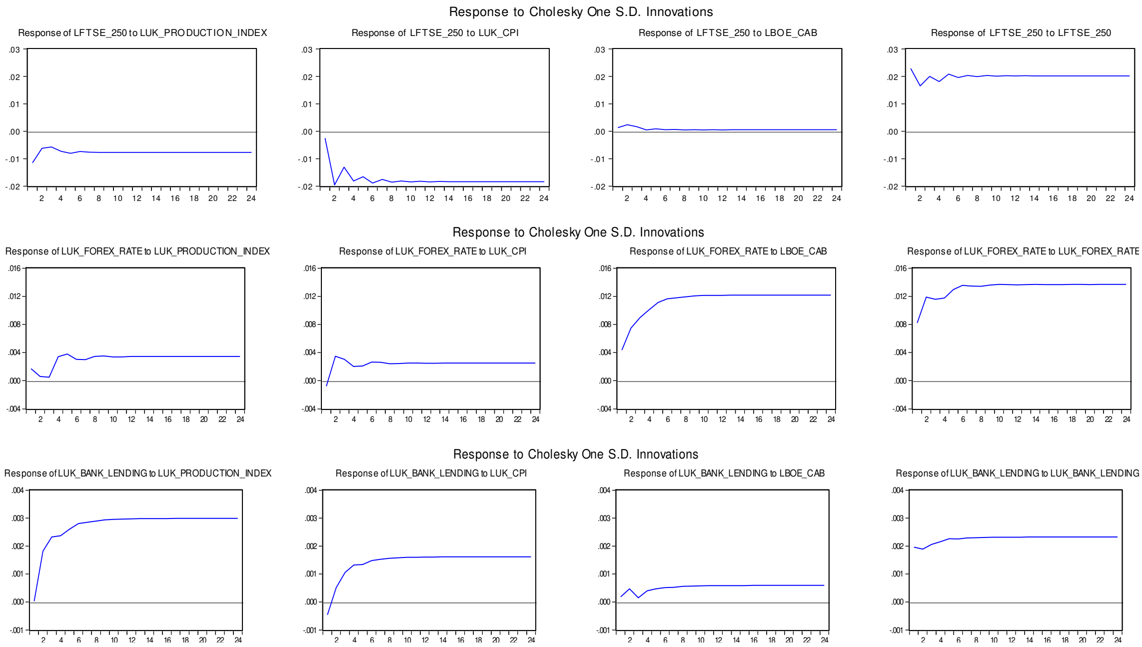
[38] Much research has been performed on the link between QME and bond yields [Joyce et al (2011), Kapetanios et al (2012), Fawley and Neely (2013)].
[39] Full results are available upon request.



Source: Author's calculations

In the second period, the responses of the financial indicators are again weak or counterintuitive (Figure 14). The reactions of the FTSE index and bank lending are largely insignificant whilst the increase in the rate of FOREX is unexpected (for the reasons given above). The FTSE 250 however, does react positively to the shock over the first four months, although the effect does not persist.

Figure 4: IRFs for Transmission Variables (UK Oct 2012 – Dec 2014)



Source: Author's calculations

To summarise, these results indicate that any positive effects that the QMEP of the BoE may have had on the economy, most likely came through the stock market channel. This suggests a small portfolio rebalancing effect occurred whereby financial investors use money obtained from the BoE to adjust their portfolios and hold a greater portion of equities or foreign assets, which may be considered as less-risky in the current climate.

Over the time period analysed then, the Japanese and UK economies experienced a number of differences. Although both faced the ZLB of interest rates, the policies implemented were subtly different. Financial institutions in Japan had previously experienced QME in 2001 and although the more recent policies were more complex, involving purchases of both risk-free and risky assets, it is possible that the understanding that Japanese investors possessed influenced the effectiveness of future QMEPs. Conversely, the QMEP introduced by the BoE in 2009 was a pioneering policy in the UK and so it is feasible that the initial weakness of the market reaction resulted from imperfect information or increased perceptions of risk in the economy.

The results of our analysis of Japanese QME are largely in line with those of HKT, who found the policy to have a positive effect on both output and price levels. In the first period, we found the policy to have a relatively large effect on output but the positive impact on price levels was small. In the second period, we found the positive impact on price levels to be stronger, while the positive influence QME had on output had weakened. This is in line with the BoJ's stated commitment to QME until such a time when inflation is once again positive and stable. Our results suggest that while the more recent rounds of QME by the BoJ have begun to achieve their stated intentions, further monetary activity might be required to stimulate the economy. This provides justification for the most recent expansion of QME announced by the BoJ in October 2014. Our analysis found the BoE's 2009 QMEP to have a small but persistent positive impact on prices in the UK, whilst future programmes caused small persistent increases in both output and price levels. This indicates that QME in low levels does not appear to have a significant impact on price levels.

Undoubtedly when implementing a policy of QME it is necessary for a central bank to spread its purchases of financial assets over time in order to avoid unwanted market reactions but from our analysis of both the Japanese and UK economies, QME only positively affects price levels after a sustained period. By October 2010[40] the BoJ had already purchased over ¥120tn (£834bn) in financial assets with little impact on price levels. Similarly in the UK, by October 2012[41] the BoE had purchased over £370bn of financial assets which accounts for 99% of its current total. Our analysis therefore indicates that QME in the UK only had an impact on price levels once this investment was maintained for a sustained time period. This finding has substantial impact for policy makers discussing future rounds of QME as these policies have come under great scrutiny in the wake of austerity measures imposed by governments.

Turning to the transmission mechanisms, we found stock markets to be the main vessel for the impact on Japanese output and price levels (again, similar to HKT). In

[40] The start of the second period within the data indicated by the structural break tests of Japanese data performed in Section 4.
[41] The start of the second period within the data indicated by the structural break tests of UK data performed in Section 4.

addition, we found that a QME shock reduced the nominal rate of interest in Japan, which also contributed to a portfolio rebalancing effect as described previously.

Our analysis of UK QMEP finds slight increases in bank lending and the FTSE 250 index resulting from the QME shock indicating these to be the transmission channels through which the minimal effects of the policy took place. An increase in bank lending is an intended outcome of traditional monetary policy, which indicates that QMEP can be an effective (albeit expensive) alternative when economies are facing the ZLB. The stock market is then an important transmission mechanism, based on the current analysis and that of HKT.

Although we adjudge QME by the BoE to have been largely ineffective, many economists argue that the position of the UK economy might have been significantly worse in the absence of QME, suggesting that the policy was effective in increasing levels of output and prices, but that the impact is masked by negative impacts of other economic factors. We find no evidence to suggest this this is the case, and so it is difficult however to justify this position based on the research in this paper.

6. Conclusions

Looking at Japanese data, this research found QME to have a small but positive impact on output and price levels, with the impact in the later time period (October 2010 onwards) greater and more persistent than that experienced initially. We found increases in the Nikkei 225, the foreign exchange rate and bank lending, and a fall in the nominal rate of interest as evidence of the impact of QME operating through these channels. The portfolio rebalancing channel was determined to be the transmission mechanism for QME by the BoJ, most notably through stock markets and the reduction in nominal interest rates.

Then, analysing the UK data, we found QME by the BoE to have had little impact on aggregate levels of output and prices over the time period analysed, which includes all QME activity that the BoE has conducted. The small effect that QME has had in the UK, most likely came through the stock market and bank lending channels, indicating a small portfolio rebalancing effect.

Although this analysis makes a strong contribution to the research surrounding the effects of QME, a number of improvements and extensions could be made to enhance understanding of the specific topic area. Perhaps the chief shortcoming is the length of the data set employed. Use of QME as a means of tackling waning output and price levels is a relatively recent phenomena and so future analysis will be able to draw upon a larger data set which will likely lead to improvements in the statistical significance of analysis.

Alternative analysis could consider other rates such as different variations of the London Inter-Bank Offered Rate (LIBOR) to determine the impact of the same shocks on short-term and long-term interest rates, extending work produced by Joyce et al (2011), Kapetanios et al (2012) and Fawley and Neely (2013). Further analysis could be conducted using different methods to determine structural breaks within the same data sets, as splitting the data at different points can have a large impact on statistical analysis and results. Markov Switching techniques used by Fujiwara (2004) and Kapetanios et al (2012) or exogenous determination based on economic theory or central bank policy decision timing could be applied to the same dataset to ascertain if their selection significantly impacts overall results.

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8. Appendices

Monetary Policy Timeline

Appendix 1: Conduct of Monetary Policy Measures by the Bank of Japan

Measures (1)	***Description***	***Date***	***Current Target (¥ tn)***	***Actual Bal as of end-Aug 2011 (2)***
Outright purchases of government bonds	Expand measures to ensure financial stability	Dec-08	¥21.6tn per year	¥62.1tn
	Subsequent size expansion on JGB purchases	Mar-09		
Fixed-rate funds-supplying operation against pooled collateral ***(3)***	Provide ample funding at very low interest rate to banks to ease financing conditions, thereby encouraging the decline of long-term rates.	Dec-09	¥35tn	¥31.2tn
	Subsequent size expansion and maturity extension	Mar 2010 and Aug 2010		
Providing support to strengthen the foundations for economic growth	Provide long-term funds at low interest rate to eligible financial institutions to finance actual investment projects in selected industries that support the foundations of economic growth	Apr-10	Not exceeding ¥3tn	¥2.9tn

	Subsequent announcement of operational framework, principal terms and conditions, and disbursements	Four times in 2010, and twice in 2011		
"Comprehensive Monetary Easing (CME)"		Oct-10		
Virtually zero-interest rate policy	Guide expectations on the duration of accommodative stance of monetary policy			
Asset Purchase Program 3/	Encourage the decline of long-term interest rate and catalyse investors' risk appetite to reduce risk premium			
	Pre-empt a deterioration in business sentiment and rise in risk aversion	Mar-11		
	Ensure a successful transition from the recovery phase following the March disaster to a sustainable growth path with price stability.	Aug-11	¥50tn	¥38.6tn

1. Additional measures following the earthquake in March 2011 were introduced, including funds-supplying operation to support financial institutions in disaster area (March) and the new lending facility to support asset-based lending (June).
2. Outstanding balance of government securities include previous purchases before easing measures introduced.
3. The size of asset purchase program was expanded by ¥5 trillion to ¥40 trillion on 14 March, of which ¥30 trillion is related to the fixed-rate funds supplying operations. The target size was further expanded in August 2011 to ¥50 trillion, of which ¥40 trillion on the fixed-rate funds supplying operations.

Source: Lam (2011)

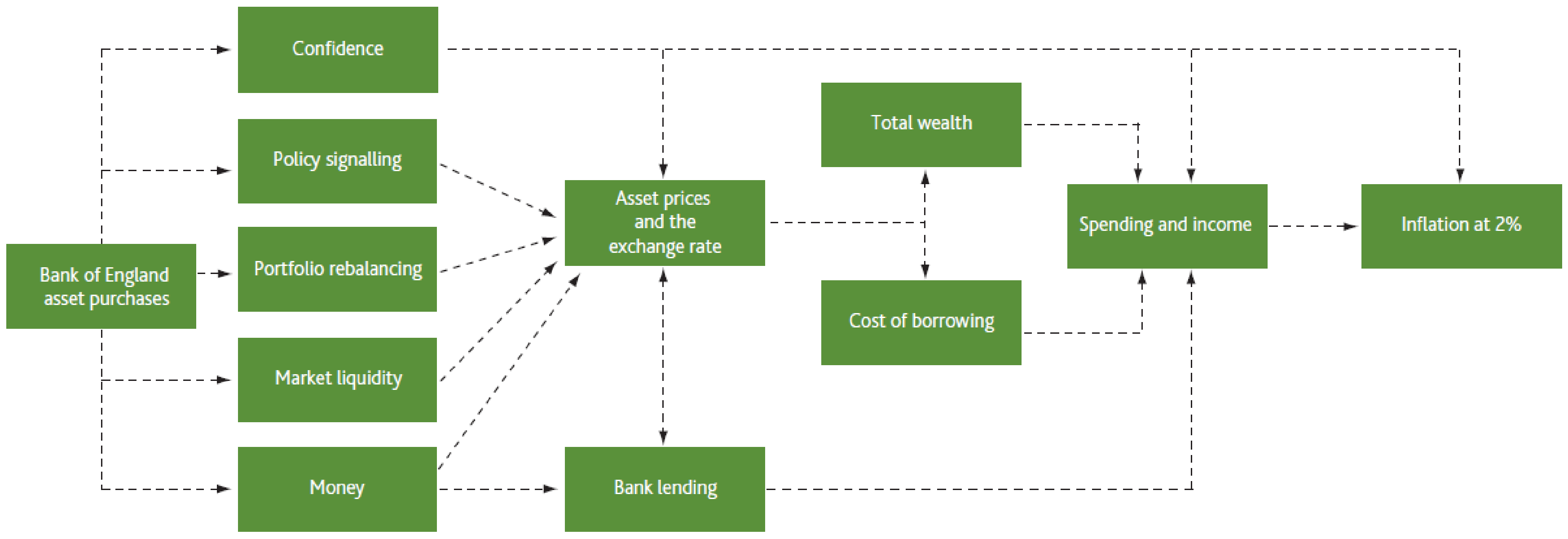
Appendix 2: Conduct of Monetary Policy Measures by the Bank of England

Date	*Event*	*Description*	*Interest Rate News*
19/01/2009	HM Treasury Statement	APF established: The BOE will purchase up to £50 billion of "high quality private sector assets" financed by Treasury issuance.	
11/02/2009	BoE Inflation Report Released	The BOE views a slight downside risk to meeting the inflation target, reiterates APF as a potential policy instrument	
05/03/2009	MPC Statement	QE announced: The BOE will purchase up to £75 billion in assets, now financed by reserve issuance; medium- and long-term gilts will comprise the "majority" of new purchases	The BoE cuts policy rate from 1% to 0.5%
05/07/2009	MPC Statement	QE expanded: The BOE will purchase up to £125 billion in assets	
06/08/2009	MPC Statement	QE expanded: The BOE will purchase up to £175 billion in assets; to accommodate the increased size, the BOE will expand purchases into gilts with remaining maturity of 3 years or more	
05/11/2009	MPC Statement	QE expanded: The BOE will purchase up to £200 billion in assets	
04/02/2010	MPC Statement	QE maintained: The BOE maintains the stock of asset purchases financed by the issuance of reserves at £200 billion; new purchases of private assets will be financed by Treasury issuance.	
06/10/2011	MPC Statement	QE expanded: The BOE will purchase up to £275 billion in assets financed by reserve issuance; the ceiling on private assets held remains £50 billion.	
29/11/2011	HM Treasury Decision	Maximum private asset purchases reduced: HM Treasury lowers the ceiling on APF private asset holdings from £50 billion to £10 billion	
09/02/2012	MPC Statement	QE expanded: The BOE will purchase up to £325 billion in assets	
05/07/2012	MPC Statement	QE expanded: The BOE will purchase up to £375 billion in assets.	

Source: Fawley and Neely (2013)

Quantitative Easing Transmission Channels

Appendix 3: Quantitative Easing Transmission Channels (Based on BoE Asset Purchases)



Source: Joyce et al (2011).