Applied Energy Symposium 2021: Low carbon cities and urban energy systems
September 4-8, 2021, Matsue, Japan
Paper ID: 35

Monetary policy drives economic prosperity: innegligible influence of energy

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ABSTRACT

This paper focuses on the impact of energy prices in the process of monetary policy influencing macroeconomics. We employ monthly data spanning the period of January 2006 to June 2021 for China for money supply amount, energy price index and purchasing managers index (PMI). Two independent empirical studies for mediation and moderation effects are introduced. We firstly apply the newly proposed Granger mediation model to link the three variables. The results document that energy prices may be impacted by changes in monetary policy, which will ultimately damage the effectiveness of monetary policy in promoting economic prosperity. Then, we obtain the time-varying causality strength from monetary policy to economic boom through the TV-GC model, and detect the influence of energy prices on such strength dynamics. The results indicate a significant effect of the energy price on the time-varying causal impact strength from the money supply on PMI in both the static and regime-switching framework. In another word, the energy price could also play a moderating effect in the process of monetary policy driving the economic boom. At last, some targeted policy recommendations are also summarized based on our findings.

Keywords: Monetary policy; Purchasing Managers' Index (PMI); economic boom; energy price; Granger mediation analysis; Moderation effect

1. INTRODUCTION

Monetary policy is often treated as a powerful tool to promote economic development, especially for developing countries. Facing economic downside risks, the government might use monetary policy to stimulate the economy through promoting investment and consumption, it is the most common macro-control method. However, as the macroeconomy is determined by various factors in addition to the policy changes, the monetary policy cannot play a consistent role in driving the economic boom over time. This makes the effect of monetary policy always unstable, and sometimes even far from expected. Consequently, it is always important to investigate the mechanism of monetary policy driving the economic boom, and what factors affect the efficiency of monetary policy. The related analysis would not only provide a more comprehensive understanding of the roles of monetary policy but also be beneficial for policy-makers to choose appropriate specific monetary policy tools and policy release time.

The mainstream mechanism of monetary policy affecting the macroeconomy is as follows. When the macroeconomy is facing depression, the governments would take some steps to alleviate the social welfare loss caused and even promoting the macroeconomy out of the turmoil. Adjusting the money supply is the main measure of monetary policy, the central bank may increase the supply of money in circulation. Then, the larger money supply amount provides better economic liquidity and lower deposit and loan interest rates, the producers are correspondingly more willing to expand their production scale and households would less prefer deposits like before. More economic activities promote the social total investment and consumption, the macroeconomy thereby moves from recession to recovery, and prosperity.

However, it is obvious that the realization of this working process requires the participation of many other conditions. One of the most important conditions is energy, it has become the crucial production input factor in modern industry. When there are high energy prices, the increased investment driven by monetary policy may be wasted in coping with the rising energy prices, and

Selection and peer-review under responsibility of the scientific committee of CUE2021

ultimately weaken the effect on economic development; while if there is a low energy price, the same monetary policy may play a more efficient role in promoting the economic boom. Moreover, the rising liquidity sourced from the money supply change might directly increase the finical speculation and price panic on commodity markets, the energy price might also be pulled up by the monetary policy. The rising price would reduce the energy activities geared towards economic growth, eventually shocks to the macroeconomy. Thus, there are two potential mechanisms that energy plays the role in monetary policy driving the economic boom. The energy might directly affect the policy effect on the economy and also play as an intermediate link to transmit the impact of policy shocks to the macroeconomy.

Due to its crucial status in the economy and the potential links with the monetary policy, this paper aims to specifically detect how the energy price plays a role in the process of monetary policy driving the economic boom. To address this problem, we used the monthly data from China spanning the period of January 2006 to June 2021. The reason why we use China as a research area is that China is the largest developing country, and its monetary policy has undertaken more tasks to promote economic growth than developed countries; additionally, China has basically achieved industrialization and the secondary industry has a dominant position in its macro economy, as an important constraint on industrial development, the role of energy may be more obviously reflected in the context of China.

There are two potential impact mechanisms of energy prices that should be examined, namely the mediation effect and the moderation effect. To confirm the mediation role of energy prices, we introduce a newly proposed Granger mediation model (GMA) based on the VAR methods. The results indicate that energy price could be negatively affected by the monetary policy, and it has a negative mediation effect on the macroeconomy. In another word, the mediation role of energy is supported. As monetary policy inevitably promotes changes in energy prices, it ultimately undermines the effectiveness in promoting economic prosperity. In parallel, we estimate the time-varying causal impact strength from the monetary policy and economic prosperity, the dynamic causality further demonstrates the effect of monetary policy on the economy is not static. We regress the energy price on such causal impact strength to present its direct impact on monetary policy playing a role. The result also provides a shred of significant evidence on our hypothesis; thus, energy also can be treated as a moderator of monetary policy affecting the macroeconomy.

To ensure the robustness of our results, we further introduce some tests after the main estimation. In specific, we conduct robust checks by changing the economic proxies, adjusting the original parameters of the GMA model, and detecting the uniqueness of the role of energy prices. The corresponding results illustrate that the mediation and moderation role of energy in the process of monetary policy promoting economic development is robust and unique.

The contributions of this study over others are four-fold. First, it investigates the effect of energy price in monetary policy on macro-economic growth, which enriches the existing literature on the understanding of monetary policy mechanisms and verifies the conclusions of previous studies on the relationship between money supply, energy, and economics. Second, considering the temporal dependence properties of time series data, we do not apply the conventional mediation effect mode but the Granger mediation method in

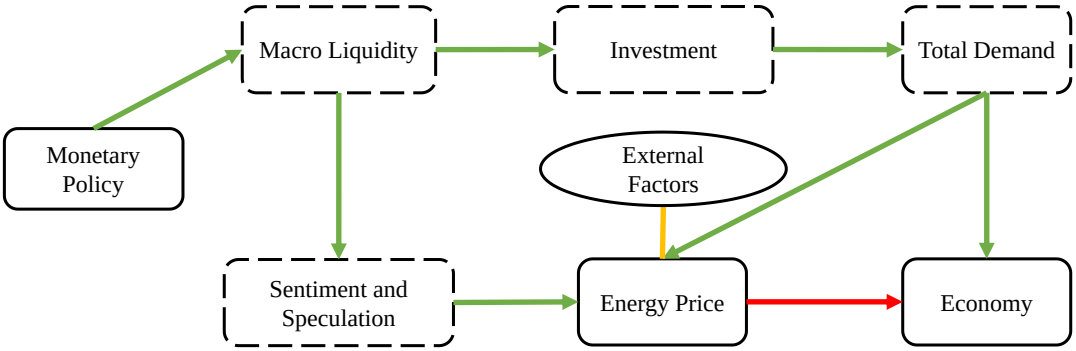

Fig 1 The working process of monetary policy in theory that considers the role of energy prices. The solid quadrilateral represents the variables considered in this article, and the dashed line represents other factors in the influence path. The green arrow line represents the positive impact, and the red represents the negative impact. The ellipse and the yellow line respectively represent the process of external factors affecting energy prices

detecting the mediation role of the energy. This method combines the Granger causality and the mediation analysis thereby providing a more appropriate analysis framework for time series. It avoids the defect that the conventional test cannot be used to obtain the lagging effect that obviously exists in the process of monetary policy functioning. Third, based on the fact that the effect of monetary policy on the economy would not be static, we introduce the time-varying granger causality test. This test efficiently captures the dynamic changes of the causal impact of the monetary policy on the economy. Thus, regressing the results on the energy prices, we could eventually find how the energy prices directly drive the economic target realization of monetary policy, namely its moderation effect. At last, since our findings are novel, we propose some targeted policy recommendations based on our conclusions, especially on the area of efficiently managing monetary policy.

The remaining parts of this paper have been organized as follows. Section 2 conduct a theoretical analysis about the relations between energy, monetary policy and macroeconomy, the hypothesizes of this paper are also proposed. Section 3 introduces the methodology we used. Section 4 is concerned with the description of variables and some basic analysis. Section 5 analyzes the main results of empirical investigation. In the last section, we discuss the main conclusions and summarize some implications.

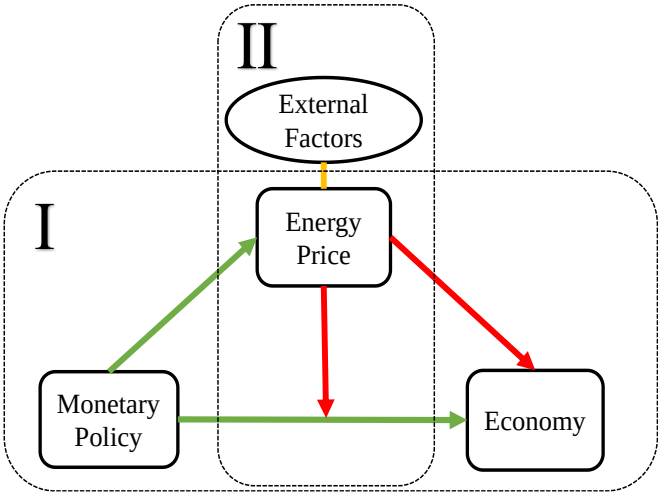

Fig 2 The simplified theoretical model. The lines and polygons have the same meanings with the Figure 1. Two swim lanes formed by short dashed rounded rectangles respecitvely the two influence mechanisms of energy price affecting the relation between monetary policy and macroeconomy.

2. THEORETICAL ANALYSIS AND HYPOTHESIS DEVELOPMENT

Monetary policy is an important tool for the government to adjust the economic situation, and it often has the ability to stimulate the economy out of recession or prevent the economy from overheating.

The main process for monetary policy to work is as follows. First, the central bank adjusts the money supply, which affects the overall liquidity level in the macro economy. The level of liquidity reflects the degree of scarcity of currency. Therefore, when liquidity changes, bank deposit and loan interest rates will also change accordingly. For enterprises, changes in loan interest rates will affect the risks and difficulties of them to expand reproduction. This change would ultimately drive the overall investment level of the society. For private sector, the change in deposit interest rate adjusts the opportunity cost of consumption, thus the overall social consumption would be different from the stages before the monetary policy adjustment. Eventually, the changes in total investment and total consumption shape the new macro-economic situation.

However, if we consider the energy in the process of monetary policy playing a role, the theoretical impact mechanisms would be different. When the overall economic liquidity changes due to the adjustment of the money supply, the financial market may be the first to be impacted. Since most energy commodities such as coal and oil have established sound financial markets, the increased liquidity may impact the original energy price level. Meanwhile, an expected effect might exist. Based on the adjustment of monetary policy, energy users may anticipate the future energy market and correspondingly change their current energy purchase plans, thereby affecting energy prices. As energy is an important input element in industrial production, it is obvious that changes in energy prices will affect the social production cost, ultimately economic prosperity. In a word, the energy might be the mediator in the pathways that monetary policy driving the economic boom. Although energy prices can be affected by monetary policy, they are still more determined by the long-term supply and demand structure, meanwhile, the geopolitics, exchange rate markets, and other financial markets may have complex pairwise links to the energy market. Therefore, energy prices may also moderate the impact of monetary policy on economic prosperity. The theoretical impact mechanisms of monetary policy considering the role of energy price are summarized in the Figure 1.

Based on our theoretical impact pathways, the energy price might be raised by monetary policy changes and eventually damaging the economic boom from the production cost channel. The energy price, therefore, might be the negative mediator in the process that monetary policy drives the economic boom. We could propose the hypothesis 1 as the follows:

H1: Monetary policy will ultimately affect the economic prosperity by influencing energy prices. (Energy is the mediator in monetary policy driving the economic boom.)

Since the energy price relates to the social production cost, the impact of monetary policy on economic prosperity may be different at different energy price levels. That is, the energy price might also play as a moderator in in monetary policy driving the economic boom. Thus, the hypothesis 2 is developed.

H2: Energy prices can affect the extent to which monetary policy promotes economic prosperity. (Energy is the moderator in monetary policy driving the economic boom.)

Our theoretical model displays how the monetary policy affects the macroeconomy with the consideration of energy prices, we simplify it by pruning the irrelevant factors. The simplified theoretical model is displayed in Figure 2, the two swim lanes respectively correspond to the two influence mechanisms based on Hypothesis 1 and Hypothesis 2.

3. METHODOLOGY

3.1 Granger mediation analysis framework

Mediation analysis is a typical statistical approach for many social and economic studies, which concentrates on detecting the intermediate variable sitting in the pathway from an independent and dependent variable. To confirm whether the energy price is an opposite mediator in monetary policy driving the economic boom, we should conduct a targeted mediation effect examination. However, most mediation models like Baron-Kenny method, marginal structural model, etc. can only measure the mediation effect at one time point, they are appropriate for the time series analysis. To solve this problem, Zhou and Luo (2019) [1] have proposed a mediation framework based on Granger causality that allow the temporal dependence among the variables. Similar to the Granger causality test, this model is also generalized from the VAR model with the lag p, and it follows the test steps of Sobel and Lindquist to confirm the mediation effects. The first step is testing the relation between explanatory variable and mediator, in this paper, the monetary policy and energy price.

$$M_t = AX_t + \sum_{j=1}^{p} \phi_{1j} X_{t-j} + \sum_{j=1}^{p} \psi_{11j} M_{t-j} + \sum_{j=1}^{p} \psi_{21j} Y_{t-j} + \varepsilon_{1t} \quad (1)$$

Where X, M, and Y are the main explanatory variable (monetary policy), potential mediator (energy price) and dependent variable (economic prosperity). The A is the coefficient to be estimated, indicating the effect from monetary policy on energy price. ϕ and ψ are the parameters for the lagged variables, the ε_{1t} is the error term. The second step aims to detect the relation between three variables and obtain the mediation effect. Also following the multivariate VAR process with the order of p.

$$Y_t = CX_t + BM_t \sum_{j=1}^{p} \phi_{2j} X_{t-j} + \sum_{j=1}^{p} \psi_{12j} M_{t-j} + \sum_{j=1}^{p} \psi_{22j} Y_{t-j} + \varepsilon_{2t} \quad (2)$$

Where all the indicators are the same as the Eq. (1), C represent the direct effect of monetary policy on economic boom while B indicate the indirect effect. Thus, the AB could represent whether the mediation effect exists or not.

3.2 Time varying granger causality model

Following Shi et al. (2018)[2], the time-varying causality tests are also derived from the VAR(p) model, whose multivariate form can be written as:

$$Y_t = Mx_t + u_t \quad (1)$$

Where t = 1, 2, ……T, Y_t is a vector of two time series causal variables (Y_{1t} and Y_{2t}) that will be detected, $x_t = (1, Y_{t-1}^{'}, Y_{t-2}^{'}, \ldots, Y_{t-p}^{'})^{'}$ and $u_t = (u_{1t}, u_{2t})^{'}$ respectively indicating the lag terms of Y_t and the error terms. Thus, the $M = [\beta_0, \beta_1, \ldots, \beta_p]$ is a $2 \times (2p+1)$ matrix, as the coefficients of lag terms. To confirm whether there is the predictable impact of Y_{2t} on Y_{1t}, we could test the hypothesis as $Y_{2t} \not\rightarrow Y_{1t}$. The simple form for Wald test of this null hypothesis is:

$$W = [\mathbb{R}vec(\widehat{M})]^{'}[\mathbb{R}(\widehat{\Omega} \otimes (X'X))\mathbb{R}']^{-1}[\mathbb{R}vec(\widehat{M})] \quad (2)$$

Let $\widehat{M}$ is the OLS estimator $\widehat{M} = (X'X)(X'X)^{-1}$, the $vec(\widehat{M})$ represents the row vectorization. $\hat{\Omega} = T^{-1}\sum_{t-1}^{T} \hat{\varepsilon}_t \hat{\varepsilon}_t^{'}$ and $\mathbb{R}$ is the $p \times 2(2p+1)$ selection matrix for setting one of the coefficients as zero under the null hypothesis. This Wald test assumes the conditional homoskedasticity and averages the sample information, thus it could lose explanation power when the errors are heteroskedastic and destroy potentially valuable structural changes.

Thus, Shi et al. (2018; 2020) [2,3] based on supremum (sup) Wald statistic sequences to solve the above problems. They use three algorithms, namely a forward recursive, a rolling window, and a recursive evolving algorithm to

reconstruct the Granger causality test. With a fine derivation (see Shi et al., 2018[2] and Shi et al., 2020[3] for more details), the estimation programs could be obtained. Shi et al. (2018, 2020) [2,3] have evaluated the empirical performance for the three algorithms and indicate the recursive evolving would be the best one. Thus, we conduct our main estimation following this algorithm. As follow, we display the details for the recursive evolving algorithm.

$$\hat{f}_e = \inf_{f\in[f_0,1]}\{f : SW_f(f_0) > scv\} \text{ and } \hat{f}_f = \inf_{f\in[\hat{f}_e,1]}\{f : W_f(f_0) < scv\} \quad (5)$$

Where cv and scv are the critical values of the Wald statistic W_f and Sup Wald statistic SW_f, respectively. f_e and f_f are the estimated origination and termination points for causality.

4. DATA AND PRELIMINARY DETECTION

4.1 Data

There are three main variables that should be considered in this paper, monetary policy, energy prices, and economic prosperity. We use the currency supply amount (M2) changes to represent the monetary policy dynamics, which has been widely used in the related studies. Since more than 70% of China's energy consumption is coal consumption, and coal has stronger rigid characteristics in industrial production and utilization. The national coal price level is used to represent the overall conditions of Chinese energy prices. To represent the macro-economic prosperity, we employ the purchasing managers index (PMI) because the PMI is a leading indicator of the economic growth. As the manufacturing sector is a core component of China's economy and always be the main focus of monetary policy, with a closely relation to energy use, this paper only focuses on the PMI in manufacturing sector to amplify the mechanism of energy prices in monetary policy driving the economy.

In order to ensure the consistency of the data characteristics in the sample and sufficient sample size, this paper selects the monthly data from January 2006 to June 2021. Monetary policy data comes from the People's Bank of China; Energy prices data is from official monthly statistics of the Ministry of Commerce of China; Manufacturing PMI data is obtained from the website of the National Bureau of Statistics of China. This article also introduces some control variables in the subsequent empirical process, and the relevant data are all from the Wind database.

4.2 Basic Granger causality analysis

The results based on the basic Granger causality test is shown in Table 1. In this table, we could find energy price and monetary policy are both the Granger cause of the PMI, while monetary policy can also predict the energy price changes. This initially verified our conjecture. When considering the impact of energy prices in the process of monetary policy promoting economic development, there may be some stable but complex connections between the three variables. The impact of monetary policy on energy prices is not very significant, but the causal influence of energy on PMI is obvious. What might be attributed to is that energy may have multiple paths in affecting economic development, not only transmitting the impact from the monetary policy but also directly playing a role in shaping the economy.

Table 1 The Granger causality results

Equation	Excluded	Wald	Df	*p*-value
pmi	energy	10.500	3	0.015
pmi	monetary	7.4996	3	0.058
energy	monetary	6.2465	3	0.099

5. MAIN EMPIRICAL RESULTS

5.1 The Granger causal mediation effects

Following the GMA model estimation procedure, we could obtain the mediation effect of energy price in driving the relation between monetary policy and macroeconomy.

Table 2 Results of mediation analysis

	Estimate	Std.Err.	LB	UB
A	-0.1216	0.0112	-0.1436	-0.0997
C	28.1524	1.2465	25.7093	30.5956
B	0.7476	0.1568	0.4403	1.0550
AB	-0.0909	0.0208	-0.1318	-0.0501

Table 2 illustrates the GMA results which includes lags of the main (mediation related) variables and an autocorrelation process of the errors. In this table, the coefficient corresponds to the Eq. (1) and Eq. (2). There are two parameters need to be focused, the C and AB are respectively the total direct effect and total indirect effect. As can be seen, we can find all the estimated parameters are significant, indicating the evidence of both the direct and indirect effect. Moreover, the AB has a negative value, which suggest that the indirect impact of expansionary monetary policy through energy prices may ultimately damage the economic development, even if such negative impacts are insignificant relative to the direct effects of monetary policy.

5.2 The direct driving effects

Based on TV-GC method, we could obtain the dynamic strength of monetary policy driving the macroeconomy. The results are displayed in Figure 3, which obviously indicate the effect of monetary policy on the economy is not static.

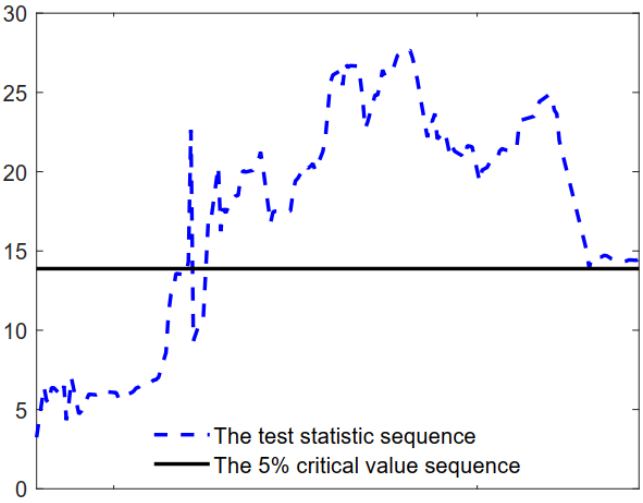

Fig 3 The dynamic causal impact strength of M2 changes affecting the manufacturing PMI.

After computing the different time-varying causal impact indexes based on the TV-GC model, the following step is to examine whether the energy price drives this impact from the monetary policy to the macroeconomy. To this end, we mainly discuss the direct driving effect estimation through the OLS modeling, as shown in Table 3. Since the influence of time series variables may be lagging, we include both the simultaneous energy price and its two lags in the estimation model. The results indicate that the two-period lag of energy prices has a significant effect on time-varying causal effects. Thus, energy prices can directly affect the role of monetary policy in economic development, that is to say, energy prices have the characteristics of moderators. Meanwhile, due to the slow transmission of the macro-economic system, the effect of energy prices is lagging.

Table 3 Results of moderation analysis

	Estimate	Std.Err.	t	P>|t|
Energy	-17.573	25.000	-0.700	0.483
L.Energy	2.689	31.106	0.090	0.931
L2.Energy	-48.409	25.411	-1.910	0.059
Controls	Y	Y	Y	Y
Dummy	Y	Y	Y	Y

5.3 Robustness checks

In order to ensure the robustness of the results, we adjusted the energy price index and reperformed the empirical steps, the results did not change. Subsequently, we adjusted the manufacturing PMI to the non-manufacturing PMI and found that the impact of energy prices disappeared, which mirrors the speculation that energy shocks the effectiveness of monetary policy through the manufacturing production. At last, we test whether other commodities prices have the similar effect as energy price, the results on agricultural product prices do not show any significant effect. All the above steps confirm our robustness.

6. CONCLUSION AND IMPLICATION

In this paper, we discuss the innegligible influence of energy in monetary policy driving economic prosperity. Based on our theoretical analysis, we infer that energy prices may have both a mediating role and a moderating effect on the connection between monetary policy and the economy. To verify our deduction, we introduce the GMA model and TV-GC method. The results suggest monetary policy might affect the macroeconomy by driving the energy prices, and energy prices could also directly shape the the time-varying causal impact from monetary policy to economic prosperity.

These findings have important implications in regard to improving the effectiveness of the monetary policy and clarifying the multiple properties of energy. Our conclusion shows, when using monetary policy to promote economic development, policy makers should reasonably choose the timing of policy release. Meanwhile, it would be necessary to devote to reduce the impact of increased liquidity on energy prices so that ensure the effectiveness of the monetary policy.

Limited by the research focus and the weakness of the paradigm, this paper can be further extended in several directions. For example, the findings could only explain the Chinese tale, it should be cautious to apply the corresponding recommendation to other economic areas. The wider research for international conditions and other countries might be a good future research line.

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