Efficiency of QEs in USA Through Estimation of Precautionary Money Demand

Yoji Morita   Shigeyoshi Miyagawa

Department of Economics, Kyoto Gakuen University, Japan, {morita-y,miyagawa}@kyotogakuen.ac.jp

Abstract

FRB adopted "quantitative monetary easing" three times as QE1 (2008m11,2010m06), QE2 (2010m11,2011m06) and QE3 (2012m09,2014m12). In this paper, we showed that "Reserve at the FRB" is effective to the economy through a transmission path of a stock market in QE1, effective through housing price channel in QE2 and QE3, and effective through an exchange rate channel in QE3, where impulse responses in VAR model are calculated with "reserve, stock prices, exchange rate, industrial production, and cpi_core (or housing price)" in monthly data of USA.

Furthermore, we investigated behaviors of M2 money in QEs periods. Decomposing M2 into transaction money demand and precautionary one, we estimated precautionary money demand as a function of industrial production, business condition denoted by napm and reserve at the FRB. We showed that increasing "Reserve at the FRB" is comparatively effective in QE1 rather than in QE2 and QE3 through the behavior of napm.

Keywords; QE1, QE2, QE3, nontraditional monetary policies

1 Introduction

The subprime problem in 2007 and Lehman crisis in 2008 caused serious depressions in the world economy. Many central banks set interest rates around zero, and carried out "nontraditional monetary policies" in large scales. Generally speaking, operation of short term interest rates based on for example Taylor rule is called "traditional monetary policy", while in financial crisis of these days a traditional monetary policy has no room to operate around zero interest rates, and hence, many central banks were forced to adopt nontraditional monetary policies. There are three kinds of nontraditional monetary easing in USA.

Federal Reserve Board (FRB) decreased FF rate from 2 % at Lehman crisis (2008m09) to 0-0.25 % (2008m12). Furthermore, additional easing policies were done by operations of buying long term government bond, Residential Mortgage-Backed Securities (RMBS) and agency debt. FRB called these policies as "Credit Easing" in the interval (2008m11,2010m06). We denote these monetary easing in this period as QE1. FRB carried out QE2 during (2010m11,2011m06), where long term government bonds of 600 billion dollars were purchased. QE3 was operated during (2012m09,2014m10), where FOMC decided on 2012m12 to buy MBS of 40 billion dollars and long term government bonds of 45 billion dollars per month. However, from 2014m01, FRB gradually decreased buying operations every month and stopped QE3 on 2014m10.

(Bernanke, 2009) said that the essence of QE1 is "credit easing", that is, reducing the cost of private brrowing by direct purchases of privately issued debt instead of government debt. (Gagnon et al., 2011) reported that large-scale asset purchases in QE1 have been successful in doing lower longer term private borrowing rates, which should stimulate economic activity. (Fratzscher et al., 2013) showed highly effectiveness of QE1 compared with QE2 and analysed the global spillovers of the FRB's QE. International spillover effects of US QE were investigated by (Bhattarai et al., 2015). (Wen, 2014) studied the likely impact of QE and its exit strategy with three aspects; (i)the timing of the exit, (ii)the pace of the exit and (iii)the private sector's expectations of when and how the FRB will exit. (Engen and Reifschneider, 2015) showed that by the unconventional monetary policies in USA the peak unemployment effect does not occur until early 2015, while the peak inflation effect is not anticipated until early 2016.

(Hall et al., 2012) analyzed European economy including financial crises 2007 and 2008, focusing on the stability of M3 money demand function through a generalized cointegration concept "TVC". (Fawley and Neely, 2013) described the circumstances of and motivations for the quantitative easing programs of the FRB, Bank of England, European Central Bank, and Bank of Japan during the recent financial crisis and recovery.

Efficiency of QE in Japan during (2001,2006) was shown by (Honda et al., 2007) through transmission paths of both stock market and exchange rate. They used SVAR model. (Sawada, 2014) applied Honda's method to USA case and showed that base money operated at QEs are efficient to the economic activity.

First, in this paper, following (Honda et al., 2007) and (Sawada, 2014), we construct VAR models with 5 variables (reserves, stock prices, exchange rate, industrial production, cpi) in QE1, QE2 and QE3, and investigate the efficiency from "reserves" to "industrial productions" through transmission paths of stock market, exchange rate and/or housing price in each of QEs.

Secondly, focusing our attention on money demand function of "M2", we decompose "M2" into precautionary

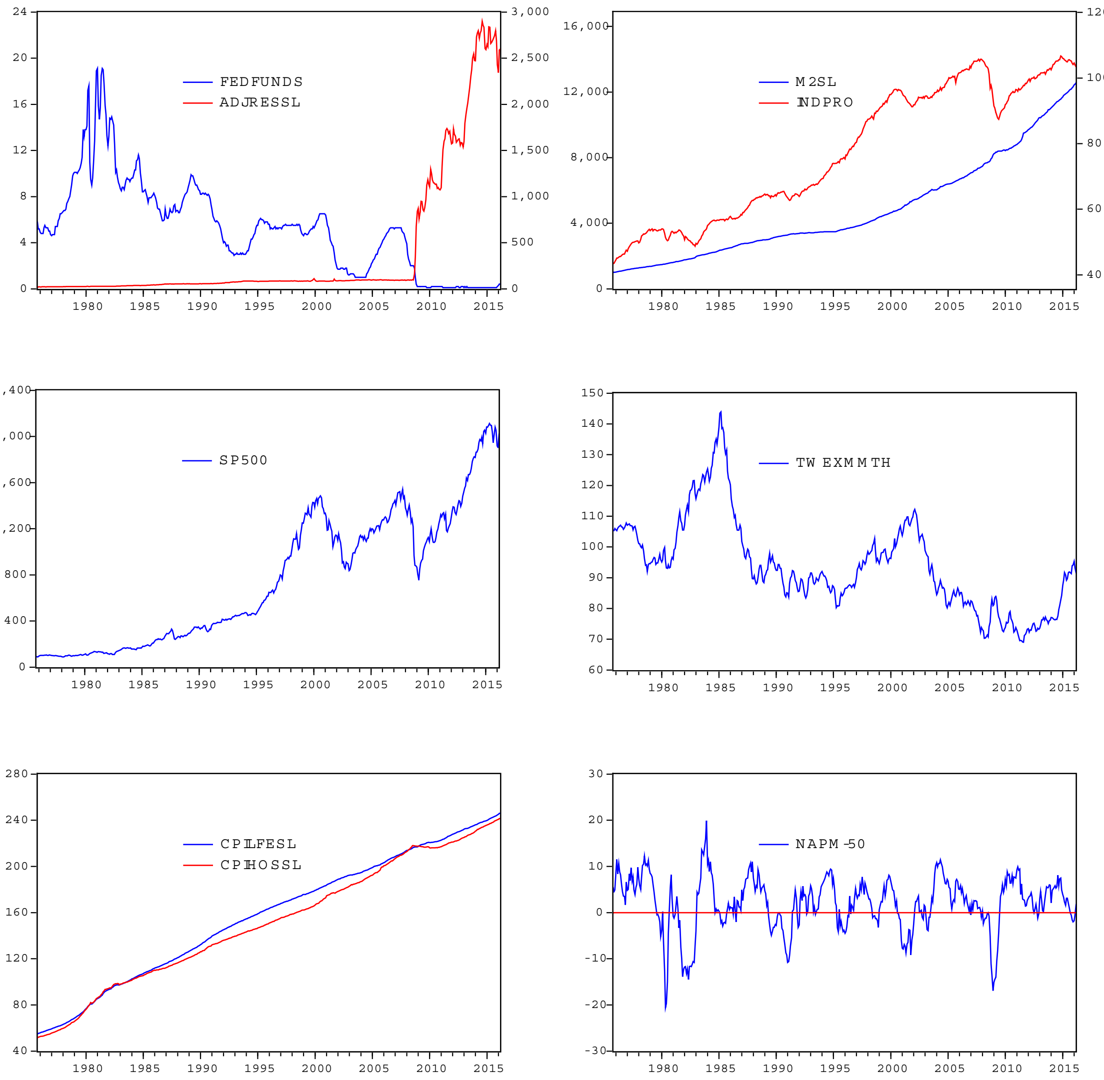

Figure 1. $fedfunds(t)$ and $adjressl(t)$, $indpro(t)$ and $m2sl(t)$, $sp500(t)$, $twexmmth(t)$, $cpilfesl(t)$ and $cpihossl(t)$, and $u(t)$ in (1975m10, 2016m03)

and transaction money demands and estimate precautionary one as a function of economic activity, reserves and business condition during (1975m10,2016m03). Thus, we can investigate behavior of M2 money in QEs. Since (Morita and Miyagawa, 2016) estimated precautionary money demand and analyzed QE monetary policy in Japan with quarterly data, we apply this method to the analysis of US data.

2 Data Properties

Monthly data through (1975m10, 2016m03) are obtained from FRED. Variables and symbolic notations are given in Table 1. See Figure1 for behavior of each variable.

Two kinds of unit root tests are carried out; DF-GLS (ERS) test with unit root as the null hypothesis and KPSS test with stationarity as the null hypothesis. The results are shown in Table 2. Every variable except $u(t)$ is shown to be nonstationary. Hereafter, we treat these variables in

Table 1. List of variables

$adjressl(t)$ = St.Louis adjusted reserves
$fedfunds(t)$ = federal funds rate
$m2sl(t)$ = M2 money stock
$indpro(t)$ = industrial production index
$cpilfesl(t)$ = consumer price index, less food & energy
$cpihossl(t)$ = consumer price index, housing
$sp500(t)$ = S&P500 index
$twexmmth(t)$ = trade weighted exchange index
$napm(t)$ = ISM manufacturing, PMI composite index
$u(t) = napm(t) - 50$
$u_-(t) = \min\{u(t),0\}$ $\quad u_+(t) = \max\{u(t),0\}$

Table 2. Unit Root Test in $(1975m10, 2016m03)$

var.	ERS	*lag*	KPSS	*trend*
$\ln(m2sl/p)$	4.98	2	2.51$*$	*const.*
$\ln(indpro)$	1.52	3	2.72$*$	*const.*
$\ln(sp500/p)$	-2.02	1	0.29$*$	*trend.*
$\ln(twexmmth)$	-1.32	1	1.47$*$	*const.*
u	$-4.33*$	2	0.01	*const.*
$\ln(adjressl/p)$	0.92	2	1.66$*$	*const.*
$\ln(p)$	0.24	9	2.61$*$	*const.*
$\ln(cpihossl)$	0.61	9	2.62$*$	*const.*

$*$ denotes 1% significance level and $p = cpilfesl$.

levels in order to avoid cointegration analysis.

3 Macro Money Systems in QEs

Letting $x = (\ln(adjressl) - \ln(p),\ \ln(sp500) - \ln(p),\ \ln(twexmmth),\ \ln(indpro),\ \ln(p))'$, we consider VAR model of the form with the lag order i given by AIC,

$$x(t) = A_0 + A_1 x(t-1) + \cdots + A_i x(t-i) + \varepsilon(t),. \quad (1)$$

3.1 Behavior in QE1=(2008m11,2010m06)

Setting sampling interval as QE1, impulse responses of (1) are depicted in Figure 2, where a solid line implies a calculated impulse response and two dotted lines show 95 % confidence intervals. For economy of space, we only show responses of 5 variables corresponding to three kinds of impulse shocks; "reserves", "sp500" and "exchange rate (twexmmth)".

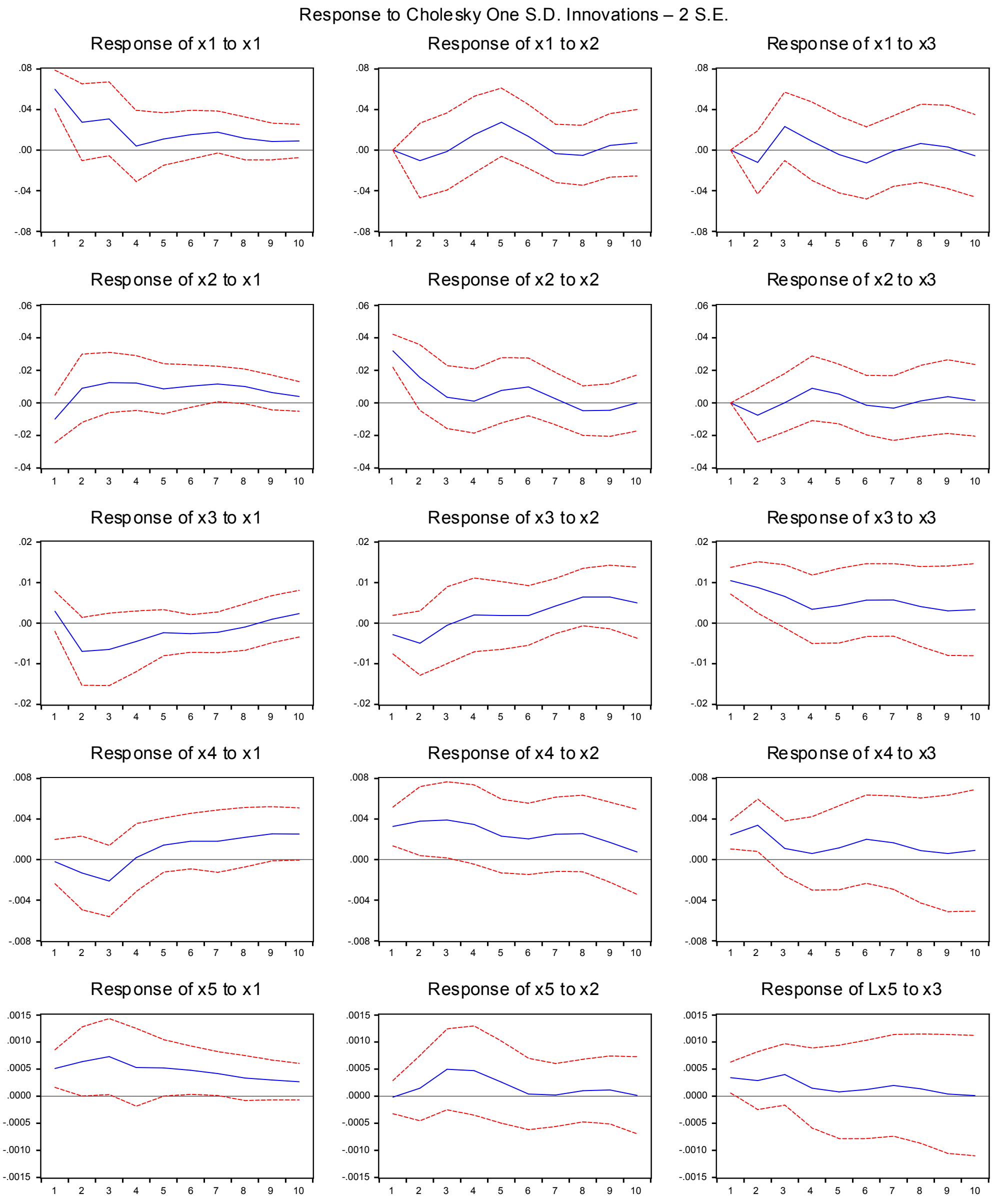

Figure 2. Impulse responses of the system with $x = (x_1, x_2, x_3, x_4, x_5)'$, where in the figure we denote $x_1 = \ln(adjressl/p)$, $x_2 = \ln(sp500/p), x_3 = \ln(twexmmth), x_4 = \ln(indpro), x_5 = \ln(p)$ in QE1=(2008m11,2011m06).

Hereafter, if necessary, we abbreviate *reserves* and *twexmmth* by *rsrvs* and *rex* respectively.

1st:	$rsrvs(\uparrow) \Longrightarrow$	$rsrvs(\uparrow)$	$stock(\cdots\uparrow)$
	$rex(\downarrow)$	$indpro(\cdots\uparrow)$	$p(\uparrow)$
2nd:	$stock(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\uparrow)$
	$rex(\cdots)$	$indpro(\uparrow)$	$p(\cdots)$
3rd:	$rex(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\cdots)$
	$rex(\uparrow)$	$indpro(\uparrow)$	$p(\uparrow)$

where $rex = twexmmth(\uparrow)$ implies "high appreciation of dollar", and where $(\cdots)$ and $(\cdots\uparrow)$ mean "statistically not significcant" and "at first not significant but after several months significantly ↑" respectively.

We can see that $reserves(\uparrow) \rightarrow indpro(\uparrow)$ on the 1st column, and that $reserves(\uparrow) \rightarrow stock(\uparrow) \rightarrow indpro(\uparrow)$ on the 1st and 2nd columns. It should be noticed, however, that $reserves(\uparrow) \rightarrow rex(\downarrow) \not\rightarrow indpro(\uparrow)$ on the 1st and 3rd columns. Therefore, we can conclde that there is a transmission path in QE1 through a stock market, but not through exchange rate.

3.2 Behavior in QE2+α=(2010m11,2012m08)

Since QE2 is too small to construct VAR model, we extend the sampling interval QE2 to $QE2+\alpha = (2010m11, 2011m06) + (2011m07, 2012m08)$ just before starting QE3.

Impulse responses of (1) are depicted in Figure 3, where a solid line implies a calculated impulse response and two dotted lines show 95 % confidence intervals.

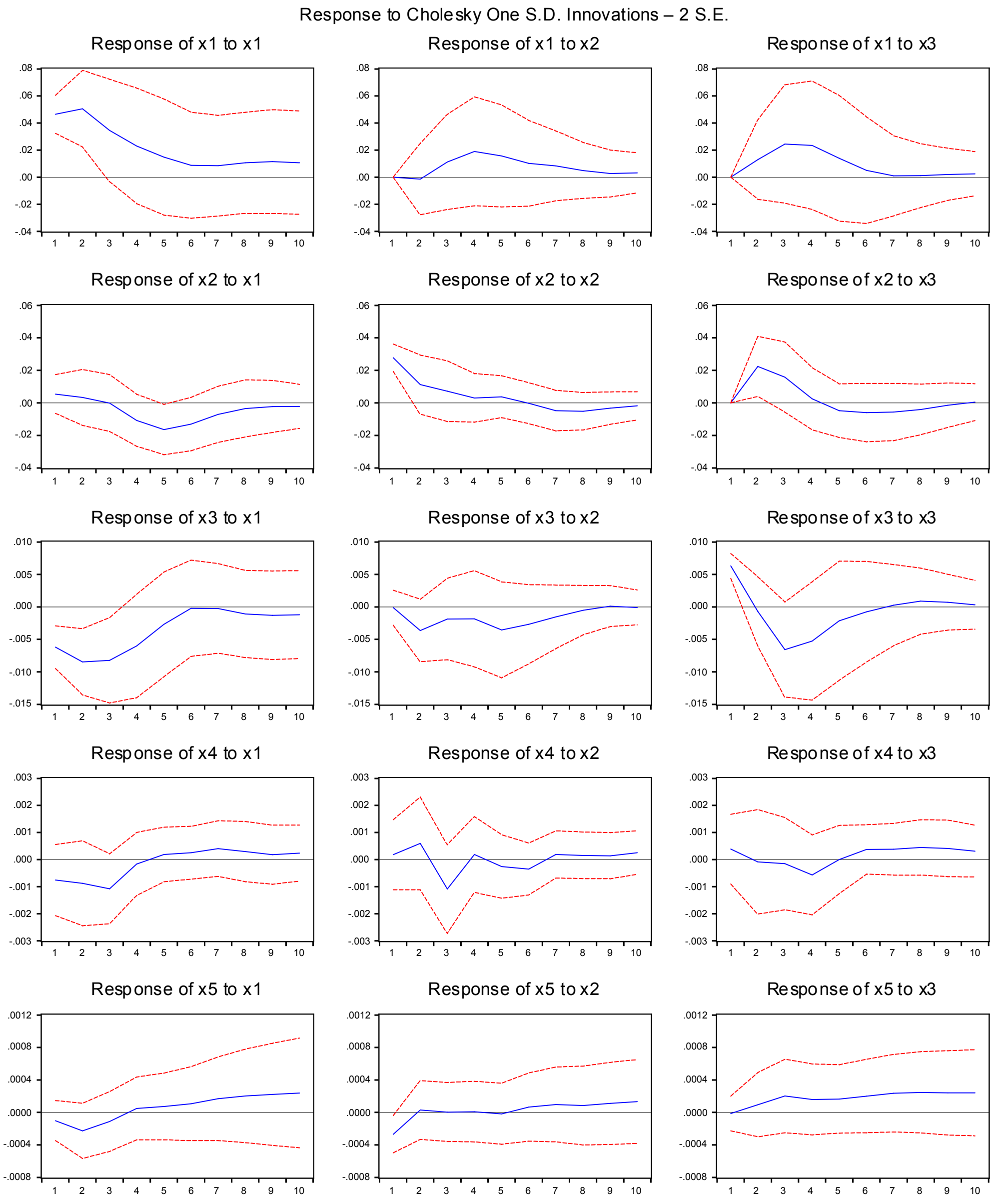

Figure 3. Impulse responses of the system with $x = (x_1, x_2, x_3, x_4, x_5)'$, where in the figure we denote $x_1 = \ln(adjressl/p)$, $x_2 = \ln(sp500/p), x_3 = \ln(twexmmth), x_4 = \ln(indpro), x_5 = \ln(p)$ in $QE2+\alpha = (2010m10, 2012m08)$.

Responses of 5 variables are shown, corresponding to three kinds of impulse shocks; ”reserves“, ”sp500“ and ”exchange rate (twexmmth)“.

1st:	$rsrvs(\uparrow) \Longrightarrow$	$rsrvs(\uparrow)$	$stock(\cdots\downarrow)$
	$rex(\downarrow)$	$indpro(\cdots\downarrow)$	$p(\cdots)$
2nd:	$stock(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\uparrow)$
	$rex(\cdots)$	$indpro(\cdots)$	$p(\downarrow)$
3rd:	$rex(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\uparrow)$
	$rex(\uparrow)$	$indpro(\cdots)$	$p(\cdots)$

In this period of QE2, we cannot say any transmission path from $reserves(\uparrow)$ to $indpro(\uparrow)$.

3.3 Behavior in QE3=(2012m09,2014m10)

Setting sampling interval as QE3, impulse responses of (1) are depicted in Figure.4, where a solid line implies a calculated impulse response and two dotted lines show 95 % confidence intervals. For economy of space, we only show 5 variables responses corresponding to three kinds of impulse shocks; ”reserves“, ”sp500“ and ”exchange rate (twexmmth)“.

1st:	$rsrvs(\uparrow) \Longrightarrow$	$rsrvs(\uparrow)$	$stock(\uparrow)$
	$rex(\downarrow)$	$indpro(\cdots)$	$p(\cdots)$
2nd:	$stock(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\uparrow)$
	$rex(\cdots)$	$indpro(\downarrow)$	$p(\cdots)$
3rd:	$rex(\uparrow) \Longrightarrow$	$rsrvs(\cdots)$	$stock(\cdots)$
	$rex(\uparrow)$	$indpro(\downarrow)$	$p(\downarrow)$

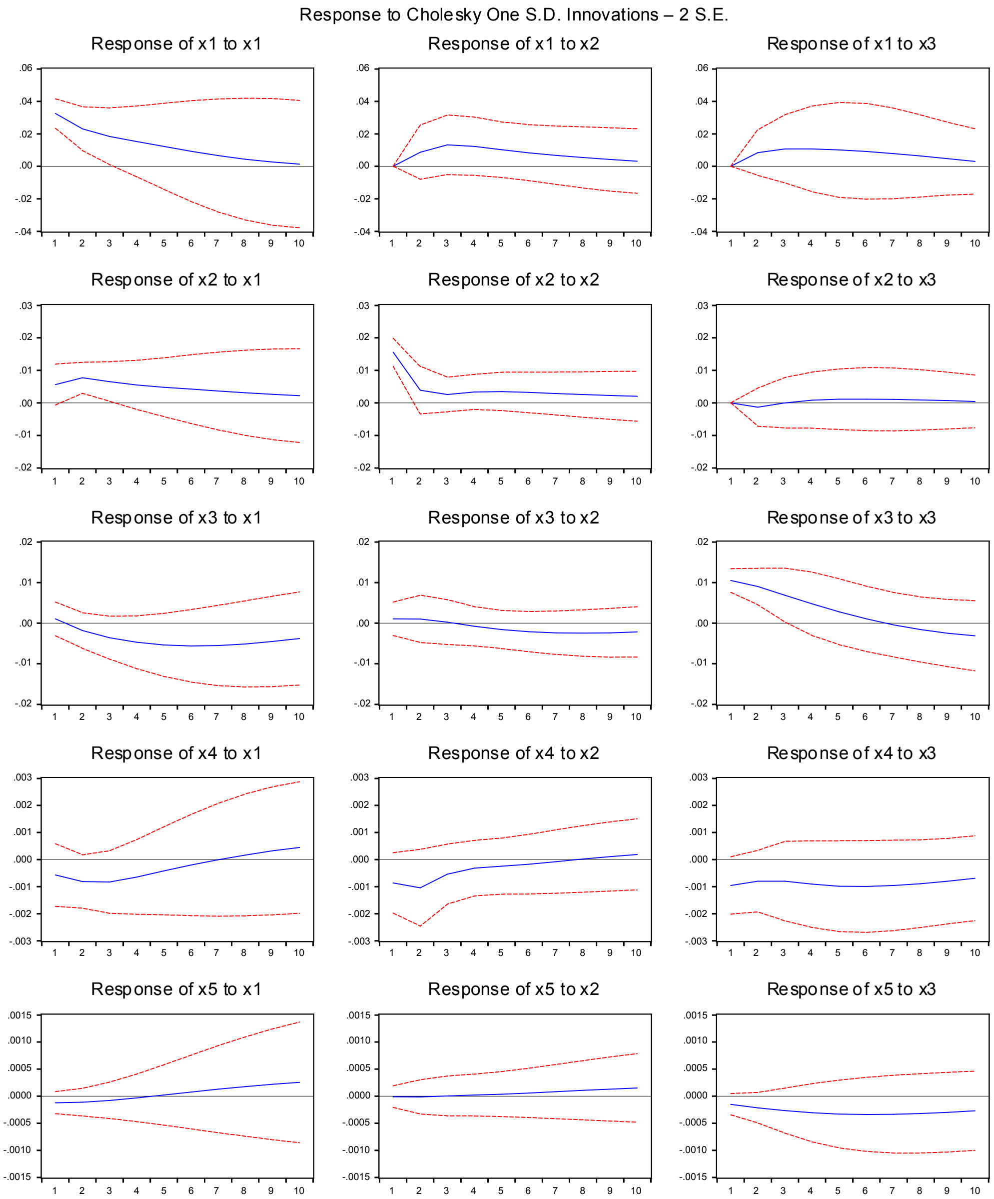

Figure 4. Impulse responses of the system with $x = (x_1, x_2, x_3, x_4, x_5)^{'}$, where in the figure we denote $x_1 = \ln(adjressl/p)$, $x_2 = \ln(sp500/p), x_3 = \ln(twexmmth), x_4 = \ln(indpro), x_5 = \ln(p)$ in QE3=(2012m09,2014m10).

We can see that $reserves(\uparrow) \to rex(\downarrow) \to indpro(\uparrow)$ on the 1st and 3rd columns, while we can see that $reserves(\uparrow) \to stock(\uparrow) \not\to indpro(\uparrow)$ on the 1st and 2nd columns.

Therefore, we can conclude that there is a transmission path in QE3 through exchange rate, but not through a stock market.

4 Transmission Path of Housing Price from Reserve to Economic Activity

In this section, we consider the influence of housing price to the economy. Defining, in (1), $x = (\ln(adjressl/p), \ln(indpro), \ln(cpihossl))'$ and estimating VAR model, we can obtain impulse responses corresponding to the sampling intervals $QE1$, $QE2+\alpha$ and $QE3$. Remark that 5 variables VAR model with $\ln cpilfesl$ replaced by $\ln cpihossl$ in the preceding section gives us a similar result as in this section with 3 variables. For economy of space, we only show the results without figures of impulse responses.

We can see that
(QE1) $reserve(\uparrow) \not\to cpihossl(\uparrow)$,
($QE2+\alpha$) $reserve(\uparrow) \to cpihossl(\uparrow) \to indpro(\uparrow)$,
(QE3) $reserve(\uparrow) \to cpihossl(\uparrow) \to indpro(\uparrow)$.

So, we can conclude that there is a transmission path through housing price in QE2 and QE3, not in QE1.

5 Decomposition of $M2$ into Transaction and Precautionary Money Demands in (1975m10, 2016m03)

In this section, we statistically quantify how much money contributed to the recovery of the economy when the FRB increased reserves. We would decompose the money stock denoted by $m2sl(t)$ into the transaction money and the precautionary money demands.

5.1 Estimation of Precautionary Money Demand

Precautionary money demand will increase when the liquidity concern among the private sector intensify in the depression, while its demand will decrease when the concern dispels in the boom. We use here the $u(t) = napm(t) - 50$, where $napm(t)$ implies "ISM manufacturing: PMI composite index" in order to qualify the unobservable variable, which would affect the precautionary money demand.

Properties of precautionary money demand can be listed as follows:

[Properties of prec. money demand]

- $indpro(\uparrow) \Longrightarrow prec.\ money\ demand(\uparrow)$ as Keynes said.
- $prec.\ money\ demand(\uparrow)$ for future anxiety when economy is in depression.
- prec. money demand is affected by reserves in QEMP.

[Assumption of prec. money demand]

$$\begin{aligned} & prec.\ money\ demand(t) \\ = \ & c_1 * indpro(t) * cpilfesl(t)/1000 \\ + \ & (c_2 * u_n(t) + c_3 * u_p(t)) * \frac{m2sl(t)}{1000} \\ + \ & c_4 * adjressl(t) * dummy_{adjressl}(t) \end{aligned} \tag{2}$$

In the above assumption, the 2nd term on the RHS means that the precautionary money demand is a function of napm, because people try to hold more money when financial anxiety rises, and that the demand may depend on the level of M2. The 3rd term represents effect of the FRB's monetary policies. We take into consideration the policy change by adding the dummy variable. The reserves began to be increased by FRB from September 2008. We have set both of $ff\ rate$ and $adjressl$ as monetary policies, but $ff\ rate$ was not significant, and was deleted in (2). Dummy variable denoted by $dummy_{adjressl}(t)$ in (2) takes value 1 for $t = (2008m09, 2016m03)$ and takes value 0 otherwise.

[Log-likelihood function] The growth rate model of $indpro(t)$ is taken into consideration, and the log-likelihood function of $\Delta\ln(indpro)$ should be maximized with respect to every parameter containing prec. money demand, where in the following equation "$prec.\ money\ demand(t)$" is abbreviated by "$prc.\ mny(t)$".

$$\begin{aligned} & \Delta\ln(indpro(t)) = d_1 * \Delta\ln(indpro(t-1)) \\ + \ & d_2 * \Delta\ln(indpro(t-2)) + d_3 * \Delta\ln(indpro(t-3)) \\ + \ & d_4 * \Delta\ln((m2sl(t-1) - prc.mny(t-1))/p(t-1)) \\ + \ & d_5 * \Delta\ln((m2sl(t-2) - prc.mny(t-2))/p(t-2)) \end{aligned} \tag{3}$$

Table 3 shows estimation results in (2) and (3) .

Table 3. Estimation results of (2) and (3) in $(1975m10, 2016m03)$

	coefficients	*std.error*	*z-statistics*	*prob.*
c_1	143.46	140.57	1.021	0.3074
c_2	-11.82	4.905	-2.410	0.0160
c_3	-4.847	3.256	-1.489	0.1365
c_4	1.003	0.345	2.907	0.0036
d_1	0.118	0.048	2.450	0.0143
d_2	0.176	0.0518	3.399	0.0007
d_3	0.247	0.0389	6.355	0.0000
d_4	0.0425	0.0290	1.468	0.1422
d_5	0.0340	0.0255	1.335	0.1819

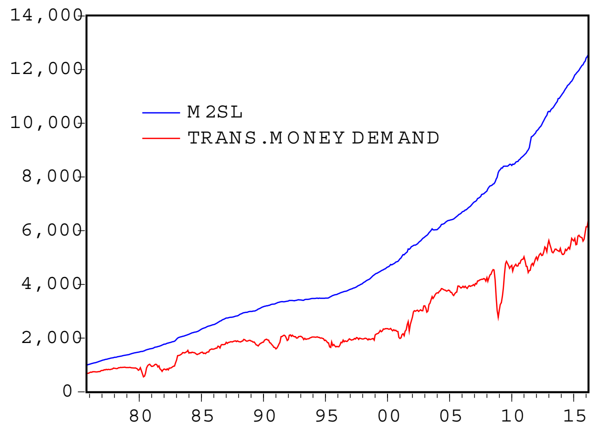

Figure 5. *m2sl* and *trans.money demand* estimated in (1975m10, 2016m03)

Figure 5 shows the nominal money stock *m2sl* and the trans. money demand. The difference "$m2sl - trans.\ money\ demand$" measures the prec. money demand. We find that the difference begins to expand rapidly around 1995, 2000 and 2008.

Figure 6 depicts the comparison of trans. money demand with prec. one in (2008m09, 2016m03) including QE1,QE2 and QE3. In this figure during the QEMP period, prec. money demand as well as trans. money demand gradually increases except for the beginning of QE1. In the zero interest rates period, there may exist the phenomena of "Liquidity trap" such that easing money by the central bank is only saved without consumption. However, in our estimation, prec. money demand increases while trans. money demand is also increasing. We may insist that the "Liquidity trap" does not exist in QEMP period.

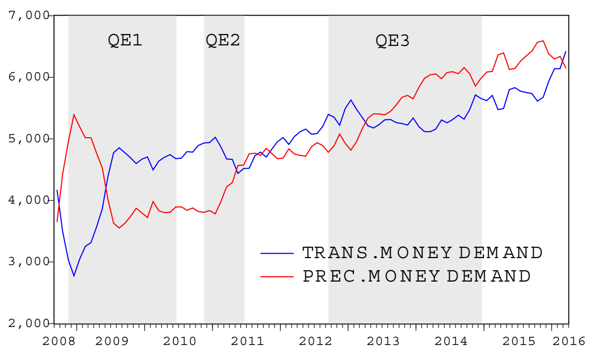

Figure 6. Estimation results of $trans.\ money\ demand$ and $prec.\ money\ demand$ in (2008m09, 2016m03)

5.2 The Role of Business Condition $u(t) = napm - 50$ in Transmission Mechanism of QEMP during $QE1, QE2+\alpha$ and $QE3$

We estimate VAR model of $y = (\ln(adjlfesl(t)),\ u(t),\ \ln(trns.\ mny\ dmnd(t)),\ \ln(prc.\ mny\ dmnd(t))^{`}$ with x replaced by y in Eq.(1) . We focus on the role of $u(t)$ in the transmission mechanism of easing monetary policy. Figures 7, 8 and 9 show impulse responses to a one standard deviation shock to four variables in periods of QE1, $QE2+\alpha$ and EQ3 respectively.

In QE1, we can see the following behavior:

1st:	$\ln(adjressl)(\uparrow) \Longrightarrow$	$adjressl(\uparrow)$
	$u(\cdots\uparrow)$	$trns.mny(\downarrow\uparrow)$
	$prc.mny(\uparrow)$	
2nd:	$u(\uparrow) \Longrightarrow$	$\ln(adjressl)(\cdots)$
	$u(\uparrow)$	$\ln(trns.mny)(\uparrow)$
	$ln(prc.mny)(\downarrow)$	
3rd:	$\ln(trns.mny)(\uparrow) \Longrightarrow$	$\ln(adjressl)(\downarrow)$
	$u(\uparrow)$	$\ln(trns.mny)(\uparrow)$
	$ln(prc.mny)(\downarrow)$	
4th:	$\ln(prc.mny)(\uparrow) \Longrightarrow$	$adjressl(\uparrow)$
	$u(\cdots\uparrow)$	$trns.mny(\cdots\uparrow)$
	$prc.mny(\uparrow)$	

Summarizing the behavior in QE1, we can say that a quantitative monetary easing has a positive effect on USA's economy. On the 1st column of Figure 7, we can see first $reserve(\uparrow) \rightarrow prec.demand(\uparrow)$. At the same time, $trans.demand$ changes from downward to upward during several months: $trans.demand(\downarrow\ \cdots\uparrow)$. u rises along with $trans.demand$ on the 1st column, while on the 2nd column, $u(\uparrow) \rightarrow trans.demand(\uparrow)$.

In $QE2+\alpha$, we can't see the path from reserve to trans. demand in Figure 8.

In QE3, on the 1st and 2nd columns of Figure 9, we can see
$reserve(\uparrow) \not\rightarrow trans.demand(\uparrow)$,
$reserve(\uparrow) \rightarrow u(\uparrow)$,
$u(\uparrow) \rightarrow trans.demand(\uparrow)$.
Thus, we can say that efficency of QEs is, in order, given by $QE1 > QE3 > QE2$.

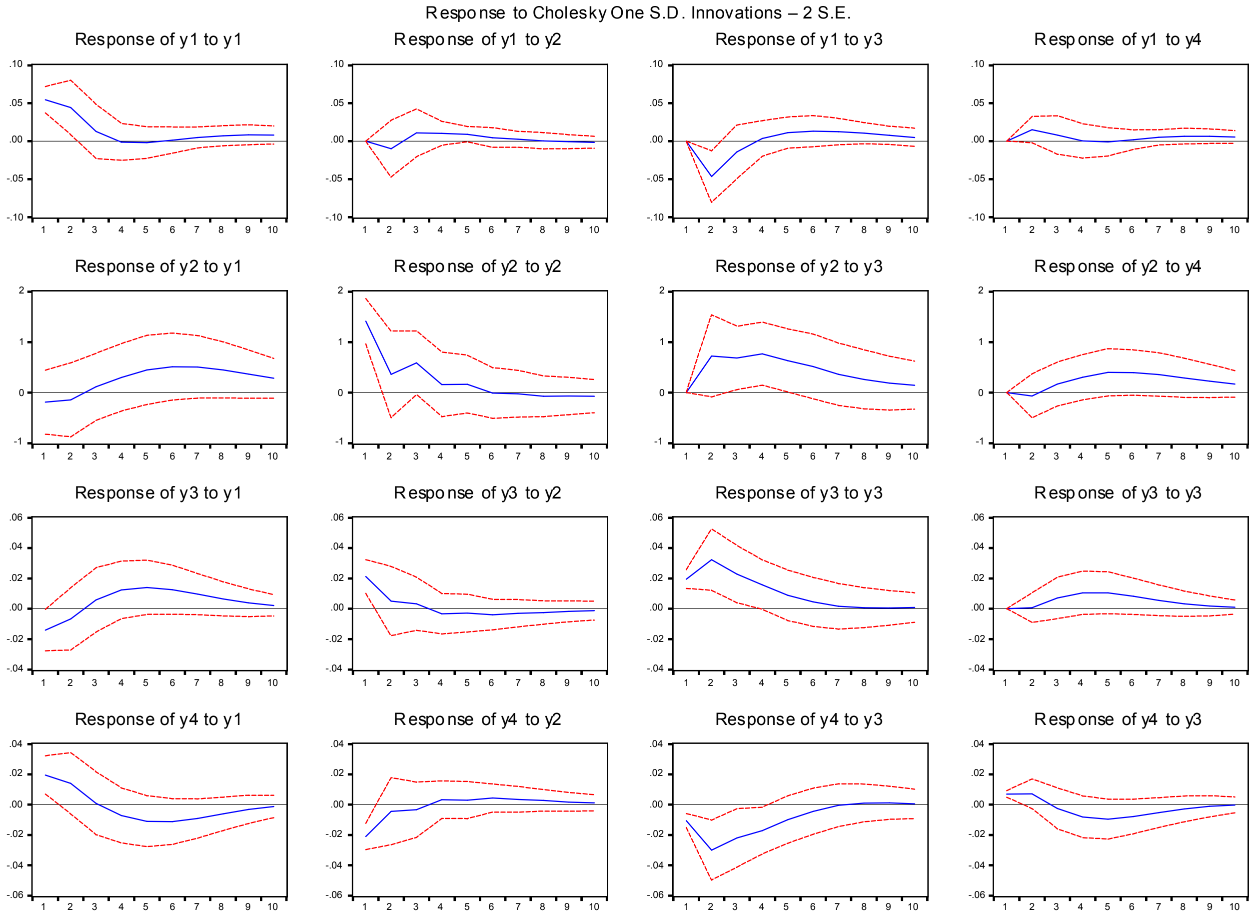

Figure 7. Impulse responses of the system with $y = (y_1, y_2, y_3, y_4,)'$, where in the figure we denote $y_1 = \ln(adjressl/p), y_2 = u(t)$, $y_3 = \ln(trans.\ money\ demand(t)), y_4 = \ln(prec.\ money\ demand(t))$ in QE1.

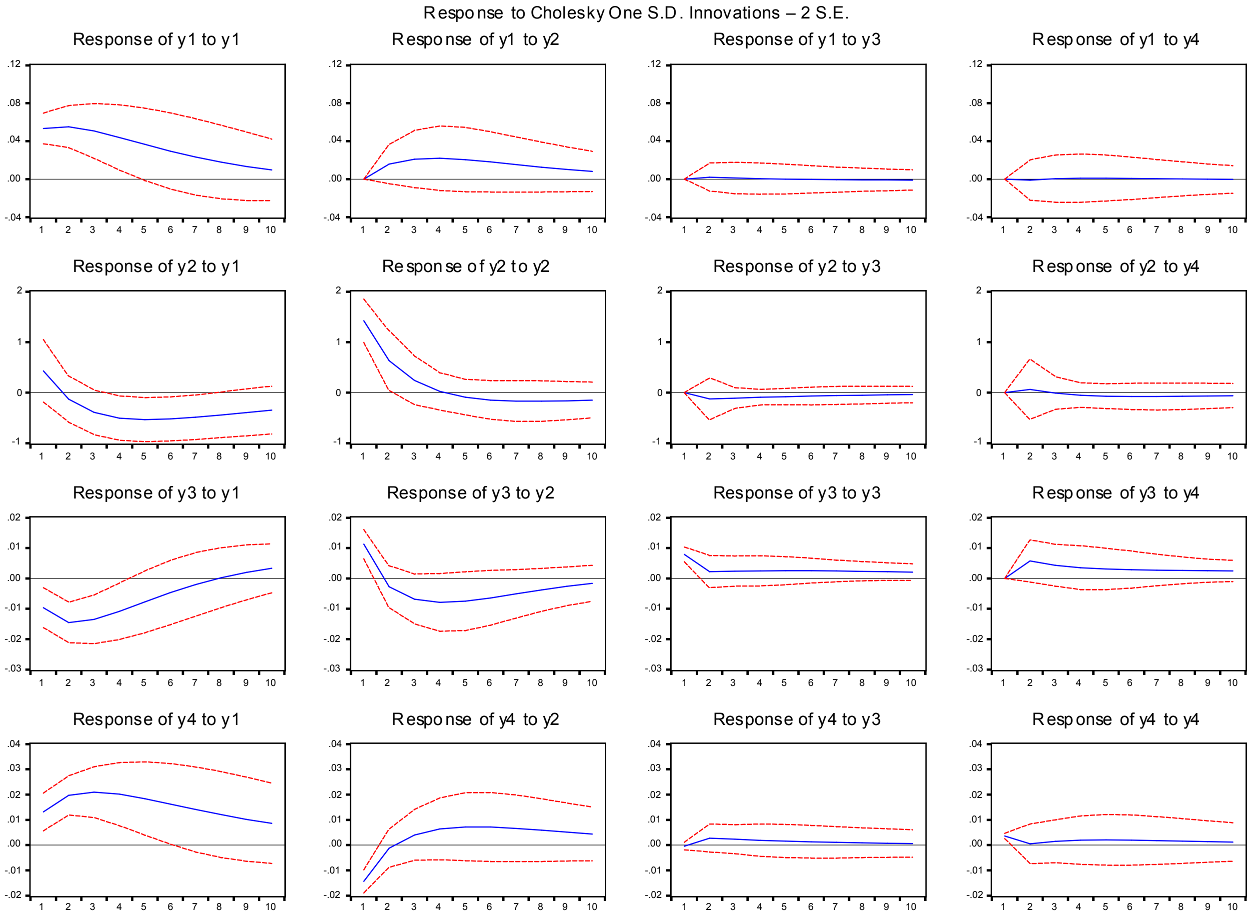

Figure 8. Impulse responses of the system with $y = (y_1, y_2, y_3, y_4,)^{'}$, where in the figure we denote $y_1 = \ln(adjressl/p), y_2 = u(t)$, $y_3 = \ln(trans.\ money\ demand(t)), y_4 = \ln(prec.\ money\ demand(t))$ in $QE2 + \alpha$.

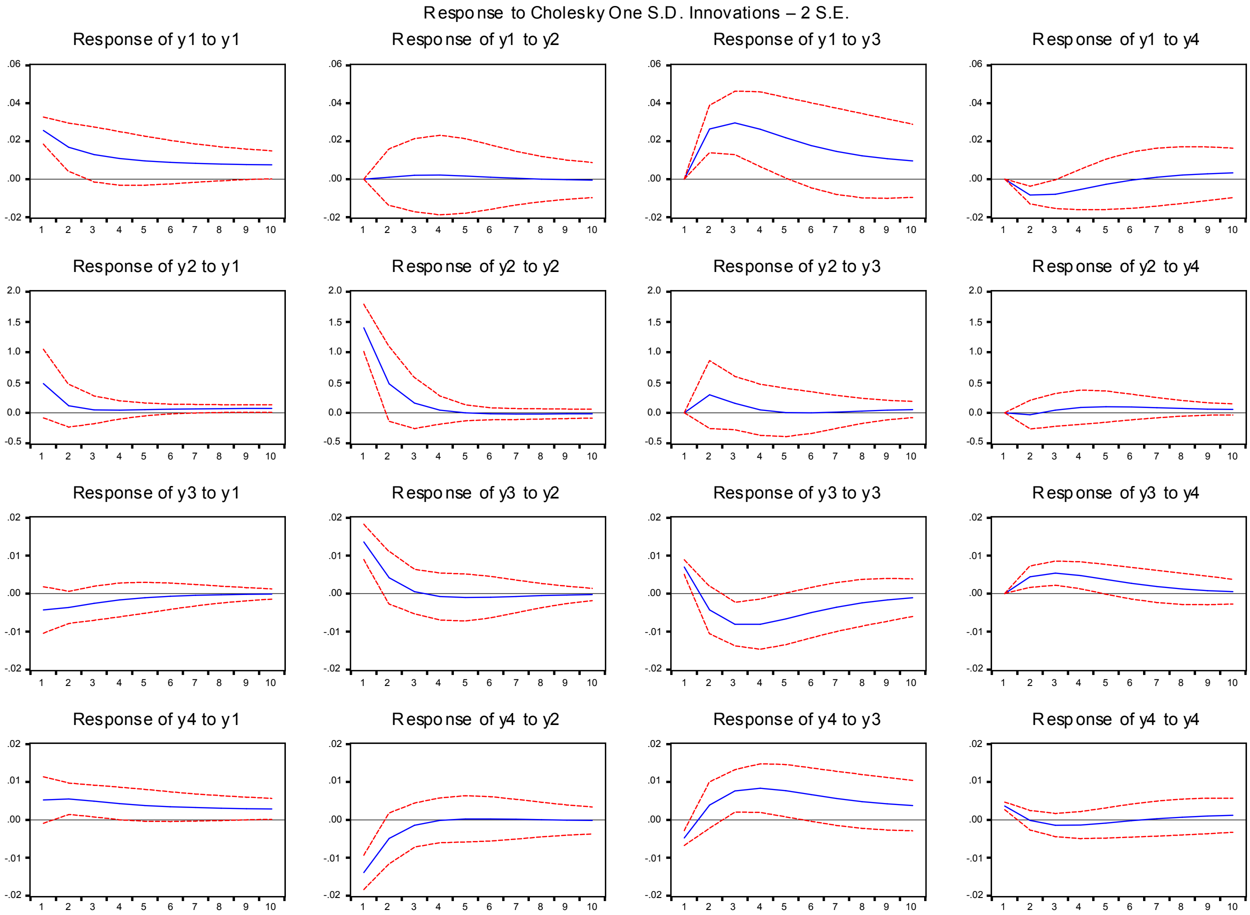

Figure 9. Impulse responses of the system with $y = (y_1, y_2, y_3, y_4,)^{'}$, where in the figure we denote $y_1 = \ln(adjressl/p), y_2 = u(t)$, $y_3 = \ln(trans.\ money\ demand(t)), y_4 = \ln(prec.\ money\ demand(t))$ in QE3.

6 Conclusions

We investigated efficiency of QE1, QE2 and QE3 in USA in two ways. First, usual VAR models were constructed and we can see that QE1 is effective through a transmission path of a stock market, QE2 and QE3 are effective through housing price path, and that QE3 is effective through an exchange rate path. Secondly, decomposing M2 into precautionary and transaction money demands, we can estimate precautionary money demand as a function on "industrial production", business condition and reserves. By investigating relationship among reserves, business condition, transaction and money demands, we see that QE1 is most effective and that QE3 is effective and that QE2 is not so effective. .

References

B.S. Bernanke. The crisis and the policy response. Technical report, London School of Economics, 2009.

S. Bhattarai, A. Chatterjee, and W.Y. Park. Effects of US quantitative easing on emerging market economies. *Globalization and Monetary Policy Institute, Working Paper*, (255), 2015.

E. Engen and D. Reifschneider. The macroeconomic effects of the Federal Reserve's unconventional monetary policies. *Finance and Economics Discussion Series*, (2015-005), 2015.

B.W. Fawley and C.J. Neely. Four stories of quantitative easing. *Federal Reserve Bank of St. Louis REVIEW*, 95(1):51–88, 2013.

M. Fratzscher, M.L. Duca, and R. Straub. On the international spillovers of US quantitative easing. *European Central Bank Working Paper Series*, (1557), 2013.

J. Gagnon, M. Raskin, J. Remache, and B. Sack. Large-scale asset purchases by the Federal Reserve: Did they work? *Economic Policy Review*, 2011.

S.G. Hall, P.A.V.B. Swamy, and G.S. Taylas. Milton Friedman, the demand for money, and the ECB's monetary policy strategy. *Federal Reserve Bank of St. Louis REVIEW*, 2012.

Y. Honda, Y. Kuroki, and M. Tachibana. An injection of base money at zero interest rates: empirical evidence from the Japanese experience 2001-2006. *Osaka University, Discussion Papers in Economics and Business*, 7(8), 2007.

Y. Morita and S. Miyagawa. Efficiency of quantitative easing in Japan during (2001, 2006) through estimation of precautionary money demand-II. In *Proceedings of SSS15 (the ISCIE International Symposium on Stochastic Systems Theory and Its Applications)*, 2016.

Y. Sawada. The effectiveness of unconventional monetary policy in USA. In *Proceedings of SSS13 (the ISCIE International Symposium on Stochastic Systems Theory and Its Applications)*, 2014.

Y. Wen. When and how to exit quantitative easing? *Federal Reserve Bankorita of St. Louis Review*, 96(3):243–265, 2014.