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Article

US interest rate spread and energy consumption by sector (evidence of pre and post implementation of the Fed's LSAPs policy)

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Research paper

US interest rate spread and energy consumption by sector (Evidence of pre and post implementation of the Fed's LSAPs policy)

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HIGHLIGHTS

- Results emphasized the significant effects of US monetary policy on energy consumption.
- The cut in interest rate spreads was reflected as a positive signal in energy consumption market.
- Mortgage spread shock had greater effects on energy consumed by the residential sector in the post LSAPs policy implementation.

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ABSTRACT

This paper represents the first empirical study to investigate the effects of interest rate spread shocks before and after the implementation of LSAPs (Federal Reserve large-scale asset purchases) on energy consumption for different sectors. The US monthly data (2002–2015) for interest rate spreads, such as term, corporate, and mortgage rate spreads, and paper bills, and the energy used by sector (residential, commercial, industrial, transportation, and electric power) were used in this study. Our analysis provided evidence that a cut in interest rate spreads was seen as a positive signal in the energy market. This paper demonstrated that the mortgage spread (MORS) shock had a significant effect on the energy consumed by the residential sector, after the implementation of unconventional monetary policies. Likewise, paper bill shocks had a significant effect on energy consumption for different sectors before the implementation of unconventional monetary policies. The results indicated that the Federal Fund Effective rate had a weak impact on components of energy consumption before the implementation of quantitative easing policies by the Federal Reserve.

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1. Introduction

Since 2007, there have been waves of economic crisis and the collapse of international companies. As a result, different types of fiscal and monetary policies have been suggested to improve the economic situation. Although central banks used the traditional tools of monetary policy and reduced interest rates to their lowest level, signs of economic improvement have not appeared and zero bound interest rates have led to the malfunction of conventional monetary policy. The experience of Japan in the late 1990s, with zero bound interest rates and unconventional monetary policies, encouraged other central banks, specifically the Federal Reserve, to use new quantitative easing policies in the United States.

In order to control the expansion of the economic crisis and to stimulate the economy, in November 2008 the US Federal Reserve (FED) employed a large scale asset policy (LSAP) and engaged in

unconventional monetary policies. The Federal Reserve pursued new expansionary monetary policies by purchasing securities such as mortgage backed securities and long term bonds on the open market. LSAPs and quantitative easing (QE) policies were executed in several stages. The first stage (QE1) began in November 2008 and lasted until March 2010. The second stage (QE2), began in November 2011 and ended in June 2011. The third stage (QE3), recognized as an operation twist,¹ was launched in September 2011. The last phase began in 2012. Economic recession in Europe, Asia, and America encourage other Central Banks to employ new monetary policies. The unconventional monetary policies used in the United States were embraced by other central banks around the world, including the European Central bank (ECB), England Central Bank, and Japan Central Bank. However, recent economic crises and the tools used by policy makers to stabilize economic conditions

¹ The Federal Reserve sold short-term treasury bonds and bought long-term treasury bonds.

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had consequences on populations, energy, and the environment that are still uncertain.

Many empirical studies have addressed supply and demand shocks that have had different effects on energy markets. To display the response of energy markets to exogenous shocks, the degree and significance of the impact of financial and economic factors on energy markets must be examined (Kilian and Murphy, 2012; Baumeister and Peersman, 2013).

The objective of this paper was to provide insight into the effects of interest rate spreads on the energy used by different sectors.

The question that might be raised here is “why is this research relevant to energy economics?” first of all, in this research has been tried to investigate reaction of US energy consumption by sector to monetary policy shocks. Analysis of energy demand especially by sector is crucial as United States and China are the main consumers of energy. Comparison Data from the U.S. Energy Information Administration indicated that energy consumption almost tripled from 1950 and 2015 and energy consumption per capita increase by 50% over this period. Moreover, an evaluation of the energy used by different sectors shows that commercial and residential sectors have experienced the highest rate of growth compared to other sectors. For example, 40% of the energy consumed in the United States was consumed by commercial and residential buildings. In the United States, the major sources of energy are petroleum, natural gas, and coal. Petroleum is the main source of energy and almost 40% of the energy consumed is provided by petroleum. This rate has not been changed significantly since 1950.

Second, reliance on non-renewable forms of energy increases vulnerability to many exogenous shocks. Energy prices, demand and supply shocks, the response of energy market to fiscal and monetary policy, and the reactions of the residential, commercial, industrial sectors to market prices, are all important factors that can play a crucial role in determining the energy consumption for different sectors. Many studies have evaluated the effects of interest rate spreads on different economics variables, however, the impact of US conventional and unconventional monetary policy on US energy consumption by sector has never been identified.

The main contribution of this paper was to evaluate the effects of US interest rate spreads over two periods of time; consequently, this paper is split into two main parts. In the first part, the interest rate spreads after November 2008 when the US FED employed unconventional monetary policies, was evaluated. In the second section, we compared the results from the first section with a period of conventional monetary policy, from before November 2008. In this way the effects of interest rate spreads in times of conventional and unconventional monetary policy on components of energy consumption could be investigated separately. Furthermore, this study made a sectoral analysis regarding the possible effects of monetary policy on sectoral primary of energy consumption consisting of energy consumed by the residential, commercial, industrial, transportation, and electric power sectors using data from the U.S. Energy Information Administration (EIA).

The empirical results revealed that the cut in US interest rate spreads was a positive sign for the market and led to increased energy consumption in most sectors in both periods of conventional and unconventional monetary policy. However, the effect of shocks caused by interest rate on energy consumption in different sectors was not significant. The findings indicated that shocks caused by mortgage spreads had a greater effect on the energy consumed by the residential sector in the post unconventional monetary policy implementation period. Moreover, the effect of paper bill shocks on the energy consumed by sector was larger before the implementation of unconventional monetary policies. Digging deeper into the results revealed that most of the interest rate spreads had a large impact on the energy consumed by the transportation and industrial sectors during periods of conventional monetary policy.

Interest rate spreads had a large impact on the energy consumed by the industrial sector post implementation of quadrative easing in 2008. These results provide new information regarding the energy used by sector, and the contribution of US interest rate spreads to fluctuations in energy consumed by different sectors.

The remainder of this article is organized as follows. Section 2 discusses the literature review. Section 3 explains the methodology and data used in this study. Section 4 reports the results and investigates the effects of shocks caused by interest rate spreads. The conclusion is presented in Section 5.

2. Literature review

One of the main issues in the study of energy study is energy consumption. Many recent empirical studies focused on the effect of economic variables on energy consumption (Table 1). There is a growing trend in the literature to investigate the relationship between economic growth and energy consumption (Apergis and Payne, 2010; Belke et al., 2011; Dergiades et al., 2013; Azam et al., 2015; Naser, 2015; Camarero et al., 2015; Jammazi and Aloui, 2015; Ahmed and Azam, 2016; Narayan, 2016; Doytch and Narayan, 2016; Fan et al., 2016; Achour and Belloumi, 2016).

Similarly, a few studies have investigated the relationship between energy consumption by sector and GDP. Bowden and Payne (2009) found a bidirectional causality between commercial and residential energy consumption with real U.S. GDP. They emphasized that the effect of GDP was greater on these two sectors than the effect of energy consumed by these two sectors. Bowden and Payne (2010) evaluated the effect of renewable and non-renewable energy consumption by sector on real US GDP. Their results supported the neutrality hypothesis² that explains the relationship between real GDP and renewable energy consumption in the commercial and industrial sectors. In the case of non-renewable energy consumption, the result supports the feedback hypothesis³ that explains the positive relationship between real GDP and non-renewable energy consumption by the commercial and industrial sectors.

Several recent studies have focused on the effect of variables, such as financial indicators that might influence the demand for energy directly or indirectly (Shahbaz and Lean, 2012; Ozturk and Acaravci, 2013; Islam et al., 2013; Ziaei, 2015). However, little is known about the relationship between conventional and unconventional monetary policy and energy consumption.

In order to investigate the effects of unconventional monetary policy on consumption, the question, “what are the possible impacts of unconventional monetary policy on energy demand or the demand for goods?” must be answered. Gagnon et al. (2011) argued that FED monetary policy announcements influence economic conditions through the portfolio balance channel. Large scale asset purchasing policies lead to a decrease in the long term securities held by the private sector. A decline in the supply of long term securities will increase the price and decrease the term premium of holding these securities and will lead to a decrease in long term interest rates. However, Bauer and Rudebusch (2011) believed that unconventional monetary policy announcements can also be effective through signalling. They argued that if the Fed’s large scale asset purchasing policy was interpreted negatively by investors in the financial markets, it would increase the demand for long term treasuries and decrease the rate of these securities. Both portfolio balancing and signalling used by conventional US policy would lead to decreases in long term interest rates, which can

² This hypothesis supports the absence of causality between real GDP and energy consumption.

³ This hypothesis supports the interrelationship and causality between real GDP and energy consumption.

Table 1
Recent empirical studies related to energy consumption and economics factors.

Authors	Country/Territory	Method	Objective	Results
Belaid (2016)	France	OLS estimation	Understanding the spectrum of domestic energy consumption	Energy prices were the most important indicators determining domestic energy consumption.
Keho (2016)	Selected African countries	Bounds Testing Approach	The factors behind energy consumption in African countries	Economic growth, industrial output and population had positive effects on energy consumption in the majority of countries.
Fizaine and Court (2016)	US and UK	Logarithmic Mean Divisia Index	Evaluate the relationship between energy expenditure, economic growth	Energy efficiency was higher for industries with stable energy consumption.
Destek (2016)	South Africa Mexico; India, Brazil and Malaysia.	Asymmetric causality approach	Evaluate the relationship between renewable energy, consumption and economic growth	Negative effects of renewable energy consumption shocks on real GDP for South Africa and Mexico; positive effects on GDP for India and the neutral effects for Brazil and Malaysia.
	Latin America and the Caribbean	Panel data Analysis	Evaluate the relationship between Economic growth and energy consumption	Estimations confirmed the Energy-Environmental Kuznets relationship
Streimikiene and Kasperowicz (2016)	EU Countries	Panel cointegration analysis, The panel FMOLS and DOLS	Assess the relationship between economic growth and energy consumption	Positive relationship between energy consumption, gross fixed capital and economic growth.
Ahmed and Azam (2016)	High, middle and Low income countries	Granger-causality	Assess the relationship between energy consumption and economic growth	Some country's result shows feedback hypothesis, and others confirm growth hypothesis
Achour and Belloumi (2016)	Tunisia	Cointegration and causality test	Investigated the causal relationship between transport infrastructure, transport energy consumption and economic growth	Unidirectional causality from railway infrastructure to rail transport related energy consumption.
Narayan (2016)	90 developing and low income countries	Panel data Analysis	Assess the relationship between energy consumption and economic growth	Strong support for the neutrality hypothesis
Doytch and Narayan (2016)	74 countries	GMM	Investigating the causal relationship between FDI and renewable energy consumption	Energy consumption-augmenting effects with respect to renewable energy
Fan et al. (2016)	China	Cointegration and causality test	Investigating the causal relationships between economic growth, energy consumption, and CO2 emissions	A bi-directional causal relationship between economic growth and energy consumption, and a unidirectional causal relationship between energy consumption to CO2 emissions.
Camarero et al. (2015)	US	Panel data Analysis	Evaluate the relationship between Economic growth and energy consumption	Important role of public spending and energy consumption in the economic growth
Jammazi and Aloui (2015)	GCC countries	Wavelet window cross correlation (WWCC)	Investigating the relationships between energy consumption, economic growth and CO2 emissions	Bilateral causal effects between energy consumption and energy growth. A unidirectional relationship between energy consumption to CO2 emissions

(continued on next page)

stimulate the demand for consumer goods (Gagnon et al., 2011). However, Glick and Leduc (2011) argued that if investors perceived unconventional monetary policy as a stimulative policy, then when long term interest rates decrease, commodity prices will increase. In other words, if investors recognize this policy as a negative signal, commodity prices will decrease and investor demand for other assets will be reduced.

Likewise, monetary policy has an impact on consumption and other components of aggregate demand through monetary policy transmission mechanisms. Exchange rates, inventory, and demand

and supply channels can affect the demand for energy. For example, according to demand, an effective expansionary monetary policy can lead to economic growth, which will have a significant effect on the demand for goods and services in different markets including the energy market.

Most of the literature related to the effect of monetary policy on commodity markets, including the energy market, have focused on the effects of conventional and unconventional commodity price levels.

Anzuini et al. (2010) found the expansionary monetary policy leads to an increase in commodity prices. They concluded that

Table 1 (continued)

Authors	Country/Territory	Method	Objective	Results
Ajmi et al. (2015)	Japan, Canada, and Italy	Cointegration and causality test	Investigating the relationships between energy consumption, income and CO2 emission	Bidirectional causality between GDP and energy consumption for Japan; unidirectional causality between GDP and energy consumption for Italy; and unidirectional causality between energy consumption to GDP for Canada.
Al-Mulali and Ozturk (2015)	MENA Region	FMOLS	Evaluate the relationship between energy consumption, urbanization, trade openness, industrial output, and the political stability	Significant long run relationship between energy consumption, urbanization, trade openness, industrial output, and the political stability
Ziaei (2015)	Selected European, East Asian and Oceania countries	PVAR	Investigating the relationships between financial development indicators energy consumption and CO2 emission	Significant effect of energy consumption shock on stock return rates in EU and significant effects of stock return rate shock on energy consumption in case of East Asia and Oceania countries
Śmiech and Papież (2014)	Selected EU countries	The bootstrap panel Granger causality approach	Assess the relationship between energy consumption and economic growth	Significant effects of economic growth, industrial output and population on energy consumption
Nasreen and Anwar (2014)	15 Asian countries	Panel data Analysis	Investigating the relationships between trade openness, economic growth and energy consumption	Positive effects of economic growth trade openness on energy consumption.

monetary policy had a significant impact on commodity price indexes and all of their components.

Mallick and Sousa (2012) evaluated the effect of monetary policy in emerging countries BRICS.⁴ They found that shocks caused by interest rates had a positive, significant impact on commodity prices in these five emerging economies.

Hammoudeh et al. (2015) evaluated the effect of US monetary policy on a range of commodity prices including energy, metal, agriculture, and food. They found contractionary monetary policies produced persistent reductions in the price of energy and metal.

Central banks and monetary authorities consider an increase in commodity prices to be a signal of inflationary pressure and an indicator of future consumer price inflation. Consequently, they respond to fluctuations of commodity prices with different monetary policy tools. Many studies recognized the relationship between commodity prices and monetary policy indicators (Cheung, 2009).

Rahman and Apostolos (2010) found that in the United States, monetary policies strengthen the impact of oil price shocks on aggregate demand and that these monetary policies also contributed to the asymmetric response of aggregate demand to energy price shocks. Kilian and Lewis (2011) found no evidence that confirmed a relationship between monetary policy announcements and energy prices. Kilian and Vega (2011) also found the same results. They argued that the price of oil did not respond immediately to monetary policy announcements. However, Basistha and Kurov (2008) stated that energy prices will respond immediately to monetary policy shocks and Federal Fund Rate innovations, but changes in energy prices several days after an announcement will not be significant.

Roza (2014) investigated the effects of US conventional and unconventional monetary policies on oil prices and determined that monetary policy had a significant effect on oil prices through the exchange rate as monetary policy affects the value of the US dollar, which has a significant impact on oil prices. Furthermore, she found that news about monetary policy has significant effect on energy future prices and volume of trade, most specifically for oil prices.

A few studies examined the effect of energy shocks on aggregate demand and they evaluated what happened when governments changed monetary or fiscal policies to respond to energy prices. William et al. (2015) investigated the effect of the time of energy shocks on output and hours worked under alternative policy regimes after World War II in the United States. They argued that monetary policy responses of the Federal Reserve to energy prices changed or magnify the effects of energy shocks on aggregate demand.

Plante (2014) investigated optimal monetary policies when economies face oil price shocks. He argued that when an economy faces an oil supply shock, interest rates will fall and when an economy faces oil demand shocks (productivity driven demand) interest rate will rise. He proved this hypothesis by employing data from the United States post 1986. He found that the Federal Reserve increased interest rates in response to oil price supply shocks and decreased the Federal Fund rate in response to oil price demand shocks.

3. Methodology

In this study, the baseline VAR model (vector autoregression model) with contemporaneous restrictions was selected to analyse the effects of US interest rate spreads on components of energy consumption. For VAR analysis, the following equation was used:

$$\beta_0 X_t = \beta_t X_{t-1} + \alpha \varepsilon_t \quad (1)$$

where X_t is the $(n \times 1)$ vector of endogenous variables, β_0 represents a $(n \times n)$ matrix of coefficients of simultaneous relations on the endogenous variables; X_{t-1} includes lag of endogenous variables, β_t is the matrix of coefficients on the lagged variables in the model; ε_t as $(n \times 1)$ vector of the innovation is orthogonal and $\sum_{\varepsilon_t} = E(\varepsilon_t \varepsilon_t')$ present variance covariance matrix of the innovation.

In the VAR model, the influence of shocks was evaluated with two specific instruments. Impulse response was used to interpret the dynamic relationship between variables while variance decomposition showed the proportional contribution of each variable shock in the model to fluctuations of other variables.

⁴ Brazil, Russia, India, China and South Africa.

There are several benefits for using VARs. First, the flexibility of VAR creates a descriptive frame for econometric models that allows experts to test the significance of economic models. Second, the economic model can be statically formulated with VAR models, without the restrictive theory and limitation of dynamic relations between variables. Third, the structure of specific kinds of models are suitable for estimating monetary policy shocks.

The VAR basic model in this study consisted of 2 groups of variables and a dummy variable represented by the following vector X_t :

$$X_t = (USIS_t, USEC_t, DUMMY) \quad (2)$$

where $USIS_t$ is the US interest rate consisting of EFFR (Effective Federal Fund Rate) and four interest spread variables including TES (term spread: spread between 10 years and 3 years treasury bill rates), CRS (corporate spread: spread between B of A, Merrill Lynch, the US corporate bond rate, and the effective Federal Fund Rate), MORS (the difference between a 30 year mortgage rate and ten year treasury bill rate), and PAB (the difference between 3 months commercial paper and 3 month treasury bills). $USEC_t$ consists of five energy consumption variables including TERS (total energy consumed by the residential sector), TECS (total energy consumed by the commercial sector), TEIS (total energy consumed by the industrial sector), TETS (total energy consumed by the transportation sector), and TEPES (total energy consumed by electric power sector). Dummy Variables were employed to recognize different stages of quantitative easing as of November 2008.

To measure the effects of US interest rate spreads on the components of energy consumption, impulse response functions and variance decomposition were used in this study. These two instruments show the proportional impact of each shock factor on the fluctuations of other factors.

4. Data

Monthly data was used between 2002M2 and 2015M3 in this analysis. We tested the relationship between each US interest rate spread and the energy consumption of each sector for two important intervals. First, the effects of interest rate spreads were analysed after the implementation of unconventional monetary policies by employing monthly data from 2008 M12 and 2015 M3 (76 observations). Secondly, the impact of interest rate spreads and FFER were analysed from the period before the employment of large scale asset policies of the Federal Reserve using 76 monthly observations from the period between 2002 M2 and 2008 M11.

The reason that we divided our study into two intervals was related to Federal Reserve policy. Prior to November 2008, the monetary policy of the Federal Reserve was arranged to boost the economy as they set interest rate above the zero. However, after November 2008, the Federal Reserve used unconventional policy. The Federal Reserve employed a zero lower bound interest rate policy by launching LASPs. LASP was meant to be an easing policy that worked by purchasing of long term assets as the Federal Reserve tried to lower long term interest rates. As shown in Fig. 1, in the months after November 2008, interest rate spreads (term, corporate, and mortgage spreads, and paper bills) decreased because long term interest rates fell and the short term rate was close to zero. By dividing this study into two parts, we investigated the effects of conventional and unconventional monetary policy prior to and after the implementation of quantitative easing. (Additional information about this database can be found in Appendix B).

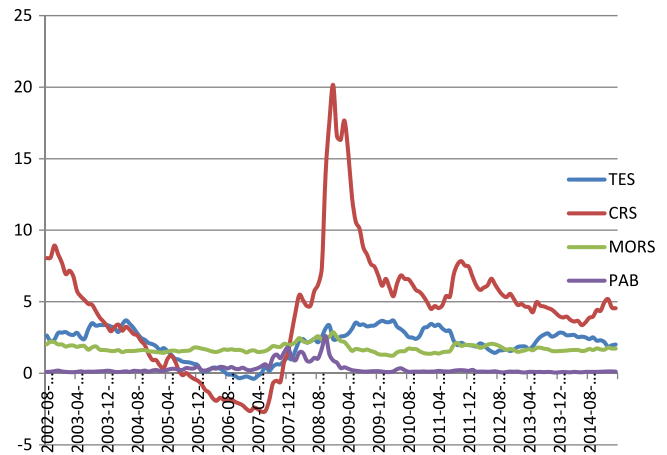


Fig. 1. US interest rate spreads.

5. Estimation process

The process of estimation is carried out in the following way; the Augmented Dickey and Fuller (1979) and Phillips and Perron (1988) unit root test are employed to examine the time series' properties of each variable. The results of the ADF unit and PP root test for all variables in model indicated that all variables non-stationary in their levels and become stationary when they are first differenced. Moreover, In order to evaluate the cointegration between unconventional monetary policy variables and energy consumption indicators (2002M2–2015M3), Johansen Cointegration test (Johansen, 1992; Johansen and Juselius, 1990) is employed (Appendix A). The Johansen Cointegration findings imply that the long run relationships between US interest rates and energy consumption indicators are not strong.

To check lag length VAR models, the possibility of serial correlations in the residual of different lag lengths was examined as recommended by Johansen (1992). Moreover, the impulse response function and variance decomposition were used to examine the impact of US interest rate spreads during the periods before and after the implementation of unconventional monetary policies.

5.1. Result—post implementation of LASPs (2008–2015)

The impulse response function (Fig. 2) indicated that the positive effect of the shock caused by a term had a weak impact on all components of energy consumption in the short run, and that any cut in the term of the spread increased the energy consumption components that took place with substantial lags. Energy consumed by the residential, commercial and transportation sectors responded simultaneously and positively to the positive impact of term spreads. However, the variance decomposition results shown in Table 2 confirmed that the energy consumed by the residential sector to term spread shock was greater in short and long terms compared to the other variables in the model.

The results (impulse response; Fig. 4) show that a cut in corporate spread leads to an increase in all energy consumption components. However, the impact of corporate spread shock on the energy consumed by the industrial sector was much greater than it was for other components of energy consumption, specifically three months after corporate spread innovations. The variance decomposition in Table 2 shows a positive shock to corporate spread that accounted for 13% of the fluctuations in the energy consumed by the industrial sector after eight horizons and 20% of its deviations after 20 horizons.

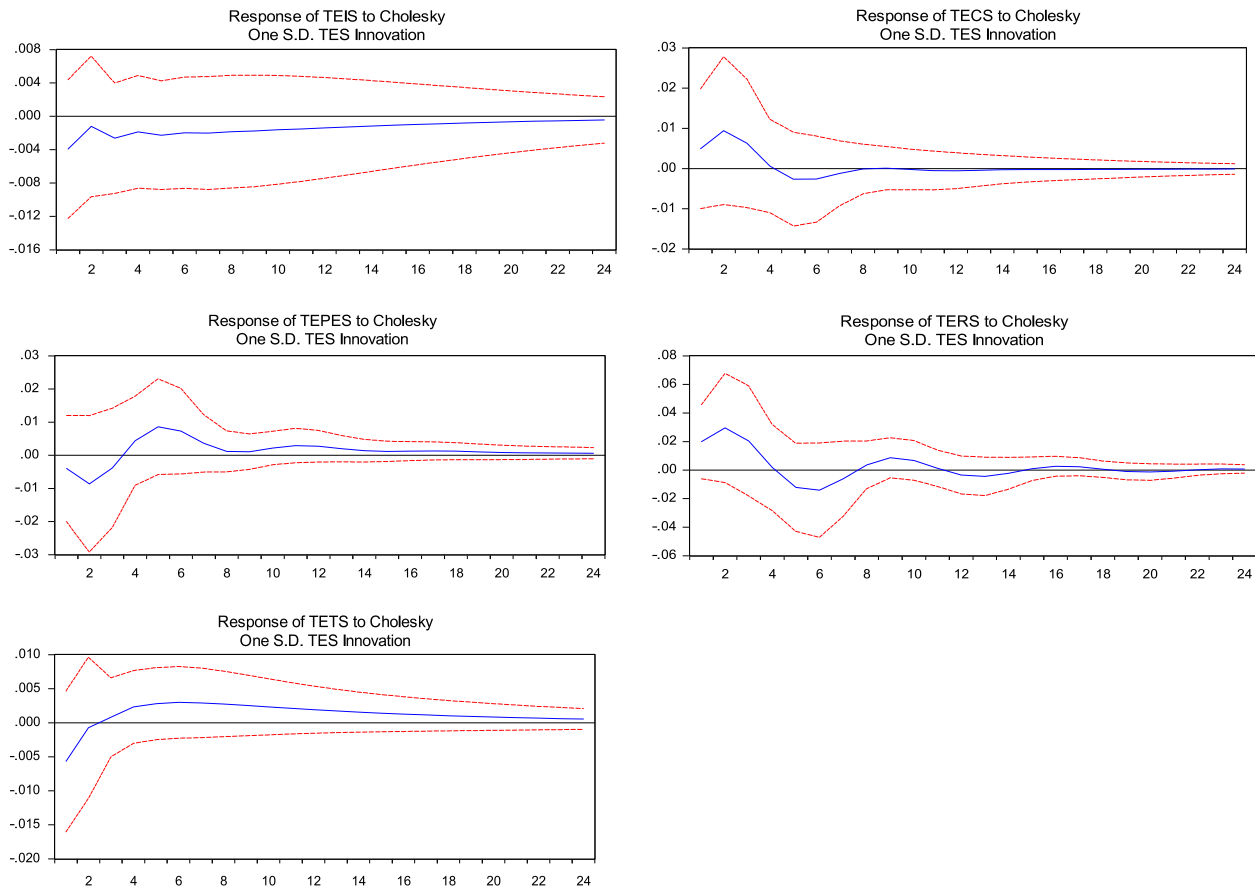


Fig. 2. Responses to positive term spread shock 2008–2015.

Table 2
Variance decomposition: 2008–2015.

Variance decomposition	Period	TERS	TECS	TEIS	TETS	TEPE
TES	2	4.55	1.76	1.22	1.61	1.13
	4	5.30	2.26	1.49	1.83	1.40
	8	5.06	2.39	2.09	3.33	2.69
	12	5.08	2.40	2.48	4.23	2.90
	16	5.08	2.40	2.69	4.63	2.98
	20	5.09	2.41	2.78	4.80	3.03
CRS	2	0.22	0.11	0.50	3.18	3.08
	4	0.24	0.19	3.87	3.25	3.54
	8	0.33	0.45	12.91	3.28	4.33
	12	0.33	0.50	16.87	3.36	4.39
	16	0.33	0.52	18.18	3.39	4.39
	20	0.34	0.53	18.59	3.41	4.40
MORS	2	5.02	2.05	1.54	2.42	3.94
	4	10.70	4.40	2.05	2.55	4.81
	8	9.90	4.30	6.24	3.68	7.13
	12	9.93	4.32	8.20	3.86	7.20
	16	9.97	4.32	8.57	3.87	7.20
	20	9.99	4.32	8.61	3.87	7.20
PAB	2	0.82	0.59	1.53	4.98	0.96
	4	0.86	1.06	3.43	4.83	1.70
	8	0.74	1.05	5.31	4.85	1.64
	12	0.72	1.06	5.67	4.85	1.65
	16	0.71	1.06	5.73	4.86	1.65
	20	0.71	1.06	5.74	4.87	1.66

The impulse response results in Fig. 6 indicated that any decrease in mortgage spreads had a sudden effect on most components of energy consumption and led to an increase of these components. Mortgage spread shock had a pronounced impact on the energy consumed by the industrial and residential sectors. After 4 horizons, 10.7% fluctuation in the energy consumed by the

residential sector was related to mortgage spread. Likewise, 8.20% deviation in the energy consumed by the industrial sector and 7.20% fluctuation in the energy consumed by the electric power sector were related to mortgage spread innovations after twelve horizons. Moreover, the effect of paper bill shocks on energy consumption components was very weak. However, Fig. 8 indicates

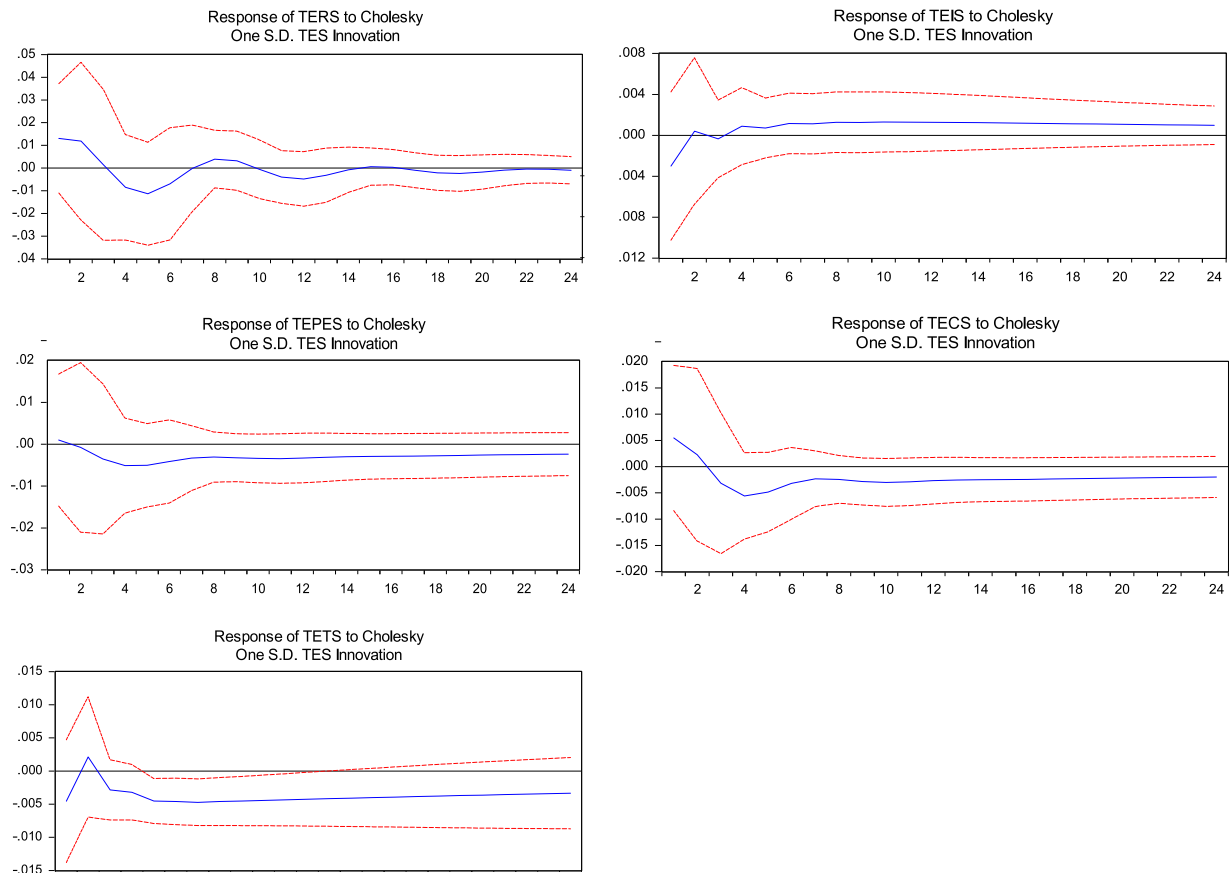


Fig. 3. Responses to positive term spread shock 2002–2008.

that any paper bill positive shocks led to a decrease in the energy consumption by each sector. The variance decomposition results shown in Table 2 indicated that paper bill shocks had the greatest impact on the energy consumed by the transportation sector.

5.2. Result—pre implementation of LASPs (2002–2008)

The effects of term spread shocks on the effects of the components of energy consumption were very weak before the implementation of unconventional monetary policies. The impulse response functions in Fig. 3 indicate that energy consumed by the industrial sector responded negatively to term spreads only two months after shock occurred. The variance decomposition results shown in Table 3 shows that term spreads had the greatest impact on the energy consumed by the transportation sector especially over the long run. Term spreads contributed to 10.7% of the fluctuations in the energy consumed by the transportation sector after 10 horizons.

The impulse responses shown in Fig. 5 indicated that the energy consumed by the industrial, transportation, and electric power sectors responded immediately and positively to a cut in corporate spreads. The variance decomposition shown in Table 3 shows that corporate spreads had the greatest effect on the energy consumed by the transportation sector. Corporate spread contributed to 24% and 48% of the movement in the energy consumed by the transportation sector after 8 and 12 horizons. Eleven percent of the fluctuations in the energy consumed by the power sector after 12 horizons were caused by corporate spread. Additionally, 7.35% movements of energy consumed by industrial sector belongs to corporate sector after 12 horizons.

The impulse response function shown in Fig. 7 indicated that the shocks caused by mortgage spreads had a significant effect on

the energy consumed by the industrial and transportation sectors. However, the impact of mortgage rate innovations on the energy consumed by the residential sector was not pronounced. After 8 horizons, 15.6% and 9.6% of the fluctuations in the energy consumed by the industrial and transportation sectors were related to mortgage spreads.

Fig. 8 impulse response function point out that after the implementation of policy the shocks caused by paper bills had weak impacts on component of energy consumption. However, the impulse response function shown in Fig. 9 indicated that a paper bill shock before the implementation of unconventional monetary policies had a significant impact on energy consumption variables such as the energy consumed by the industrial, transportation, and residential sectors compared to the results after employing LASPs. After 12 horizons, the variance decomposition recorded in Table 3 shows that 10% and 11% of the fluctuations in the energy consumed by the residential and transportation sectors, 17.22% of the fluctuations in the energy consumed by the transportation sector, and 12.7% of the fluctuations in the commercial sector were related to paper bills.

Similarly, the impulse response function in Fig. 10 shows that the impact of Effective Federal Fund Rate shocks on all energy consumption components was weak. The effects of Effective Federal Fund Rates on the energy consumed by the transportation sector was greater than it was for other components. The variance decomposition illustrated in Table 3 shows that the Effective Federal Fund Rate contributed to 10.6% and 20% movement in the energy consumed by the transportation sector after 4 and 8 horizons.

6. Conclusion

Energy consumption and reliance on non-renewable sources of energy is one of the important issues facing the United States.

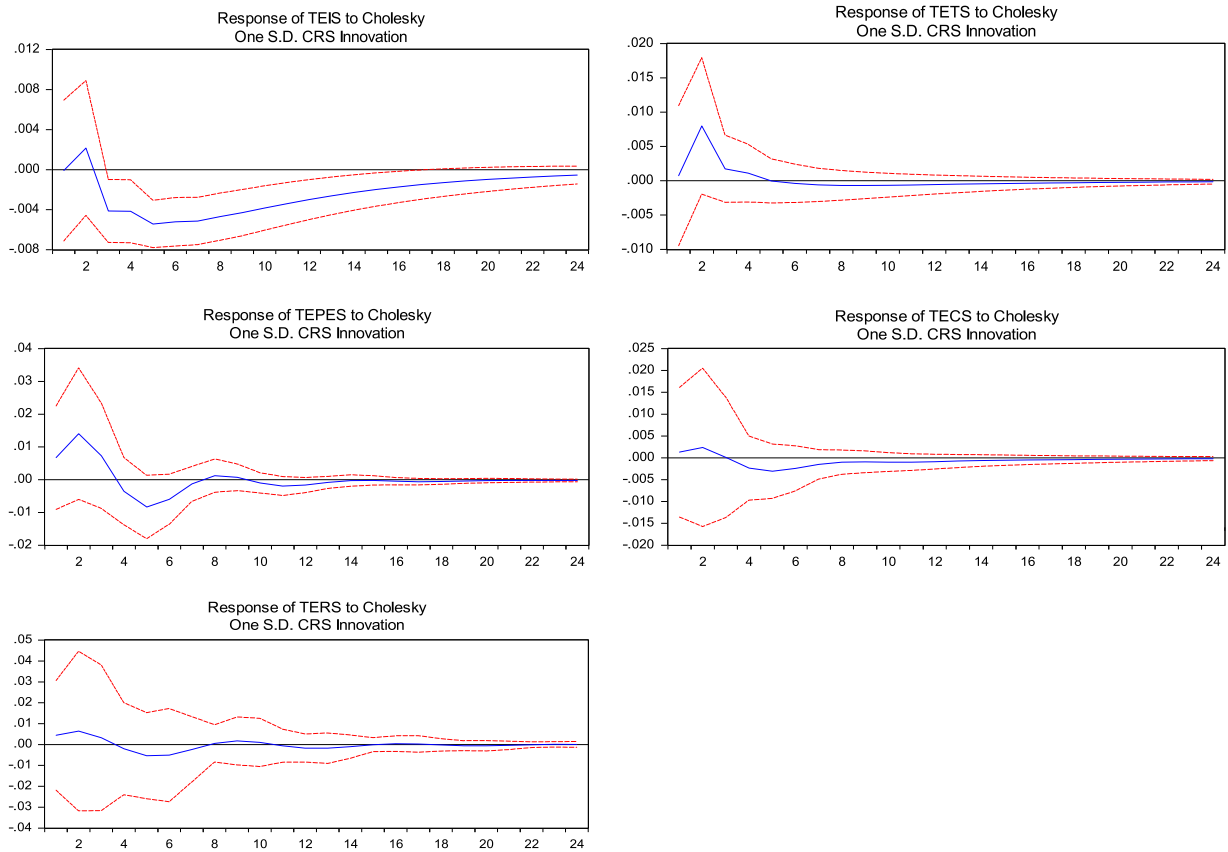


Fig. 4. Responses to corporate spread shock 2008–2015.

Table 3
Variance decomposition: 2002–2008.

Variance decomposition	Period	TERS	TECS	TEIS	TETS	TEPES
TES	2	1.35	0.66	0.94	1.55	0.01
	4	1.47	1.35	0.90	2.54	0.47
	8	1.64	2.06	1.28	7.04	1.12
	12	1.66	2.60	1.84	10.70	1.60
	16	1.66	3	2.33	13.53	1.98
CRS	2	0.11	0.10	2.12	0.22	0.82
	4	0.16	0.21	3.93	8.25	1.76
	8	0.24	0.38	6.04	24.84	6.36
	12	0.29	0.46	7.35	48.32	10.99
	16	0.33	0.50	8.57	59.93	16.12
MORS	2	0.34	0.28	5.24	1.23	4.92
	4	0.79	0.28	8.96	2.39	5.19
	8	0.88	0.46	15.63	9.68	5.70
	12	0.88	0.57	20.44	16.17	5.75
	16	0.91	0.66	23.93	20.27	5.80
PAB	2	4.78	2	2.16	5.77	1.46
	4	5.75	5.87	6.45	5.05	2.17
	8	9.92	11.03	13.01	7.84	3.15
	12	10.04	12.71	17.22	11	3.61
	16	10.31	13.40	19.94	12.51	3.85
	2	0.40	1.03	133	5.61	0.72
	4	3.55	2.24	2.31	10.69	0.86
	8	3.43	2.87	2.63	19.94	1.79
	12	3.25	4.04	2.84	26.80	2.90
	16	3.45	5.36	3.55	31.66	3.90
20	3.48	6.51	4.49	35.13	4.69	

Many studies have investigated the effect of socio- economic factors on energy consumption. In this study we studied the effect

of new, unconventional monetary policies employed after 2008 on the energy used by different sectors.

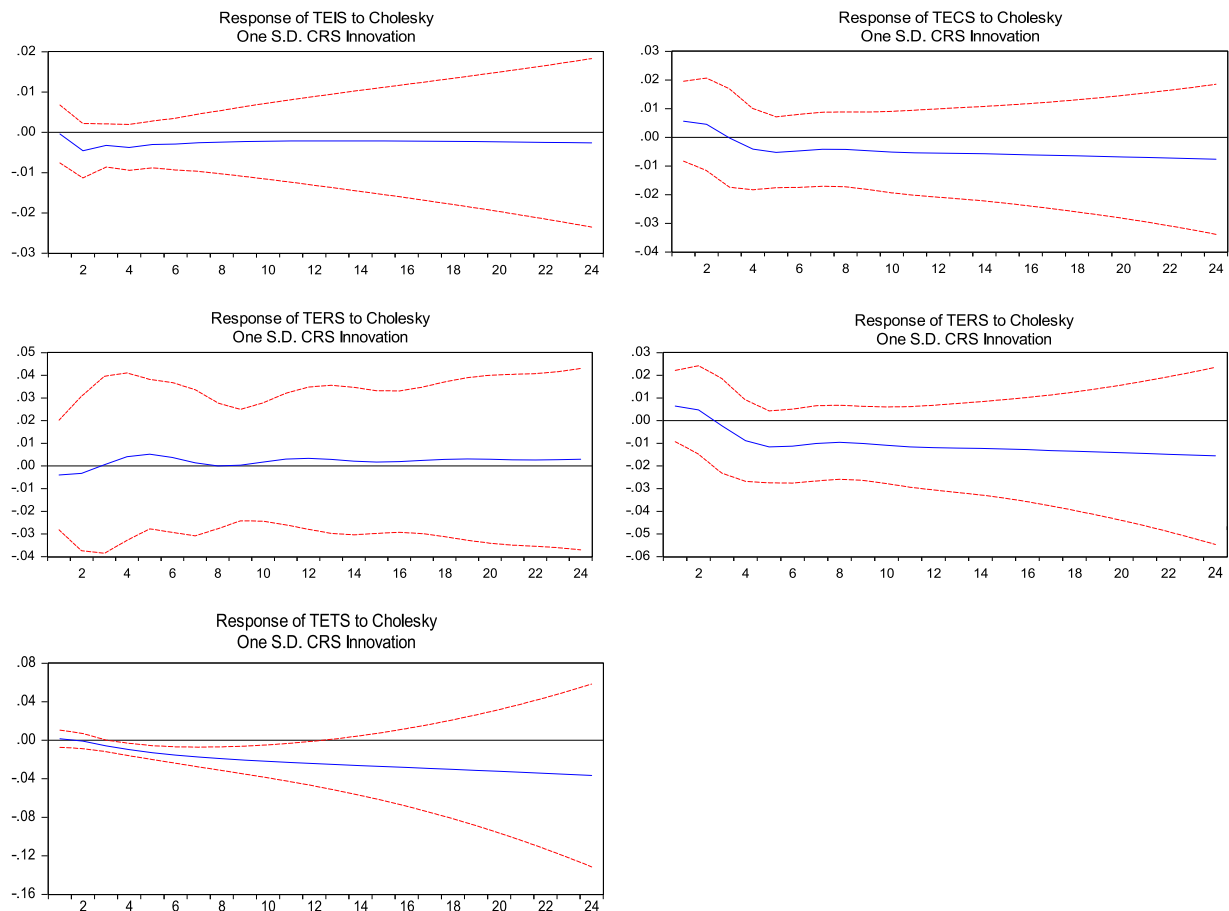


Fig. 5. Responses to positive corporate spread shock 2002–2008.

According to signalling and portfolio balancing, unconventional monetary policy will lead to a decrease in long term interest rates. This deduction was confirmed by the spread between the interest rates shown in Table 1. However, the crucial sign that shows the efficiency of monetary policies is the reaction of the market to the policies employed by central banks. This study attempted to answer the question, “Are these policies perceived as good or bad signals by the energy market?” by comparing the periods before and after the implementation of LSAPs policies. The empirical findings of this study lead to several conclusions.

Our result indicated that before and after the implementation of unconventional monetary policies, any cut in interest rate spreads were seen as positive signals by the market and led to increased energy consumption.

The impact of term spread shocks on energy consumption for different sectors were greater after the policies were implemented. After the implementation of unconventional policies, the effects of term spread on the energy consumed by the residential sector was higher it was for the other variables.

However, the variance decomposition result showed that the impact of a corporate spread shock was greater before the policies were implemented, specifically for variables such as the energy consumed by the transportation and electric power sectors. The results indicated that corporate spreads had a significant effect on the energy consumed by the industrial sector before and after the implementation of quantitative easing.

The shocks caused by mortgage spreads had a significant effect on the energy consumed by the residential sector after the implementation of large scale asset policies. Mortgage spread had a large impact on the energy consumed by the industrial and

transportation sectors before the implementation of the policies. Meanwhile, the influence of the Effective Federal Fund Rate as a monetary policy tool, on energy consumption variables was weak. Finally, our findings show that the effects of paper bills on energy consumption were much more pronounced before the policies were implemented compared to the period following the implementation of quantitative easing.

The results in this study indicated that the energy consumed by different sectors responded differently to interest rate spreads before and after the implementation of unconventional monetary policies. This study confirmed that the effects of new monetary policies should be investigated not just only for aggregate demand and main economic indicators, but also the effects should be scrutinized for their effect on other important issues such as the environment and energy markets. Even though the impacts of monetary policy on energy consumption are not pronounced, the results of this empirical study indicate that the energy consumed by different sectors responded differently towards new policies imposed by the Federal Reserve or Federal Government. William et al. (2015) argued that effects of an energy shock would be amplified due to policies used by governments or monetary authorities.

However, we should consider the effects of other variables, such as political and environmental indicators, on the energy consumed by different sectors over different periods of times. Future studies should differentiate between renewable and non-renewable forms of energy and the effects of monetary or fiscal policy on renewable and non-renewable energy consumption.

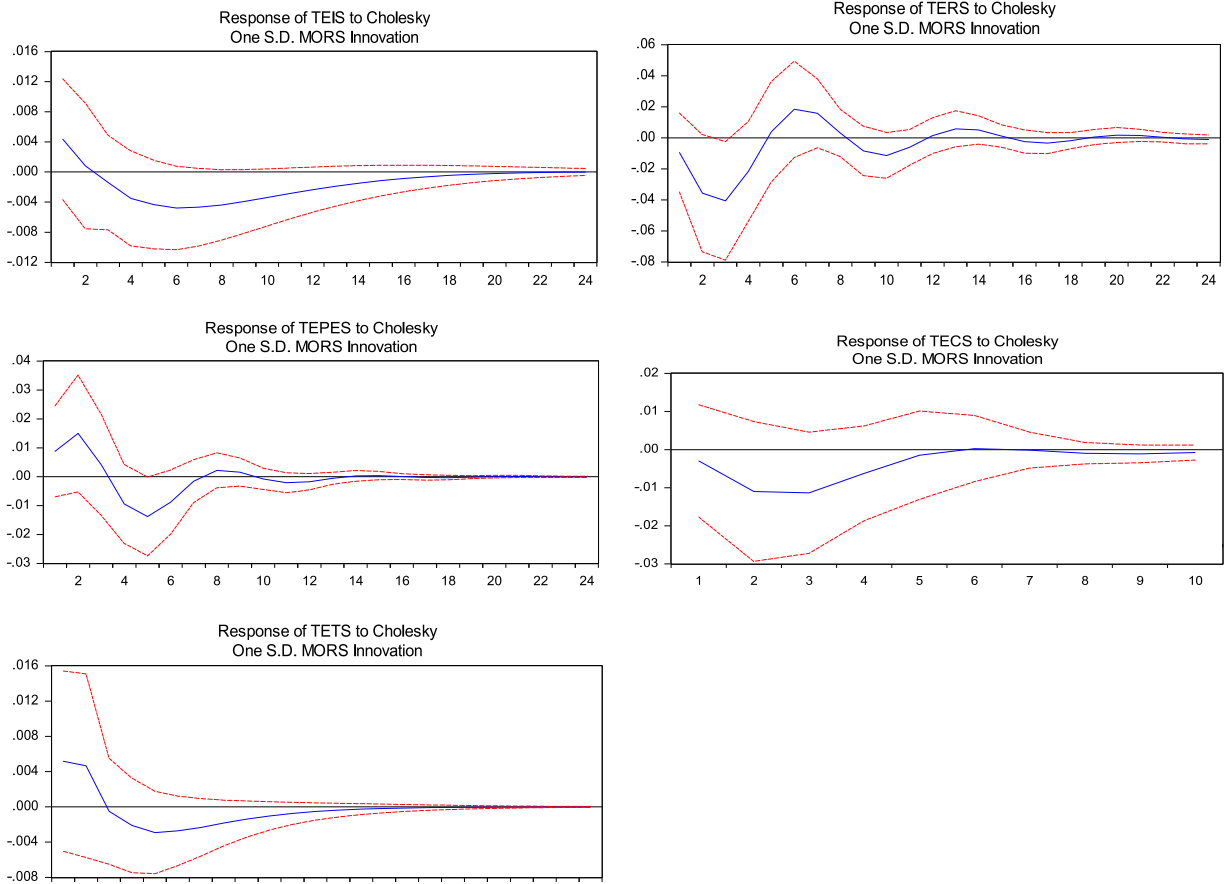


Fig. 6. Responses to mortgage spread shock 2008–2015.

Appendix A. Cointegration test

Cointegration between EFR and TERS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	41.36	17.41	24.22	38.21
$r < 1 r = 2$	17.12	12.18	12.47	9.41
$r < 2 r = 3$	7.32	3.63	4.48	3.83

Cointegration between TES and TERS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	39.85	28.68	22.25	20.12
$r < 1 r = 2$	16.50	14.38	12.44	10.25
$r < 2 r = 3$	3.2	2.73	3.4	3.72

Cointegration between CRS and TERS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	24.14	30.42	20.16	24.86
$r < 1 r = 2$	6.22	14.24	4.18	15.62
$r < 2 r = 3$	2.18	2.60	1.42	3.87

Cointegration between MORS and TERS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	68.43	74.25	26.89	34.51
$r < 1 r = 2$	10.43	16.54	4.12	6.81
$r < 2 r = 3$	3.21	4.73	2.12	5.01

Cointegration between PAB and TERS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	23.41	29.53	17.13	21.15
$r < 1 r = 2$	9.14	16.79	7.41	8.24
$r < 2 r = 3$	4.15	6.01	3.67	5.54

Cointegration between EFR and TECS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	148.20	28.68	122.75	20.12
$r < 1 r = 2$	24.43	14.48	22.15	14.23
$r < 2 r = 3$	2.27	2.80	2.82	2.84

Cointegration between TES and TECS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	135.23	28.68	122.11	20.32
$r < 1 r = 2$	12.09	13.51	8.74	13.27
$r < 2 r = 3$	4.1	6.54	3.8	4.42

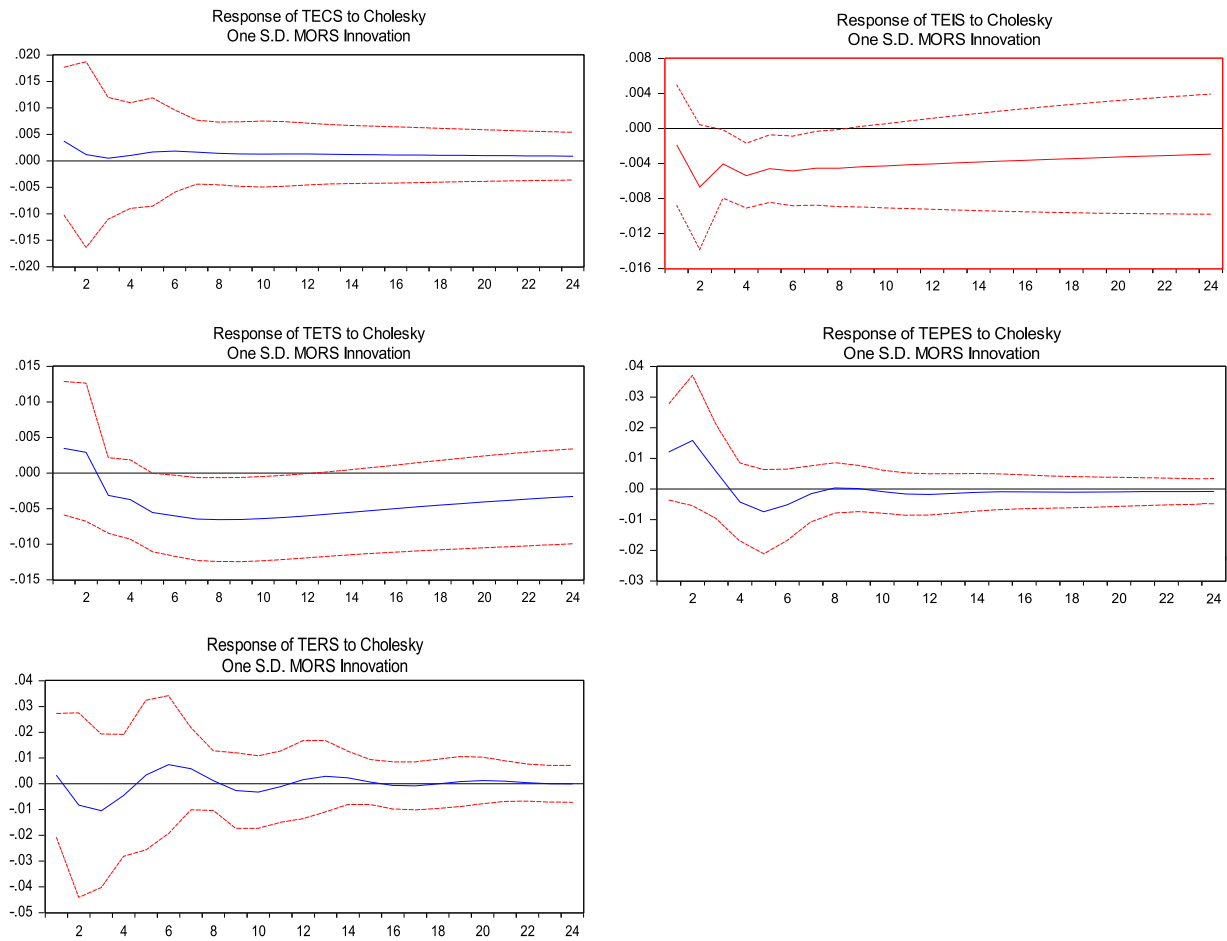


Fig. 7. Responses to mortgage spread shock 2002–2008.

Cointegration between CRS and TECS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	152.48	30.52	126.54	23.14
$r < 1 r = 2$	31.14	15.32	27.01	13.25
$r < 2 r = 3$	3.15	2.83	3.14	3.80

Cointegration between MORS and TECS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	74.21	24.19	89.12	31.73
$r < 1 r = 2$	18.99	19.44	16.53	23.15
$r < 2 r = 3$	3.11	4.53	2.72	3.94

Cointegration between PAB and TECS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	108.05	41.73	96.04	37.23
$r < 1 r = 2$	8.94	11.53	6.19	12.54
$r < 2 r = 3$	4.3	3.22	2.94	3.85

Cointegration between EFFR and TETS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	36.21	28.78	28.75	20.12
$r < 1 r = 2$	6.36	14.47	6.12	13.25
$r < 2 r = 3$	0.23	3.73	0.23	3.83

Cointegration between TES and TETS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	37.76	28.68	27.82	19.12
$r < 1 r = 2$	11.92	16.50	9.95	15.37
$r < 2 r = 3$	1.07	4.72	0.96	4.21

Cointegration between CRS and TETS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	28.86	30.80	21.53	22.14
$r < 1 r = 2$	8.34	16.50	7.40	15.27
$r < 2 r = 3$	0.91	4.1	0.91	4.14

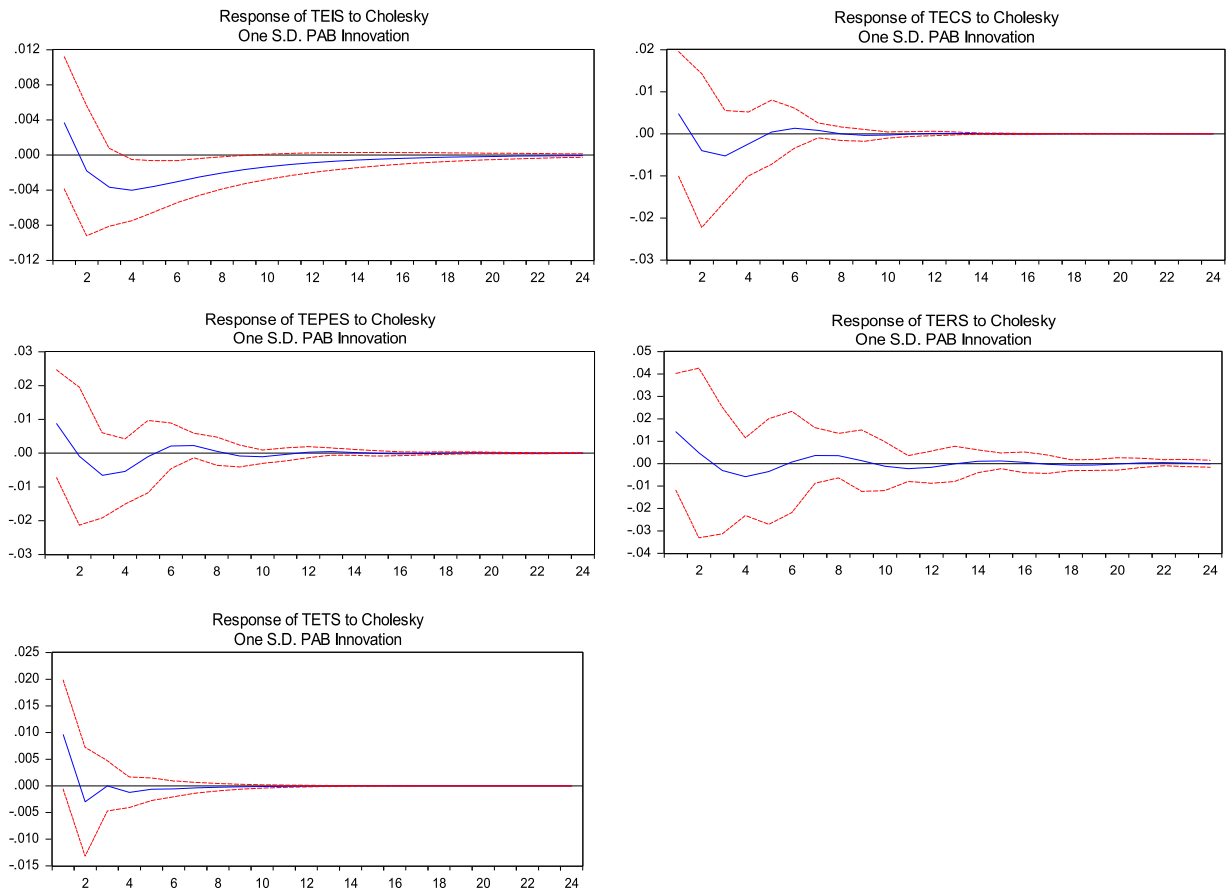


Fig. 8. Responses to paper bill shock 2008–2015.

Cointegration between MORS and TETS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	31.43	47.61	29.14	34.68
$r < 1 r = 2$	11.9	14.61	8.13	12.20
$r < 2 r = 3$	1.43	3.29	1.76	3.82

Cointegration between PAB and TETS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	44.51	48.72	31.29	34.81
$r < 1 r = 2$	13.09	16.76	7.19	9.42
$r < 2 r = 3$	1.87	3.19	1.63	3.42

Cointegration between EFR and TEIS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	40.84	32.09	31.05	23.49
$r < 1 r = 2$	7.32	11.54	8.23	12.11
$r < 2 r = 3$	1.43	4.94	1.29	4.12

Cointegration between TES and TEIS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	46.31	32.98	35.29	20.31
$r < 1 r = 2$	15.17	19.43	11.61	16.79
$r < 2 r = 3$	1.15	3.81	1.23	4.01

Cointegration between CRS and TEIS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	31.94	37.23	23.54	26.31
$r < 1 r = 2$	7.09	13.47	8.11	13.91
$r < 2 r = 3$	0.81	3.21	0.61	2.98

Cointegration between MORS and TEIS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	29.21	35.4	20.81	27.43
$r < 1 r = 2$	13.21	17.84	9.15	14.61
$r < 2 r = 3$	1.22	3.33	1.12	3.79

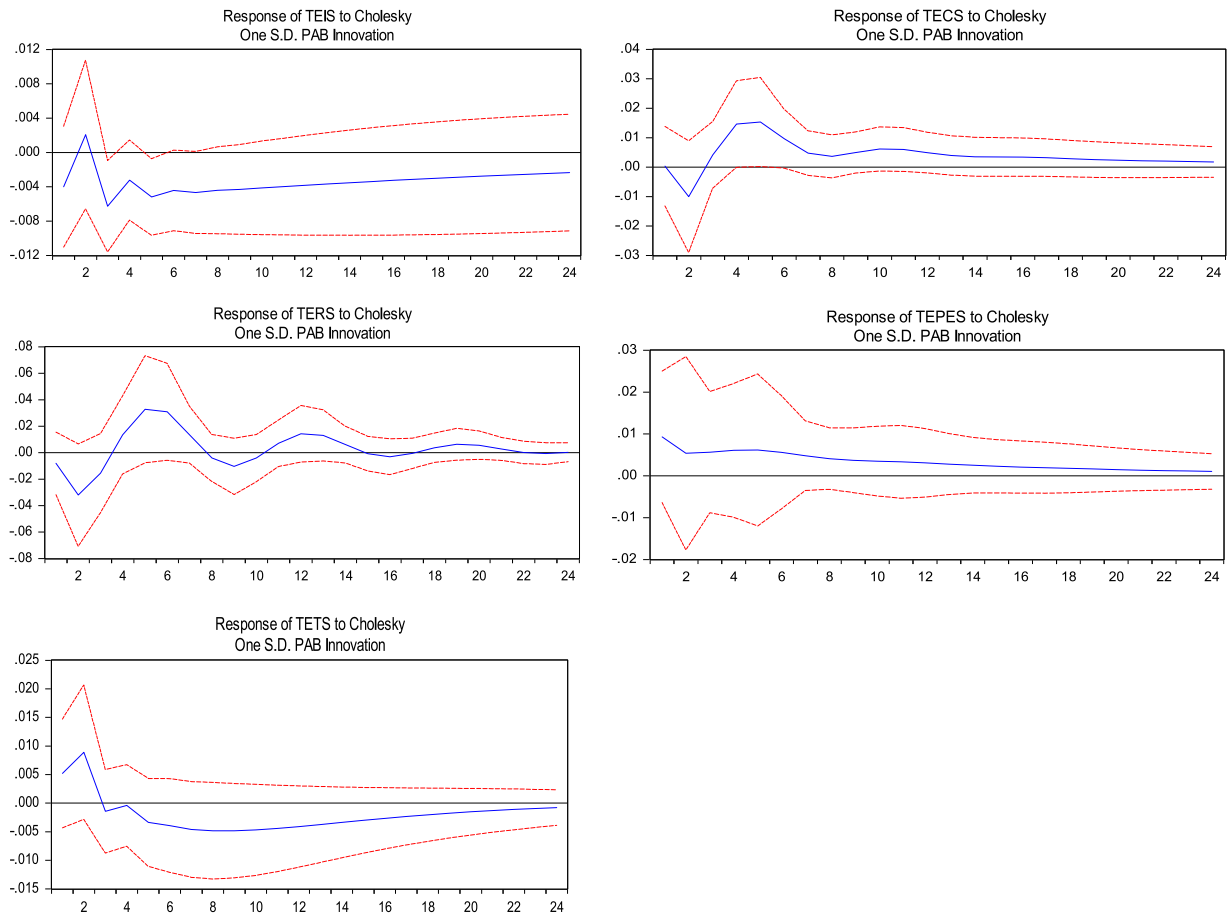


Fig. 9. Responses to paper bill shock 2002–2008.

Cointegration between PAB and TEIS.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	46.29	53.97	35.11	39.22
$r < 1 r = 2$	12.51	17.38	9.22	11.43
$r < 2 r = 3$	1.22	4.19	1.71	3.85

Cointegration between EFR and TEPES.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	36.24	30.72	31.85	23.14
$r < 1 r = 2$	7.35	16.59	6.11	14.29
$r < 2 r = 3$	0.23	3.76	0.22	3.79

Cointegration between TES and TEPES.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	55.39	30.78	39.75	22.14
$r < 1 r = 2$	18.64	16.43	10.39	15.27
$r < 2 r = 3$	8.29	3.94	8.27	3.93

Cointegration between CRS and TEPES.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	61.94	39.22	34.73	28.14
$r < 1 r = 2$	19.65	18.22	8.76	10.9
$r < 2 r = 3$	3.14	4.91	2.9	3.85

Cointegration between MORS and TEPES.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	33.16	29.53	22.43	19.05
$r < 1 r = 2$	13.42	15.84	11.87	12.76
$r < 2 r = 3$	1.08	2.98	1.25	2.68

Cointegration between PAB and TEPES.

$H_0 H_1$	Trace statistic	0.05 critical value	Max-Eigen statistics	0.05 critical value
$r < 0 r = 0$	43.21	36.75	32.19	19.41
$r < 1 r = 2$	14.05	18.15	13.75	16.22
$r < 2 r = 3$	1.02	3.23	0.99	3.65

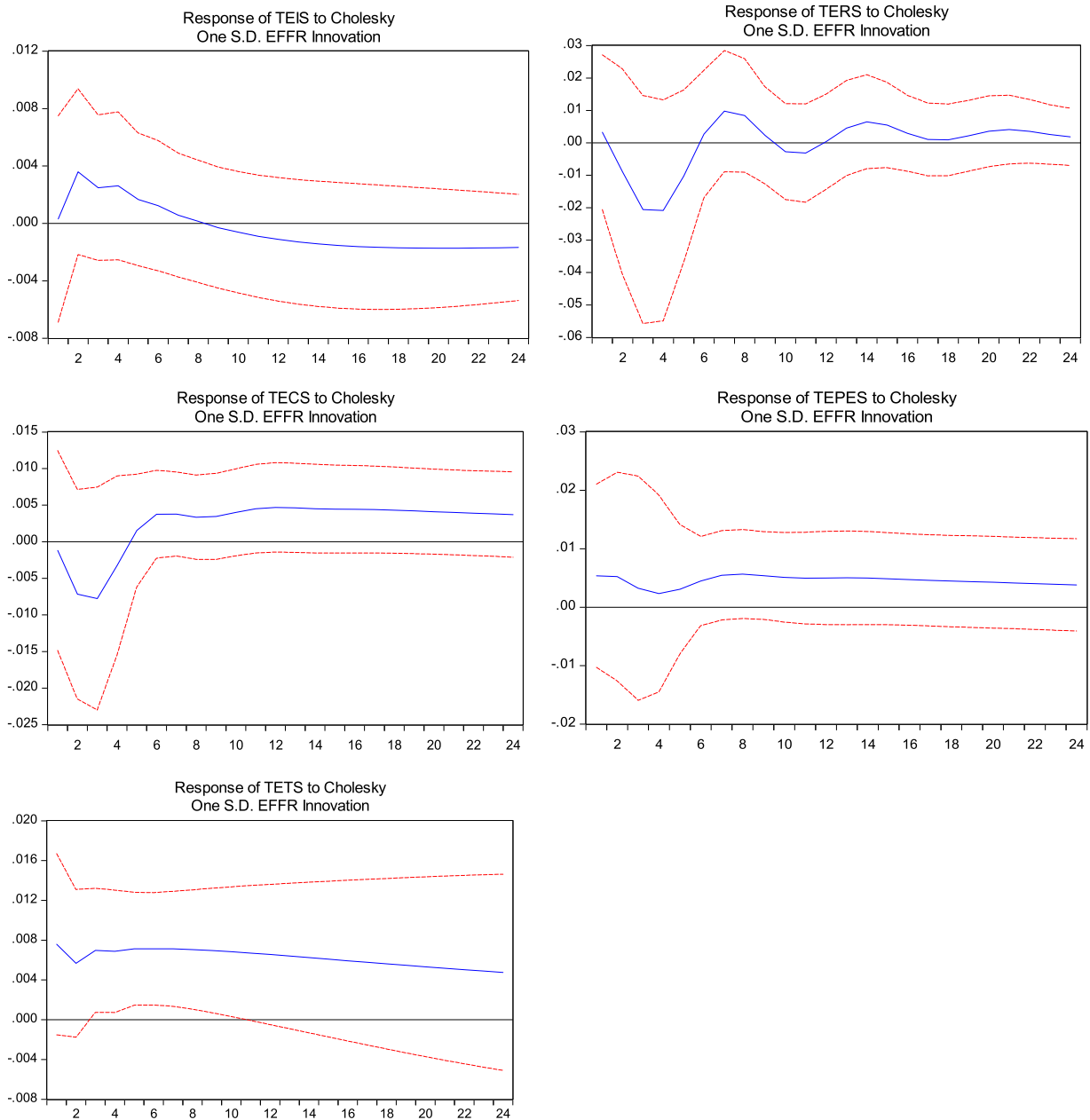


Fig. 10. Responses to Federal Fund effective rate shock 2002–2008.

Appendix B. Data

Indices	Symbol	Source
Spread between 10 years and three years treasury security yields rate	TES	Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).
Spread between BofA Merrill Lynch US corporate bond rate and the effective Federal Funds Rate	CRS	Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).
Federal Fund Effective Rate	EFFR	Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).
Spread between the 30 years mortgage rate and ten years treasury bond rate	MORS	Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).

Indices	Symbol	Source
Spread between commercial paper (3months)–treasury bill (3 months)	PAB	Federal Reserve Economic Data (FRED) (Federal Reserve Bank of St. Louis).
Total energy consumed by the residential sector	TERS	US energy information administration database
Total energy consumed by the commercial sector	TECS	US energy information administration database
Total energy consumed by the industrial sector	TEIS	US energy information administration database
Total energy consumed by the transportation sector	TETS	US energy information administration database
Total energy consumed by the electric power sector	TEPES	US energy information administration database

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