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Effectives of Monetary Policy under the High and Low Economic Uncertainty States: Evidence from the Major Asian Economies

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ABSTRACT

Effectives of Monetary Policy under the High and Low Economic Uncertainty States: Evidence from the Major Asian Economies

This study examines the monetary policy effectiveness of five major Asian countries (China, Hong Kong, India, Japan, and South Korea) using a quantile vector autoregression (QVAR) model-based spillover estimation approach of Balcilar *et al.* (2020b) at different quantile paths. To do this, we first obtain the spillover index from interest rate to industrial production and consumer price index under the high and low levels of uncertainty. The full sample results from our analysis provide partial supporting evidence for the economic theory, which asserts that monetary policy efficiency must fall during periods of high economic uncertainty. Furthermore, this approach also allows us to uncover asymmetric effects of economic policy uncertainty and lending rate on macroeconomic indicators. The impacts of interest rate and domestic and foreign (US, EU) uncertainty shocks on major Asian markets present significant asymmetric characteristics. Moreover, our time-varying results suggest that monetary policy shocks are more effective and potent on Asian economies during very low and very high uncertain times than normal economic periods.

JEL Classification: economic policy uncertainty, monetary policy efficiency, quantile spillover, QVAR

Keywords: C32, E44, F42, G01

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1. Introduction

The theoretical literature establishes a connection between monetary policy effectiveness and uncertainty through two important mechanisms: *nonlinearities in the interest rate* and *the credit transmission channel*. The nonlinearities theory argues that the monetary policy efficiency decreases during high uncertainty states due to real options effects, precautionary savings, and uncertainty-dependent price-setting mechanisms (Vavra, 2013; Bloom, 2014). Another reason that the monetary policy efficiency weakens when the future is uncertain is because firms adopt a wait-and-see approach and postpone their investment decisions to avoid the cost of irreversible investments pursuant to the real options theory (see, e.g., Bloom, 2009, 2014). The precautionary savings theory, on the other hand, claims that investors prefer precautionary saving and shift their expenditures to the future owing to present uncertainty circumstances (see, e.g., Bloom, 2014). And last, the uncertainty-dependent price-setting mechanism attributes the decrease in the effectiveness of monetary policy to the continuous price adjustment of firms due to uncertainty (Vavra, 2013). Thus, economic agents are less responsive to policy shocks in these situations where uncertainty and unpredictability prevail. Hence, this makes central banks more aggressive to reach their goals of monetary policy such as price stability, maximum employment, and currency stability.

The evidence from various empirical studies confirms this view (see, among others, Bernanke, 1983; Dixit and Pindyck, 1994; Bloom, 2009; Aesveit *et al.*, 2017; Balcilar *et al.*, 2017; Castelnovo and Pellegrino, 2018; Pellegrino, 2018; Lien *et al.*, 2019; Cekin *et al.*, 2020). For instance, Aastveit *et al.* (2017) investigate the macroeconomic influence of monetary policy changes during different uncertainty states in the US by utilizing the interacted VAR methodology. Later, they extend their analysis to include Canada, the United Kingdom, and Norway economies by adding the US uncertainty measure as the interacted variable. Their empirical findings provide evidence that the impact of monetary policy on an economy weakens significantly during periods of increased uncertainty, particularly for Canada and the US. Furthermore, Balcilar *et al.* (2017) examines the role of the US economic policy uncertainty on the effectiveness of monetary policy in the Euro area and find evidence in favor of the policy ineffectiveness hypothesis contingent on the economic policy uncertainty of the US. Moreover, Gupta and Jooste (2018) investigate the unconventional monetary policy effectiveness in eight OECD countries (Canada, Germany, France, Italy, Japan, Spain, UK, and US) that

implemented unconventional monetary policy in the wake of the 2007 subprime mortgage crisis due to zero-bound rate problem. They reach the same conclusion as previous studies.

The credit transmission channel theory, unlike nonlinearities in the interest rate, argues that monetary policy shocks are more effective and potent on economies during financial crises since firms suffer from liquidity constraints due to the rise of external finance premiums (see, among others, Morgan, 1993; Bernanke *et al.*, 1999; He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014). Many studies in the literature provide differing empirical evidence for this theory. For instance, Balke (2000) and Li and St-Amant (2010) find that monetary shocks have a larger impact on output in times of tight credit, or high financial stress, than in normal times, and that contractionary monetary shocks have a larger impact than expansionary monetary shocks by using a threshold vector autoregression (TVAR) model. Using Markov switching models, Garcia and Schaller (2002) and Lo and Piger (2005) conclude that monetary policy has greater effects during recessions than during expansions. More recently, Fry-Mckibbin and Zheng (2016) examine the impact of monetary policy during periods of low and high financial stress in the US economy by utilizing the TVAR model. They find evidence indicating that expansionary monetary policy has a higher proportionate effect on output during periods of high financial stress than normal times. Furthermore, Janssen *et al.* (2019) show that monetary policy has significantly larger effects on output and inflation and other macroeconomic indicators such as credit, asset prices, uncertainty, and consumer confidence during financial crises for twenty advanced economies. Similar conclusions are also reached by Burgard *et al.* (2019). These studies show that monetary policy can be a powerful tool for economic stimulus during crisis times in the euro area. However, these expansionary monetary policy impacts are observed to be short-lived.

The empirical methodology used in most of the above studies¹ is a constant coefficient mean-based multivariate vector autoregressive model, which models interactions on the mean of the relevant conditional distribution and ignores interactions on other parts. The constant-coefficient linear VAR model focuses on the forecast of analyzed variables conditioned on the mean distribution, constraining it exclusively to a specific location of the conditional

¹ Aastveit *et al.* (2017), Balcilar *et al.* (2017) and Pellegrino (2018) use interacted VAR (IVAR) model to examine the effects of monetary policy shocks on macroeconomic variables for different countries. Even if IVAR model differentiates impulse responses of monetary policy shocks at the high and low levels of uncertainty by calculating above and below the mean of the historical distribution of the uncertainty, the parameters are based on a mean-based estimation and does not allow dynamics vary across the support of the distribution.

distribution and ignores succession of small and varied shock which might have a crucial impact on the structure of the economic model. Furthermore, these mean-based multivariate models underestimate the contagion from larger economic shocks during recession and expansion times. This consequence implies that the mean-based models need to be altered to capture the effect of larger shocks at the tails of the distribution. The quantile vector autoregression (QVAR) model, extend the linear VAR approach and can model richer effects than mean-based models. The QVAR model does not restrict itself to the conditional mean, and therefore it permits to draw of state-dependent shocks at different locations, thus offering a global view on the relationships between variables (Montes-Rojas, 2017). Hence, this study brings a new perspective to the literature that deals with how real economic indicators react to interest rate changes at the high and low uncertainty levels.

Using both foreign (US and EU) and domestic economic policy uncertainty, we use the quantile spillover estimation approach of Balcilar *et al.* (2020b) to examine how monetary policy effectiveness for these five major Asian economies (China, Hong Kong, India, Japan, and South Korea) changes conditional on different economic policy uncertainty levels. The QVAR model allows investigating potential dynamic heterogeneity not covered by the mean-based impulse response function of mean-based VARs. This approach also allows us to construct different fictitious cases (quantile paths) by analyzing the multivariate quantile indexes. Expressing differently, we estimate the spillover indices from interest rate to macroeconomic variables (industrial production and consumer price inflation) in two different extreme economic cases in addition to the median response. The first case represents the economic environment where the central bank dramatically cuts its policy rate in a recession with high economic policy uncertainty, while the second case represents the economic situation where the central bank raises interest rates in an expansion to combat inflation and moves to prevent the economy from overheating during low uncertainty times. In so doing, we attempt to detect asymmetries between these two cases and explore the possible changes in monetary policy efficiency of Asian economies during extreme low/high economic policy uncertainty times by comparing them with the median response.

To analyze the response of macroeconomic variables to monetary policy shocks from the QVAR model, we utilize the Diebold and Yilmaz spillover index (hereafter the DY index due to Diebold & Yilmaz 2009, 2012). The literature using the DY index in the fields of finance and macroeconomics is very large. It has found applications in many contexts such as equity

markets (Diebold & Yilmaz 2009), foreign exchange markets (Baruník *et al.* 2016, 2017), sovereign and corporate credit spreads (Greenwood-Nimmo *et al.* 2019), asset markets, and international spillovers (Balcilar *et al.* 2019; Balcilar *et al.* 2020 a, b). It provides a dynamic interaction among multivariate time series by structural inference, whereas constant coefficients characterize the conventional linear VAR model. For spillover dynamics, several authors draw attention to the asymmetric spillover dynamics of macroeconomic shocks (see, e.g., Neftci 1984; Granger 2003; Engle & Manganelli 2004; Balcilar *et al.* 2020b). This feature was pointed out by Fisher (1933) and Keynes (1936) as early as in the 1930s.

This study contributes to the existing literature mainly in three aspects. Firstly, this study is the first attempt to discuss monetary policy effectiveness in different economic policy uncertainty states by the quantile spillover estimation approach of Balcilar *et al.* (2020b). In so doing, we have the opportunity to compare the spillover effect from monetary policy changes with two different extreme scenarios where economic uncertainty is either high or low. Thus, we provide strong evidence whether these countries need to implement more aggressive monetary policy in environments where uncertainty is higher than the normal times. Secondly, our approach allows us to examine heterogeneous responses depending on the state of the economy and to uncover the asymmetric effects. The determination of the existence of the asymmetric effect is important to reveal whether the shocks have a permanent or transitory effect in economies that are in transition from low uncertainty state to high uncertainty state. Our third contribution to literature is that we use a large set of variables that have not been used before. These variables include consumer price index (CPI), prime lending rate (LR), industrial production index (IP), Brent crude oil price (BRENT) in the local currency, domestic news based economic policy uncertainty (EPU), the United States EPU, and the European Union EPU. Moreover, the monthly frequency data covers the period 1998M1–2019M4 for China and Hong Kong; 2003M1–2019M4 for India; 1987M1–2019M4 for Japan; 1990M1–2019M4 for South Korea.

Our main findings are multifold. First, these five Asian economies respond differently to monetary policy shocks in good and bad times and this can be seen evidence of the existence of an asymmetrical effect. The asymmetric spillover indices from economic policy uncertainties and interest rates to industrial production and consumer price index have different magnitudes across countries and these asymmetric effects are sometimes stronger during low uncertainty periods and sometimes during high uncertainty periods. Second, we provide partial evidence to support the economic theory claiming that monetary policy is less effective when

economic uncertainty is high based on the full sample results. We find that responses of output and inflation to monetary policy shocks varies across the high and low uncertainty times and weaker responses may occur during high uncertainty times. However, the time-varying analysis gives us a more clearer picture regarding the view that the effectiveness of monetary policy declines in an environment of high uncertainty. That said, episodes of monetary policies of Asian central banks is more effective when they take serious monetary policy action even during the high and low uncertainty states. Hence, we can say that our empirical findings are in line with previous studies that support credit transmission channel theory. Lastly, the median spillover effects from interest rates to macroeconomic indicators are almost always lower than those spillovers obtained in the high and low uncertainty states. Hence, this study provides invaluable information for policymakers by unveiling the relationships between interest rates and other macroeconomic variables for major Asian countries.

The rest of the paper is organized as follows. Section 2 details the methodology. Section 3 describes the data and reports the empirical results. The last section concludes the paper.

2. Methodology

In this study, we utilize the DY spillover index approach of Balcilar *et al.* (2020b), which based on the forecast error variance decomposition (FEVD) of a quantile vector autoregression. The QVAR based DY index is based on the multivariate quantile estimation of Montes-Rojas (2017, 2019). Following Balcilar *et al.* (2020b), we can shortly describe the procedure starting with the reduced form QVAR model at the quantile θ as follows:

$$Q_{\theta}(Y_t|X_t) = C_{\theta} + A_{\theta}X_t, \quad t = 1, 2, \dots, T \quad (1)$$

where Q is an $n \times 1$ vector, which corresponds to the multivariate quantiles of the n random variables, $A_{\theta} = (A'_{\theta,1}, A'_{\theta,2}, \dots, A'_{\theta,n})'$ is an $n \times k$ matrix of coefficients with $A_{\theta,i}$, for each $i \in 1, 2, \dots, n$, representing $1 \times k$ vector of coefficients for the j th element of Y_t , and C_{θ} is an $n \times 1$ vector of coefficients. In this study, we utilize a multivariate directional quantile approach,

which estimates the conditional quantile of variable i , as proposed by Montes-Rojas (2017), based on the covariates and quantiles of all other variables.²

To obtain the DY spillover index, we first calculate the generalized impulse response functions (GIRF) and then obtain FEVDs from these IRFs. To get the FEVDs, we use the counterfactual change approach of Montes-Rojas (2019). Let us define the lag polynomial $A(\theta, L) = \sum_{j=1}^p A_{\theta, j} L^j$ in the lag operator L , where the h -lag coefficient vector $A_{\theta, h} = (A_{\theta, 1, h}, A_{\theta, 2, h}, \dots, A_{\theta, n, h})$ is $1 \times n$ and defined on all endogenous variables in Y_t , for $j = 1, 2, \dots, p$. The QVAR model in Equation (1) can be written as

$$Q_{\theta}(Y_t|X_t) = C_{\theta} + A(\theta, L)X_t \quad (2)$$

where $A_{\theta}X_t = A(\theta, L)Y_t = \sum_{j=1}^p A_{\theta, j}Y_{t-j}$.

Then, we obtain h -step forecast of Y_t , each step associated with a $n \times 1$ quantile vector θ_j , which is related to quantile forecast path $\theta_{1 \dots h} = \{\theta_1, \theta_2, \dots, \theta_h\}$. Accordingly, the h -step quantile forecast is given by

$$Q_{\theta_{1 \dots h}}(Y_{t+h}|X_t) = C_{\theta_h} + A(\theta_h, L)Q_{\theta_{1 \dots k}}(Y_{t+k}|X_t)$$

where $Q_{\theta_{1 \dots k}}(Y_{t+k}|X_t) = Y_{t-k}$ if $L^k(t+h) \leq t$ and $Q_{\theta_{1 \dots k}} = \{\theta_1, \theta_2, \dots, \theta_k\}$ is the k -step quantile path for $k = 1, 2, \dots, h-1$. From the definition in Eq. (2), the h -step forecast can be written as

$$Q_{\theta_{1 \dots h}}(Y_{t+h}|X_t) = C_{\theta_h} + \left[\prod_{j=1}^h A_{\theta_j} \right] X_t + \sum_{j=1}^{h-1} \left[\prod_{k=j+1}^h A_{\theta_k} \right] C_{\theta_j} \quad (3)$$

Using Eq. (3), we can calculate the counterfactual change, $\delta = (\delta_1, \delta_2, \dots, \delta_n)'$, and forecast $Q_{\theta_{1 \dots h}}(Y_{t+h} + \delta|X_t)$ for $\delta \in \mathcal{Y} \subseteq \mathbb{R}^m$ in a similar way. Hence, we can extend the GIRF of Koop *et al.* (1996), Pesaran and Shin (1998), Lanne and Nyberg (2016) to quantile generalized

² Unlike other equation-by-equation estimation methods (see, e.g., Cecchetti & Li 2008; Schüller 2014; White *et al.* 2015; Chavleishvili and Manganelli 2016; Linnemann and Winkler 2016; Zhu *et al.* 2016; Ando *et al.* 2018; Han *et al.* 2019), Montes-Rojas (2017) develops a multivariate model approach that solves for a fixed point on the multivariate quantile space based on directional quantiles. This approach solves for multivariate conditional quantiles given the covariates.

impulse response function (QIRF) by utilizing the h -step ahead forecast $Q_{\theta_{1...h}}(Y_{t+h}|X_t)$ and the h -step ahead change forecast $Q_{\theta_{1...h}}(Y_{t+h} + \delta|X_t)$ for a given quantile path $\{\theta_1, \theta_2, \dots, \theta_h\}$ and shock δ as follows:

$$\text{QIRF}(h, \delta) = Q_{\theta_{1...h}}(Y_{t+h} + \delta|X_t) - Q_{\theta_{1...h}}(Y_{t+h}|X_t) \quad (4)$$

The quantile-specific FEVD can be defined as:

$$\lambda_{\theta,ij}(h) = \frac{\sum_{l=0}^h \text{QIRF}(l, \delta_j)_i^2}{\sum_{j=1}^n \sum_{l=0}^h \text{QIRF}(l, \delta_j)_i^2}, \quad i, j = 1, 2, \dots, n \quad (5)$$

where $\lambda_{\theta,ij}(h)$ denotes the h -step-ahead generalized FEVD, while i and j represent variable and shock, respectively. Hence, the sum over all shocks in each variable equal to one, i.e., $\sum_{j=1}^n \lambda_{\theta,ij}(h) = 1$, and total decomposition of all series sum to n , i.e., $\sum_{i,j=1}^n \lambda_{\theta,ij}(h) = n$ by construction. Using the quantile variance decomposition in Eq. (5), we can obtain various valuable indexes at different quantiles. For example, the total spillover index, which calculates the contribution of spillovers of shocks across the variables under consideration to the total forecast error variance for quantile θ , can be obtained as follows:

$$S_{\theta}^T(h) = \frac{\sum_{i,j=1, i \neq j}^n \lambda_{\theta,ij}(h)}{\sum_{i,j=1}^n \lambda_{\theta,ij}(h)} \times 100 = \frac{\sum_{i,j=1, i \neq j}^n \lambda_{\theta,ij}(h)}{n} \times 100 \quad (6)$$

where $S_{\theta}^T(h)$ represents the total spillover index. Furthermore, one may also obtain the directional spillover received by variable i from all other variables j to understand the relationship between related variables. This can be computed as follows:

$$DS_{\theta, i \leftarrow j}(h) = \frac{\sum_{j=1, j \neq i}^n \lambda_{\theta,ij}(h)}{n} \times 100 \quad (7)$$

Similarly, we get the directional spillovers transmitted by variable i to all other variables j as:

$$DS_{\theta, i \rightarrow j}(h) = \frac{\sum_{j=1, j \neq i}^n \lambda_{\theta,ji}(h)}{n} \times 100 \quad (8)$$

Finally, subtracting the results obtained in Eq. (7) from the results in Eq. (8), the net spillover for variable i is at quantile θ is computed as:

$$NS_{\theta,i}(h) = DS_{\theta,i \rightarrow j}(h) - DS_{\theta,i \leftarrow j}(h) \quad (9)$$

3. Data and empirical results

In this study, we use monthly data of Brent crude oil price (BRENT) in the local currency, consumer price index (CPI), industrial production index (IP), prime lending rate (LR), and news-based economic policy uncertainty (EPU) for five big Asian countries, i.e., China, Japan, Hong-Kong, India, and South Korea. Besides representing international economic policy uncertainty, we obtain the United States and European Union EPU indices for the primary goal of the study. We use year-on-year growth rates for CPI, IP, and BRENT, natural logarithm transformation for all EPU series, and LR is in annual percentage. Furthermore, we seasonally adjust the CPI and IP series to remove their seasonal dynamics. The BRENT, CPI, IP, and LR data are derived from Thomson Reuters DataStream, while the EPU indices are obtained from www.policyuncertainty.com. The observation periods across countries vary due to data availability. In order to use longest span available, we do not use the same time span for each country. We collect monthly observations over the period from January 1998 to April 2019 for China and Hong Kong, from January 2003 to April 2019 for India, from January 1987 to April 2019 for Japan, and from January 1990 to April 2019 for South Korea.

Figure 1 exhibits the time series plots of all series for the corresponding countries over the study period. As shown in this plot, the year-on-year growth of CPI and IP fluctuates over the analysis period. Nonetheless, we see a mild upward trend in Hong Kong, while this is reflected in the South Korean inflation series as a downward trend. The inflation rate in India starts to fall after a steady increase from the beginning of the observation period to 2010. In general, we can say that policy rates are decreasing in all countries over time. The policy interest rate, which tended to increase in almost all countries before the 2007 subprime mortgage crisis, was rapidly reduced to cope with the economic contraction. Generally speaking, we notice that important economic events result in a sudden change in macroeconomic indicators, as mentioned by Bloom (2009) and Baker *et al.* (2016). They provide evidence that economic shocks tend to increase uncertainty in the economy, which in turn, produces a rapid drop, rebound, and

overshoot in macroeconomic indicators such as stock price, investment, unemployment rate, aggregate output, and productivity growth. On the other hand, it is crucial to state that the economic policy uncertainty indices for all Asian countries, except India, have a slightly increasing trend. Finally, we can deduce that the corresponding Asian central banks have to conduct monetary policy in a more uncertain global environment, as evident in Figure 1, after the 2007 subprime mortgage crisis.

Table 1 reports descriptive statistics of the series used in this study. According to Table 1, Asian countries' year-on-year inflation rate is positive on average, except China, where negative growth rates are observed. The year-on-year growth of industrial production takes negative values just in China and Hong Kong. Moreover, the annual interest rates for all countries have a general declining tendency, particularly after the subprime crises. It should also be emphasized that, on average, the country with the highest interest rate is India, followed by South Korea. The most volatile variable is the crude oil price, among other indicators, as shown by the standard deviation. Interestingly, the average mean of economic policy uncertainty index in China is highest among other economies, including the US and EU, with considerable volatility. As for the oil price year-on-year growth, we observe a positive mean value with somewhat a high standard deviation. Furthermore, none of the series are normally distributed as revealed by skewness, kurtosis, and Jarque-Bera test statistics. For the autocorrelation, the Ljung-Box test statistics of first [Q(1)] and the fourth [Q(4)] autocorrelation tests are reported in Table 1. These test statistics fail to support the null hypothesis of the white noise process (i.e., i.i.d. process) for all series. Last, we examine the autoregressive conditional heteroskedasticity of all series employing the first [ARCH(1)] and the fourth [ARCH(4)] order Lagrange multiplier (LM) test and the null hypothesis of no ARCH effects is strongly rejected for all series.

We carry out four kinds of unit root test statistics, namely the augmented Dickey-Fuller (ADF) test (Dickey and Fuller 1979), Elliott–Rothenberg–Stock (ERS) test Elliott *et al.* (1996), the Phillips–Perron (PP) test (Phillips and Perron 1988), and the KPSS stationarity test proposed by (Kwiatkowski *et al.* 1992). Table 2 reports the unit root tests performed on logarithms of CPI series, logarithms of IP series, logarithms of all EPU series, and LR series. As we can see in Table 2, the unit root tests imply somewhat conflicting results. Based on the results in Table 2, we use the year-on-year growth rates of CPI, IP, and BRENT series, log levels of EPU series, and levels the LR series in the estimation.

3.1. Full sample analysis

We estimate a seven-variable QVAR model for each Asian economy under different (high and low) economic policy uncertainty conditions. For the high and low EPU states, we use two different quantile vector paths as follows.

Case 1 (High EPU with recession): $\theta_{\text{USEPU}} = \theta_{\text{EUEPU}} = \theta_{\text{EPU}} = 0.95, \theta_{\text{BRENT}} = 0.50, \theta_{\text{IP}} = \theta_{\text{CPI}} = \theta_{\text{LR}} = 0.05$

Case 2 (Low EPU with expansion): $\theta_{\text{USEPU}} = \theta_{\text{EUEPU}} = \theta_{\text{EPU}} = 0.05, \theta_{\text{BRENT}} = 0.50, \theta_{\text{IP}} = \theta_{\text{CPI}} = \theta_{\text{LR}} = 0.95$

Case 1 reflects periods of high economic uncertainty (bad times). We assume that the central bank dramatically cuts its policy rate for achieving both inflation and growth objectives in these bad times. The internal and external economic policy uncertainty indices at 0.95 quantiles correspond to a high uncertainty environment. In contrast, the industrial production and consumer price index at 0.05 quantiles reflect a rapid decline in industrial production and demand. Case 2 is the opposite of Case 1. It represents periods of low economic uncertainty (good times). In times of low uncertainty, we assume that the central bank raises its policy rate to keep inflation low and prevent the economy from overheating. In these two cases, we prefer to keep the median quantiles for the oil market since we are not interested in examining the dynamics of spillover in Asian markets during different oil market states. Using these two alternative cases, we calculate the quantile spillovers from US EPU, EU EPU, country specific EPU, Brent oil price, and lending rate to industrial production and consumer prices during an economic boom and bust phase. It is assumed that uncertainty is low in economic boom periods and high in economic bust periods. We determine the lag order p of the QVAR models using the Akaike Criteria (AIC) in a mean-based VAR model. The lag order is determined as one for China and India, while it is selected as two for other countries. We order variables as BRENT, EPU, US EPU, EU EPU, CPI, IP, and LR. The QRIF step is 12 for all countries, i.e., $h = 12$.

Table 3 evaluates the full sample quantile spillover results for the five Asian countries. The left and middle panels of Table 4 report spillover indices during the high and low economic

uncertainty states. Besides, the right panel of Table 4 shows the asymmetric effect, which is obtained by subtracting low quantile spillover indices from high quantile spillover indices. As we can see from the table, considerable differences are observed between the high and low economic policy uncertainty quantile paths in some Asian economies. The full sample empirical findings also provide insights about the monetary policy effectiveness in these Asian economies, given the spillover effects from lending rate to industrial production and inflation outlook during both good and bad times. We can postulate that monetary policy effectiveness should decrease with the increasing uncertainty in economic policy. One explanation for this is that the economic units such as households, firms, and investors do not react to the central bank's expansionary monetary policy as in normal times. During very uncertain times, households prefer to save rather than consume, and firms may postpone their new investment decisions until confidence returns. Therefore, the asymmetric spillover effects from interest rate to industrial production and inflation, shown on the right panel of Table 4, should take a negative value. Nonetheless, not all findings support this assumption. The Indian and Japanese real economic activity and prices receive higher spillover effects from interest rate during bad times than good times. Although we have strong evidence to support the monetary policy effectiveness postulate, we cannot say that this argument receives full support in the other three Asian countries.

In addition to empirical findings regarding monetary policy effectiveness, the full sample results also give important information on the quantile asymmetric spillover effect from other variables (US EPU, EU EPU, domestic EPU, and oil market), but we do not enter into details in order not to wander from the subject. To highlight just a few important findings, we can say the following: (1) The asymmetric spillover from European Union uncertainty to Hong Kong industrial production is noteworthy in good times. (2) On the other hand, we observe high asymmetric effect of domestic economic policy uncertainty on the consumer price index of South Korea and the industrial production index of Japan in bad times. (3) As for India, we see that the foreign economic policy index spillover on consumer price in good times is bigger than those in bad times. (4) Last but not least, the spillover index from the oil market to inflation of Hong Kong during tranquil times is much greater than the one in a high uncertainty state. Hence, we provide evidence that some Asian markets stand out among others with large and quite asymmetric spillover from EPUs and the interest rate to economic activity.

3.2. Time-varying analysis

In this section, we expand the previous analysis in two ways. Firstly, the full sample analysis assumes that the coefficients of QVAR models are persistent and do not change over time. This assumption is indeed very strong in the presence of conditions that cause structural changes in the economy, such as economic crises, natural disasters, epidemics, wars, etc. Therefore, the full sample analysis under this assumption may give misleading results. To address this issue, we estimate QVAR models by utilizing 120-months rolling window estimation and then calculate the time-varying spillover indices from this rolling estimation at various quantile paths. Secondly, we add two additional cases to investigate monetary policy effectiveness in five Asian countries. The two cases we included in the analysis are as shown below.

Case 3 (Median Response): $\theta_{USEPU} = \theta_{EUEPU} = \theta_{EPU} = \theta_{BRENT} = \theta_{IP} = \theta_{CPI} = \theta_{LR} = 0.50$

Case 4 (High external EPU): $\tau_{USEPU} = \tau_{EUEPU} = 0.95, \tau_{EPU} = \tau_{BRENT} = \tau_{IP} = \tau_{CPI} = \tau_{LR} = 0.50$

Thus, the rolling analysis adds a third and fourth quantile paths to Case 1 and Case 2 to compare them with economic scenarios with normal economic conditions (Case 3) and high external EPU (Case 4). Case 3 represents the median quantile path³ and it is obtained by taking all variables at 0.5 quantiles. On the other side, we also calculate the monetary policy effectiveness of Asian economies only in times of high uncertainty of external economic policy uncertainty. To do this, we construct Case 4, which represents the economic environment when there is high external economic policy uncertainty. The external economic policy uncertainty indices at 0.95 quantiles correspond to a very high uncertainty environment in the US and EU. It is important to reveal how the monetary policy of these Asian countries, which have intense foreign trade and capital flow relations with the USA and the EU, changes in cases where the uncertainty in the outside world is high. It should also be noted that we prefer to keep the median quantiles for the oil market in all cases since we are not interested in examining the dynamics of spillover in Asian markets during different oil market states in this study.

³ Generally, a canonical case fixed with $\theta = \{0.5, \dots, 0.5\}$ for all $i = 1, 2, \dots, h$ delivers similar estimates to the mean-based VAR forecasts (Montes and Rojas, 2019). So actually, we can compare different economic scenarios with the standard VAR model result with this analysis.

Figure 2-6 shows the time-varying spillover empirical findings under four cases explained above. The left panels (Panel 1) of Figures 2-6 report three time-varying spillover indices from interest rate to industrial production, inflation, and the sum of these two observed variables during high uncertainty, low uncertainty times, as well as periods of normal economic conditions. In so doing, we can compare the spillover index in a state where central banks cut (raise) the policy rates sharply to avoid an economic contraction (overheating) in different times of economic uncertainty with the spillover index obtained from the median shocks ($\tau = 0.5$), which represents the normal times. In this way, we can examine how the effectiveness of the monetary policy conducted by central banks changes in these scenarios that represents the high and low economic uncertainties. The time-varying QVAR analysis produces more robust and policy-oriented results than full-sample analysis, because time-varying models relax the strict constant-coefficient assumption and take structural changes into account. The right panel (Panel 2) of Figures 2-6 plot the spillover indices from the lending rate to industrial production, consumer price index, and ‘others’ during a high external uncertain economic environment. The plots in Panel 2 of the figures allow us to evaluate central banks’ monetary policy effectiveness in times of high economic uncertainty in the US and EU. As we discuss below, the fact that these values are close to zero means that the efficiency monetary policy has decreased.

Analogous to the full sample results, we do not have supporting evidence for the hypothesis that monetary policy is less effective when uncertainty is high. As shown in Panel 1 of Figure 2, the quantile spillover effects from interest rate to real economic activity and prices during Case 1 and Case 2 are very close to each other, implying that monetary policy effectiveness in China has the same effectiveness during the high and low economic policy uncertainty states. Hence, we do not obtain supportive evidence for the ‘wait-and-see’ theory in China over the observation period, contradicting the empirical findings of Lien *et al.* (2019). Lien *et al.* (2019) investigate whether uncertainty has any influence on the China’s monetary policy effectiveness by utilizing a smooth transition vector autoregression (STVAR) model and conclude that China’s monetary policy is less effective when uncertainty is high. One interesting fact is that the spillover effects of interest rate on macroeconomic variables during low and high uncertainty states are always higher than the spillover effect obtained by median shocks, namely normal conditions. Consequently, these empirical findings shows that China’s easing monetary policy during high-uncertainty states and contractionary monetary policy during low-

uncertainty states are more effective than monetary policy during normal conditions. Panel 2 of Figure 2 shows the monetary policy effectiveness when the external economic policy uncertainty is high. The empirical finding shows that the rolling spillover index in this scenario is lower than those in Case 1 and Case 2.

Panel (1) of Figure 3 illustrates that the spillover indices for Hong Kong industrial production are generally above the spillover index in normal times. However, the responses of inflation to monetary policy shocks during all cases do not take very different values from each other, suggesting that further policy action might have limited efficacy in controlling inflation during abnormal times (i.e. very low and very high uncertainty times). Moreover, from Panel 1 of Figure 4, we can observe that monetary policy is more effective under the high and low uncertainty states compared to the normal economic state for India. This situation can be seen more clearly in Panel 1(c) of Figure 4. Indeed, the fact that there is a higher spillover in good times than that of bad times is encouraging for Indian monetary policy over the most analysis periods. We obtain a similar finding for the Japanese economy as reported in Figure 5. We can say that the interest policy implemented by the Bank of Japan (BoJ) during the high and low uncertainty times is more effective than the monetary policy conducted in normal times. Except for the period between 2004-2010, where the effectiveness of the monetary policy on industrial production and inflation takes similar values in periods when uncertainty is high or low. Lastly, the empirical findings for South Korea show that while the spillover effects from interest rate to macroeconomic indicators during low uncertainty states fluctuate significantly, those during high uncertainty states follow a stable path. The low uncertainty state spillover effect sometimes falls under the median spillover effects, suggesting that the monetary policy effectiveness declines in some in negligible subperiods.

In addition to these cases, we also investigate the spillover effect from the lending rate to macroeconomic variables when the external economic policy uncertainty is high as shown in Panel 2 of Figures 2-6. The main purpose of this additional analysis is to examine whether effectiveness of monetary policy decreases over time in an environment where the external economic policy uncertainty is high. Considering the history of the monetary policy actions, it is known that foreign economic uncertainties are taken more seriously, especially after the 2007 subprime mortgage crisis, by countries in the recent past. Monetary policy by central banks may also take into account of uncertainty in major advanced economies. In this context, it is unclear that how the spillover effect from interest to macroeconomic variables would change

in the Asian economies. Panel 2 of Figures 2-6 do not have a clear results on how monetary policy effectiveness changed in response to high external EPU. Overall, the spillover from interest rate to industrial production and consumer prices declined around 2013s, but it has been low in all period. Especially in South Korea, the monetary policy effectiveness declined after the 2007 subprime mortgage crisis (see Figure 6).

Overall, the evidence from our case-based analysis does not confirm that the monetary policy effectiveness of major Asian economies weakens during the high and low uncertainty states. In contrast, both industrial production and consumer price index are more responsive to the aggressive policy rate cut and they both increase in this extreme case. Hence, the Asian central banks should not refrain from the conduct monetary policy to combat recession (overheating) and inflation (deflation) problems when uncertainty is high (low). That is, our empirical findings under these scenarios mostly support the credit channel hypothesis which asserts that monetary policy shocks are more effective and potent on economies during financial crises as supported by many empirical studies such as Li and St-Amant (2010), Lo and Piger (2005), Fry-Mckibbin and Zheng (2016), Janssen *et al.* (2019), and Burgard *et al.* (2019). In addition to the findings of these studies, the results obtained in this study are important for the following reason. While these studies show that the policy effectiveness of central banks is greater than in normal times in times of financial distress, we also conclude that this situation exists for the case when the central bank increases the rate significantly during very low uncertainty states. In other words, a very sharp interest rate hike and interest rate cut have significant impacts on Asian markets during the high and low uncertainty times, respectively.

4. Conclusions

Central banks come across several uncertainties when determining monetary policy. One of the critical drawbacks here is whether central banks' monetary policy effectiveness weakens during the high uncertainty times because economic uncertainties are among the most important factors that make policymakers difficult to make decisions. Under this economic premise, it is of great importance to investigate the spillover index from interest rates to other variables in different economic scenarios, where economic policy uncertainty is very high or very low. Understanding the effectiveness of central banks' sound monetary policy design and the evaluation of its implications seem to require taking the relationship between interest rates and macroeconomic variables into account. There is no consensus in the literature regarding

whether financial and economic uncertainty decreases monetary policy effectiveness. The nonlinearities theory argues that the efficiency of monetary policy weakens during the high uncertainty state, while credit transmission channel theory claims the opposite of this argument. To contribute to this discussion in the literature, we examine the quantile spillover effects to capture how the monetary policy effectiveness of five major Asian economies (China, Hong Kong, India, Japan, and South Korea) changes during very low and very high uncertainty times by utilizing a QVAR model-based spillover estimation approach of Balcilar *et al.* (2020b). Besides, we also examine the time-varying spillover indices from the lending rate to macroeconomic variables when the external economic policy uncertainty is high.

The paper studies two monetary policy cases in both full-sample and time-varying analysis. The first case (bad times) represents the economic environment where the central bank dramatically cuts its policy rate in a recession with very high economic policy uncertainty, while the second case (good times) represents the economic situation where the central bank raises interest rates in an expansion to combat inflation and attempts to prevent the economy from overheating during a low uncertainty state. In so doing, we try to find whether the monetary policy effectiveness of Asian economies decreases during the high uncertainty times. Under the assumption that the Asian central banks follow the simple monetary policy rule suggested by Taylor (1993), it makes sense to create these two scenarios to measure the monetary policy efficiency and asymmetries. The full sample results show that the Indian and Japanese real economic activity and prices receive higher spillover effects from interest rate during good times than bad times, supporting the nonlinearities in the interest rate channel. However, we do not get evidence to support this theory in China, Hong Kong, and South Korea.

The time-varying analysis based on the rolling QVAR model (even if full sample analyzes provide mixed results) suggests that the effects of monetary policy shocks are generally higher during the high and low uncertainty times than those in normal times for all the five Asian countries. Hence, these empirical findings support the credit channel theory for all Asian countries, indicating that central banks don't have to worry about a decrease in monetary policy efficiency in environments where economic uncertainty is either high or low. Previous studies, which provide evidence in favor of the credit channel hypothesis, arguing that the policy effectiveness of central banks is greater in financial distress times than in normal. We also find evidence that this situation holds for the case when the central bank increases the rate

significantly during the low uncertainty times. Put it differently, radical changes in the policy rate by the five Asian central banks affect markets strongly regardless of economic uncertainty.

References

- Aastveit, K.A., Natvik, G.J., Sola, S., 2017. Economic uncertainty and the influence of monetary policy. *Journal of International Money and Finance* 76, 50-67
- Ando, Tomohiro and Greenwood-Nimmo, Matthew and Shin, Yongcheol, 2018. Quantile Connectedness: Modelling Tail Behaviour in the Topology of Financial Networks. Available at: <http://dx.doi.org/10.2139/ssrn.3164772>
- Baker, S.R., Bloom, N., Davis, S.J., 2016. Measuring economic policy uncertainty. *The Quarterly Journal of Economics* 131, 1593-1636
- Balcilar, M., Demirer, R., Gupta, R., Van Eyden, R., 2017. The impact of US policy uncertainty on the monetary effectiveness in the Euro area. *Journal of Policy Modeling* 39, 1052-1064
- Balcilar, M., Ozdemir, Z.A., Ozdemir, H., Wohar, M.E., 2020a. Fed's Unconventional Monetary Policy and Risk Spillover in the US Financial Markets. *The Quarterly Review of Economics and Finance*, <https://doi.org/10.1016/j.qref.2020.01.004>
- Balcilar, M., Ozdemir, Z.A., Ozdemir, H., Wohar, M.E., 2020b. Transmission of US and EU Economic Policy Uncertainty Shock to Asian Economies in Bad and Good Times. Institute of Labor Economics (IZA), *IZA discussion paper* No. 13274, Bonn, Germany. <http://ftp.iza.org/dp13274.pdf>
- Balcilar, M., Usman, O., Agbede, E.A., 2019. Revisiting the Exchange Rate Pass-Through to Inflation in Africa's Two Largest Economies: Nigeria and South Africa. *African Development Review* 31, 245-257
- Balke, N.S., 2000. Credit and economic activity: credit regimes and nonlinear propagation of shocks. *Review of Economics and Statistics*, 82(2), 344-349
- Baruník, J., Kočenda, E., Vácha, L., 2016. Asymmetric connectedness on the US stock market: Bad and good volatility spillovers. *Journal of Financial Markets* 27, 55-78
- Baruník, J., Kočenda, E., Vácha, L., 2017. Asymmetric volatility connectedness on the forex market. *Journal of International Money and Finance* 77, 39-56
- Bernanke, B.S., 1983. Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal of Economics* 98, 85-106
- Bernanke, Ben S, Mark Gertler, and Simon Gilchrist, 1999. The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics*, 1, 1341– 1393.
- Bloom, N., 2009. The impact of uncertainty shocks. *Econometrica* 77, 623-685
- Bloom, Nicholas, 2014. Fluctuations in uncertainty. *Journal of Economic Perspectives*, 28, 153–175
- Brunnermeier, Markus K and Yuliy Sannikov, 2014. A macroeconomic model with a financial sector. *American Economic Review*, 104, 379–421
- Burgard, J. P., Neuenkirch, M., & Nöckel, M., 2019. State-Dependent Transmission of Monetary Policy in the Euro Area. *Journal of Money, Credit and Banking*, 51(7), 2053-2070
- Castelnuovo, E., Pellegrino, G., 2018. Uncertainty-dependent effects of monetary policy shocks: A new-Keynesian interpretation. *Journal of Economic Dynamics and Control* 93, 277-296
- Cecchetti, S.G., Li, H., 2008. Measuring the impact of asset price booms using quantile vector autoregressions. *Working Paper*; Department of Economics, Brandeis University: Waltham, MA, USA
- Cekin, S. E., Hkiri, B., Tiwari, A. K., & Gupta, R., 2020. The Relationship between Monetary Policy and Uncertainty in Advanced Economies: Evidence from Time-and Frequency-Domains. *The Quarterly Review of Economics and Finance*. Available at: <https://doi.org/10.1016/j.qref.2020.05.010>

- Chavleishvili, S., Manganelli, S., 2016. Quantile impulse response functions. *Working Paper*, European Central Bank, 17
- Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association* 74, 427-431
- Diebold, F.X., Yilmaz, K., 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal* 119, 158-171
- Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting* 28, 57-66
- Dixit, A.K., Dixit, R.K., Pindyck, R.S., 1994. Investment under uncertainty. *Princeton University Press*.
- Elliott, G., Rothenberg, T., Stock, J., 1996. Efficient tests for an autoregressive unit root. *Econometrica* 64, 813-836
- Engle, R.F., Manganelli, S., 2004. CAViaR: Conditional autoregressive value at risk by regression quantiles. *Journal of Business & Economic Statistics* 22, 367-381
- Fisher, I., 1933. The debt-deflation theory of great depressions. *Econometrica: Journal of the Econometric Society*, 337-357
- Fry-Mckibbin, R., & Zheng, J., 2016. Effects of the US monetary policy shocks during financial crises—a threshold vector autoregression approach. *Applied Economics*, 48(59), 5802-5823
- Garcia, R., & Schaller, H., 2002. Are the effects of monetary policy asymmetric? *Economic inquiry*, 40(1), 102-119
- Granger, C.W., 2003. Time series concepts for conditional distributions. *Oxford Bulletin of Economics and Statistics* 65, 689-701
- Greenwood-Nimmo, M., Huang, J., Nguyen, V.H., 2019. Financial sector bailouts, sovereign bailouts, and the transfer of credit risk. *Journal of Financial Markets* 42, 121-142
- Gupta, R., & Jooste, C., 2018. Unconventional monetary policy shocks in OECD countries: how important is the extent of policy uncertainty? *International Economics and Economic Policy*, 15(3), 683-703
- Han, H., Jung, W., Lee, J.H., 2019. Estimation and Inference of Quantile Impulse Response Functions by Local Projections: With Applications to VAR Dynamics. Available at: <http://dx.doi.org/10.2139/ssrn.3466198>
- He, Zhiguo and Arvind Krishnamurthy, 2013. Intermediary asset pricing. *American Economic Review*, 103, 732–70.
- Keynes, J.M., 1936. *The General Theory of Employment. Interest and Money*, McMillan, London
- Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics* 74, 119-147
- Kwiatkowski, D., Phillips, P.C., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics* 54, 159-178
- Lanne, M., Nyberg, H., 2016. Generalized forecast error variance decomposition for linear and nonlinear multivariate models. *Oxford Bulletin of Economics and Statistics* 78, 595-603
- Li, F. and P. St-Amant, 2010. Financial stress, monetary policy, and economic activity. *Working Paper of Bank of Canada* 2010-12. Bank of Canada, Ottawa, Canada.
- Lien, D., Sun, Y., & Zhang, C., 2019. Uncertainty, confidence, and monetary policy in China. *International Review of Economics & Finance*. (In Press, Corrected Proof) Available at: <https://doi.org/10.1016/j.iref.2019.11.017>
- Linnemann, L., Winkler, R., 2016. Estimating nonlinear effects of fiscal policy using quantile regression methods. *Oxford Economic Papers* 68, 1120-1145

- Lo, M. C., & Piger, J., 2005. Is the response of output to monetary policy asymmetric? Evidence from a regime-switching coefficients model. *Journal of Money, credit and Banking*, 865-886.
- Montes-Rojas, G., 2017. Reduced form vector directional quantiles. *Journal of Multivariate Analysis* 158, 20-30
- Montes-Rojas, G., 2019. Multivariate Quantile Impulse Response Functions. *Journal of Time Series Analysis* 40, 739-752
- Morgan, D. P., 1993. Asymmetric effects of monetary policy. *Economic Review-Federal Reserve Bank of Kansas City*, 78, 21-33.
- Neftci, S.N., 1984. Are economic time series asymmetric over the business cycle? *Journal of Political Economy* 92, 307-328
- Nils Jannsen & Galina Potjagailo & Maik H. Wolters, 2019. Monetary Policy during Financial Crises: Is the Transmission Mechanism Impaired? *International Journal of Central Banking*, 15(4), 81-126.
- Pellegrino, G., 2018. Uncertainty and the real effects of monetary policy shocks in the Euro area. *Economics Letters* 162, 177-181
- Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. *Economics Letters* 58, 17-29
- Phillips, P.C., Perron, P., 1988. Testing for a unit root in time series regression. *Biometrika* 75, 335-346
- Schüler, Y.S., 2014. Asymmetric effects of uncertainty over the business cycle: A quantile structural vector autoregressive approach. University of Konstanz Department of Economics, 2014-02. Available at: <http://nbn-resolving.de/urn:nbn:de:bsz:352-0-275836>
- Taylor, J. B., 1993. Discretion versus policy rules in practice. In *Carnegie-Rochester conference series on public policy* 39, 195-214
- Vavra, Joseph, 2013. Inflation dynamics and time-varying volatility: New evidence and an Ss interpretation. *Quarterly Journal of Economics*, 129, 215–258.
- White, H., Kim, T.-H., Manganelli, S., 2015. VAR for VaR: Measuring tail dependence using multivariate regression quantiles. *Journal of Econometrics* 187, 169-188
- Zhu, H., Su, X., Guo, Y., Ren, Y., 2016. The Asymmetric Effects of Oil Price Shocks on the Chinese stock market: Evidence from a quantile impulse response perspective. *Sustainability* 8, 766

Figure 1. Time series plots of the series used in estimation

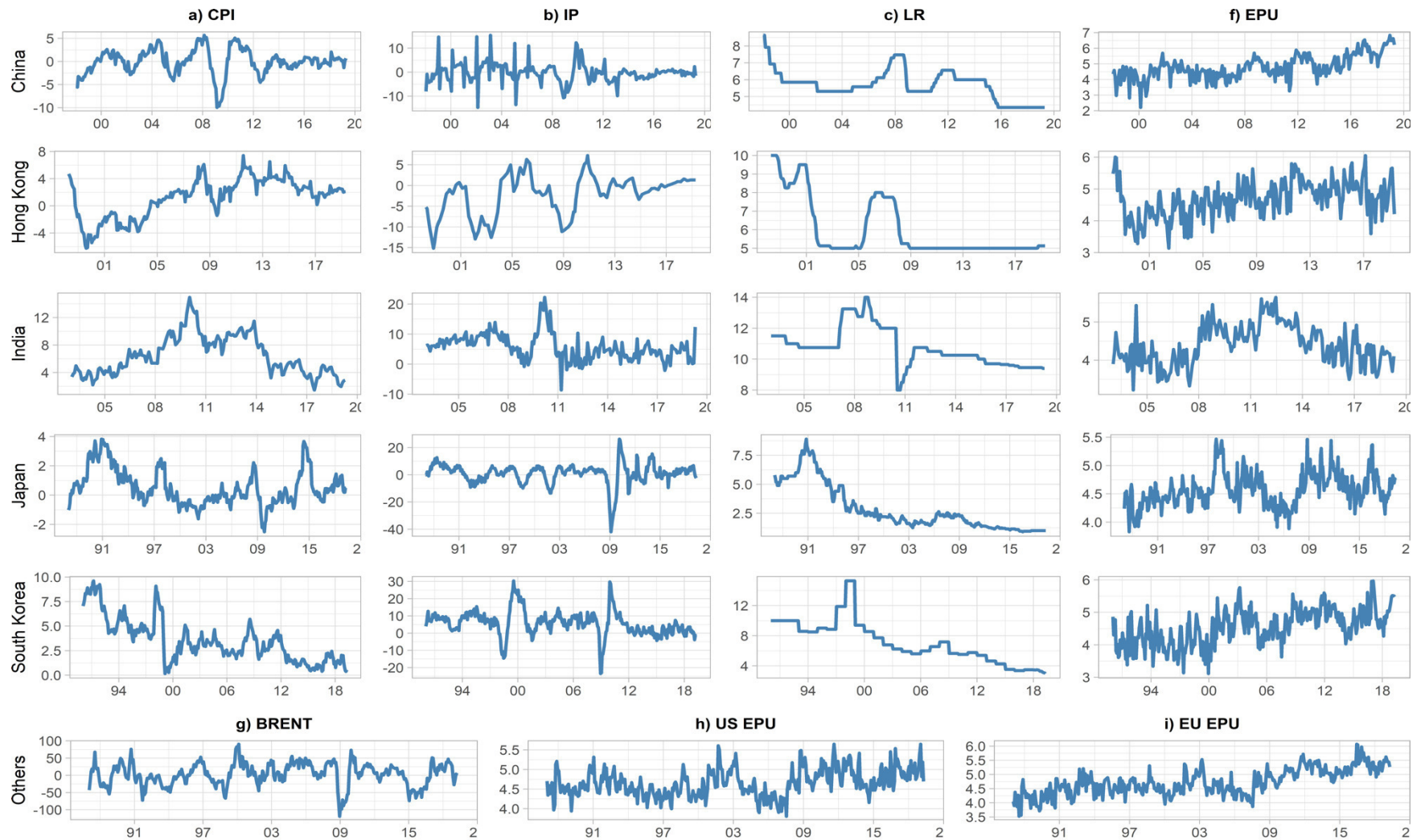


Table 1. Descriptive statistics

Series	N	Mean	S.D.	Min	Max	Skewness	Kurtosis	JB	Q(1)	Q(4)	ARCH(1)	ARCH(4)
China (January 1998 – April 2019)												
CPI	256	-0.03	2.75	-9.96	5.68	-0.68	1.38	41.39***	221.67***	684.72***	207.39***	210.39***
IP	256	-0.22	4.07	-14.73	15.40	0.48	3.12	117.39***	31.24***	119.17***	39.30***	44.16***
LR	256	5.69	0.88	4.35	8.64	0.48	0.50	12.76***	238.51***	833.86***	233.29***	231.88***
BRENT	256	5.20	34.98	-100.47	94.98	-0.39	0.12	6.62**	211.13***	604.32***	161.53***	160.97***
EPU	256	4.80	0.77	2.21	6.84	0.09	0.23	1.06	140.87***	475.93***	57.49***	79.30***
Hong Kong (April 1998 – April 2019)												
CPI	253	1.22	2.90	-6.25	7.42	-0.53	-0.52	14.78***	235.82***	874.86***	198.52***	197.78***
IP	253	-2.23	4.79	-15.16	7.22	-0.71	-0.38	22.67***	246.16***	841.94***	225.05***	232.23***
LR	253	5.98	1.56	5.00	10.00	1.28	0.09	69.81***	246.93***	915.60***	246.93***	245.61***
BRENT	253	5.45	37.43	-100.81	101.86	-0.40	0.08	7.04**	213.48***	626.54***	167.91***	166.87***
EPU	253	4.68	0.57	3.14	6.05	-0.14	-0.26	1.45	103.55***	256.59***	32.78***	31.91***
India (January 2003 – April 2019)												
CPI	195	6.41	2.86	1.45	14.94	0.60	-0.39	13.03***	182.00***	642.80***	157.02***	156.53***
IP	195	5.75	4.39	-8.62	22.24	0.70	1.80	43.95***	97.56***	340.13***	70.02***	77.37***
LR	195	10.75	1.24	8.00	14.00	0.64	0.01	13.54***	181.85***	624.82***	171.07***	172.68***
BRENT	195	2.07	32.47	-89.30	61.09	-0.75	0.06	18.62***	159.64***	443.93***	121.99***	124.52***
EPU	195	4.40	0.53	3.22	5.65	0.15	-0.67	3.54	100.83***	322.35***	33.47***	42.64***
Japan (January 1987 – April 2019)												
CPI	388	0.52	1.23	-2.51	3.83	0.73	0.14	35.38***	358.71***	1232.21***	325.17***	325.19***
IP	388	0.90	7.60	-41.97	26.25	-1.65	7.39	1071.84***	332.75***	962.29***	328.05***	337.61***
LR	388	2.85	1.96	0.90	8.90	1.20	0.30	95.58***	384.64***	1501.94***	376.79***	374.94***
BRENT	388	3.13	32.84	-119.35	90.77	-0.48	0.36	17.22***	305.69***	808.54***	212.29***	215.45***
EPU	388	4.57	0.30	3.83	5.47	0.51	0.41	19.62***	254.04***	703.34***	136.22***	139.44***
South Korea (January 1990 – April 2019)												
CPI	352	3.51	2.21	0.16	9.62	0.85	0.12	43.28***	334.58***	1177.08***	319.63***	319.41***
IP	352	5.77	7.21	-23.51	30.35	0.03	2.50	93.83***	296.11***	883.79***	246.83***	250.44***
LR	352	7.09	2.76	2.97	15.28	0.80	0.69	45.56***	343.03***	1308.40***	311.89***	309.34***
BRENT	352	2.78	29.31	-93.82	87.66	-0.16	0.64	7.90**	260.11***	661.45***	162.17***	161.57***
EPU	352	4.55	0.55	3.11	5.97	-0.08	-0.41	2.67	198.66***	523.71***	79.47***	79.89***
Other Variables (January 1987 – April 2019)												
US EPU	388	4.66	0.35	3.80	5.65	0.33	-0.15	7.57**	201.55***	486.05***	55.37***	55.32***
EU EPU	388	4.73	0.46	3.52	6.07	0.15	-0.40	3.80	261.64***	860.41***	133.63***	145.29***

Note: The asterisks ***, * and, * represent the significance level at 1%, 5%, and 10%, respectively.

Table 2. Unit root tests

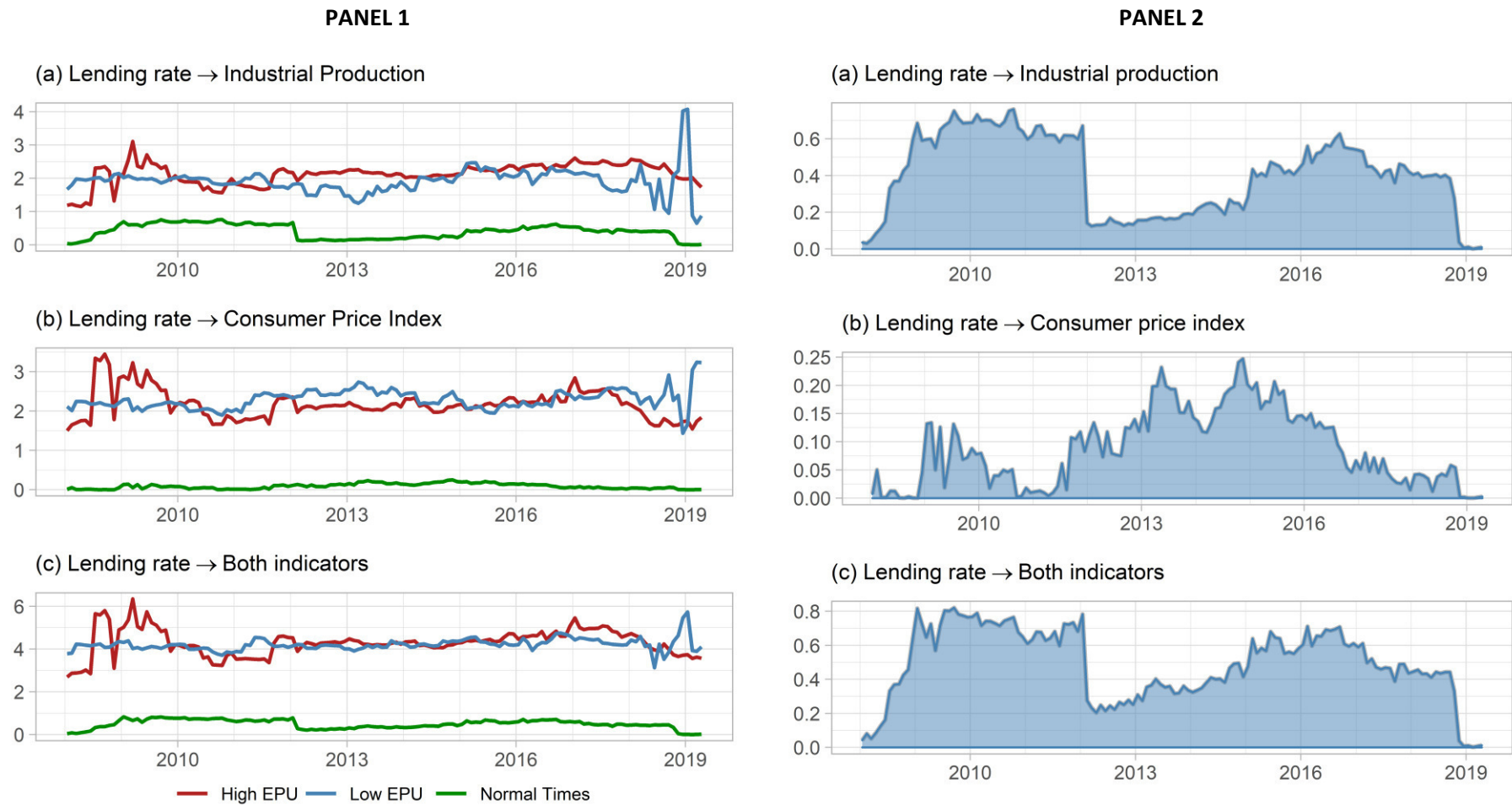
	Series	ADF	ADF	ERS	ERS	KPSS	KPSS	PP	PP	Series	ADF	ADF	ERS	ERS	KPSS	KPSS	PP	PP
		(Const)	(Trend)	(Const)	(Trend)	(Const)	(Trend)	(Const)	(Trend)		(Const)	(Trend)	(Const)	(Trend)	(Const)	(Trend)	(Const)	(Trend)
China	CPI	-1.80	-2.05	4.34*	15.27	0.53**	0.17**	-1.48	-1.87	D(CPI)	-3.44**	-3.46**	0.04***	0.09***	0.04	0.02	-3.91***	-3.92**
	IP	-2.66*	-3.69**	2.22**	7.29	0.72**	0.22***	-6.69***	-8.17***	D(IP)	-5.01***	-6.49***	0.06***	0.20***	0.3	0.05	-12.40***	-12.58***
	LR	-1.01	-1.75	21.30	16.45	1.29***	0.21**	-0.84	-1.56	D(LR)	-3.95***	-3.97**	0.72***	1.20***	0.11	0.17	-3.20**	-3.17*
	BRENT	-1.76	-2.28	22.41	8.35	1.65***	0.32***	-1.64	-2.34	D(BRENT)	-3.90***	-4.09***	0.59***	1.41***	0.27	0.05	-4.35***	-4.55***
	EPU	-4.96***	-6.23***	4.31*	14.06	1.12***	0.21**	-12.76***	-14.34***	D(EPU)	-5.07***	-5.12***	0.22***	0.81***	0.1	0.05	-10.03***	-10.07***
Honk Kong	CPI	1.08	-4.08***	181.39	387.34	1.33***	0.38***	2.43	-3.73**	D(CPI)	-2.31	-2.27	21.87	12.73	1.16***	0.32***	-2.15	-2.53
	IP	-2.25	-1.78	142.03	41.83	1.36***	0.28***	-4.01***	-1.75	D(IP)	-3.17**	-3.45**	3.12**	3.42***	0.34	0.04	-2.68*	-2.76
	LR	-2.40	-2.82	36.56	19.39	0.85***	0.12*	-2.68*	-1.86	D(LR)	-3.82***	-3.87**	0.79***	1.90***	0.10	0.06	-2.81*	-2.81
	BRENT	-3.13**	-2.68	31.16	23.21	0.80***	0.36***	-2.34	-2.01	D(BRENT)	-4.80***	-4.74***	0.60***	1.86***	0.46*	0.06	-3.98***	-4.34***
	EPU	-4.45***	-8.00***	2.35**	5.00**	0.88***	0.11	-7.09***	-8.37***	D(EPU)	-6.27***	-6.27***	0.36***	0.84***	0.06	0.06	-11.56***	-11.55***
India	CPI	-1.24	0.19	2523.67	61.62	1.40***	0.20**	-0.80	-0.14	D(CPI)	-1.73	-2.06	4.99	15.71	0.35*	0.32***	-1.73	-1.91
	IP	-1.55	-2.23	502.86	23.58	1.36***	0.33***	-1.16	-2.55	D(IP)	-3.25**	-3.50*	0.55***	1.67***	0.52**	0.04	-5.66***	-6.34***
	LR	-1.98	-2.59	4.41	6.97	0.70**	0.12	-1.91	-2.52	D(LR)	-3.98***	-4.02***	0.20**	0.69***	0.07	0.05	-3.56***	-3.56**
	BRENT	-2.53	-2.93	2.98**	8.83	0.29	0.22***	-2.31	-2.45	D(BRENT)	-4.13***	-4.14***	0.66***	2.18***	0.24	0.1	-3.63***	-3.78**
	EPU	-2.77*	-2.71	2.84**	7.13	0.3	0.26***	-5.13***	-5.13***	D(EPU)	-3.98**	-4.07***	0.82***	2.69***	0.2	0.07	-7.84***	-7.90***
Japan	CPI	-3.53***	-2.84	283.01	135.28	1.05***	0.34***	-3.91***	-2.95	D(CPI)	-3.09**	-3.27*	1.38***	4.26**	0.53**	0.27***	-2.93**	-3.07
	IP	-3.92***	-4.00***	12.604	9.81	0.39*	0.07	-3.63***	-3.67**	D(IP)	-5.16***	-5.16***	0.02***	0.05***	0.06	0.06	-5.05***	-5.04***
	LR	-1.22	-1.88	39.49	11.74	1.80***	0.35***	-1.33	-1.70	D(LR)	-5.94***	-5.93***	0.15***	0.56***	0.09	0.09	-5.01***	-5.00***
	BRENT	-1.65	-3.05	5.121	8.76	1.76***	0.24***	-1.60	-3.00	D(BRENT)	-5.31***	-5.29***	0.55***	1.22***	0.12	0.1	-5.32***	-5.31***
	EPU	-4.19***	-4.35***	1.077***	1.63***	0.42*	0.10	-6.23***	-6.56***	D(EPU)	-7.12***	-7.11***	0.41***	1.24***	0.03	0.03	-8.20***	-8.19***
South Korea	CPI	-5.38***	-2.25	4074.65	295.99	2.12***	0.47***	-7.34***	-2.59	D(CPI)	-3.80***	-4.98***	13.52	5.09**	1.43***	0.13*	-3.00**	-3.89**
	IP	-1.88	-0.93	536.14	31.25	2.13***	0.45***	-2.11	-1.16	D(IP)	-4.18***	-4.44***	0.32***	0.55***	0.45*	0.06	-4.37***	-4.62***
	LR	-1.30	-2.74	15.61	6.95	1.69***	0.10	-1.28	-2.77	D(LR)	-3.55***	-3.61**	0.39***	1.22***	0.14	0.05	-3.90***	-3.97**
	BRENT	-1.62	-3.19*	6.14	6.68*	1.56***	0.25***	-1.86	-2.87	D(BRENT)	-5.00***	-4.99***	0.23***	0.82***	0.13	0.13*	-5.38***	-5.37***
	EPU	-5.55***	-7.40***	0.64***	2.14***	1.47***	0.07	-6.62***	-9.07***	D(EPU)	-8.48***	-8.46***	0.46***	0.98***	0.05	0.05	-10.72***	-10.71***
Other	USEPU	-6.73***	-7.18***	0.318***	1.17***	0.66**	0.12	-7.75***	-8.41***	D(USEPU)	-9.29***	-9.32***	0.80***	2.45***	0.08	0.04	-10.68***	-10.69***
	EUEPU	-3.45***	-4.98***	8.399	4.32**	1.65***	0.18**	-5.59***	-9.26***	D(EUEPU)	-8.15***	-8.13***	0.36***	1.04***	0.04	0.04	-11.21***	-11.20***

Notes: ***, **, and * represent significance level at 1%, 5% and 10% respectively. D(x) represents the first difference of the series x.

Table 3. The spillover effects during the high and low uncertainty periods

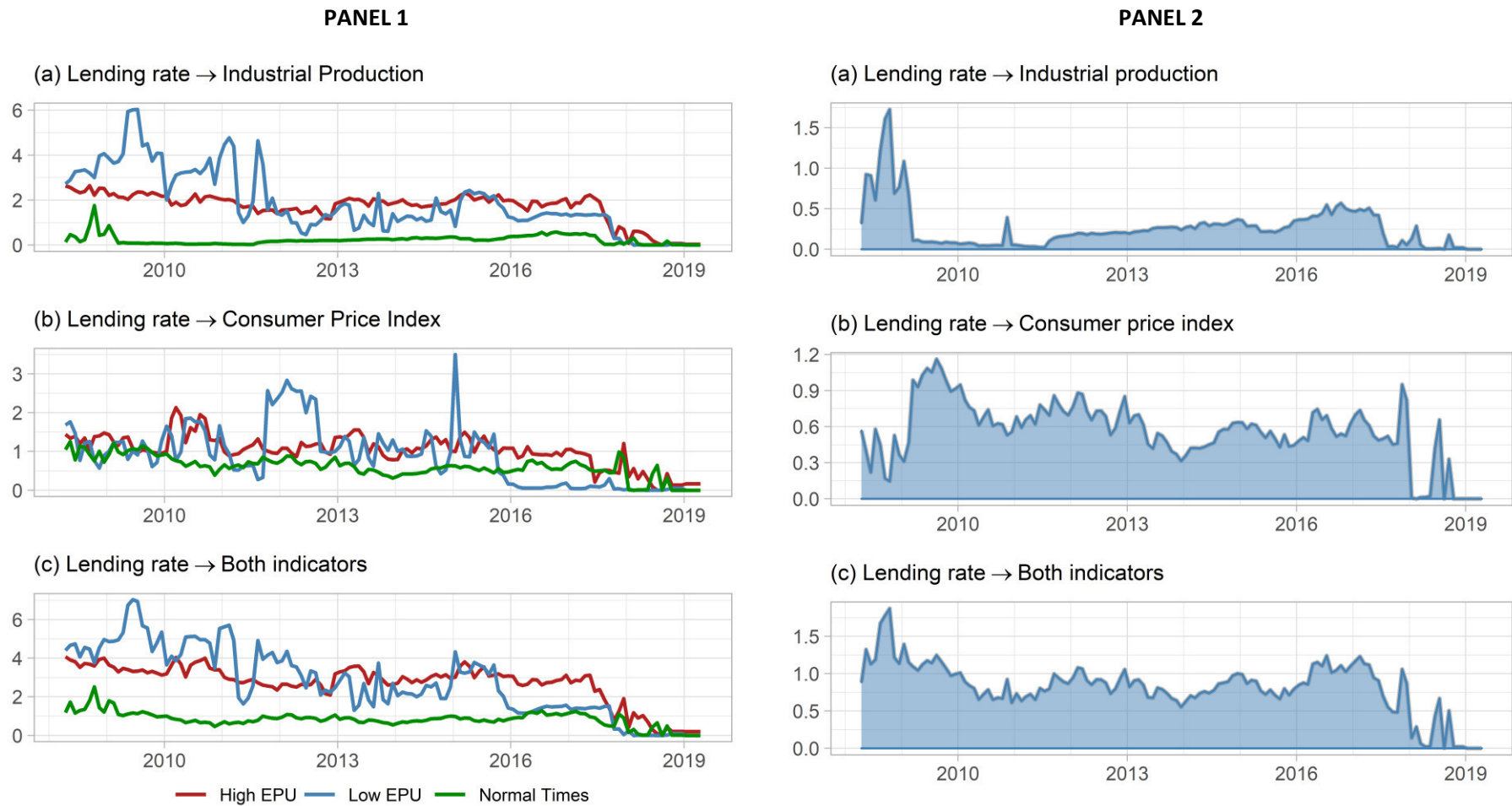
HIGH EPU						LOW EPU						ASYMMETRY					
(a) China						(a) China						(a) China					
<i>From (j)</i>						<i>From (j)</i>						<i>From (j)</i>					
<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR
IP	15	12.92	14.34	0.21	13.06	IP	13.78	16.86	17.63	3.15	12.33	IP	1.22	-3.94	-3.29	-2.94	0.73
CPI	18.44	15.6	16.55	0.32	12.02	CPI	14.72	17.53	18.82	2	12.95	CPI	3.72	-1.93	-2.27	-1.68	-0.93
(b) Hong Kong						(b) Hong Kong						(b) Hong Kong					
<i>From (j)</i>						<i>From (j)</i>						<i>From (j)</i>					
<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR
IP	15.67	12.79	16.38	2.19	17.13	IP	17.32	21.05	15.14	0.93	8.53	IP	-1.65	-8.26	1.24	1.26	8.6
CPI	16.21	14.61	17	1.13	10.9	CPI	12.19	11.88	13.4	8.57	11.33	CPI	4.02	2.73	3.6	-7.44	-0.43
(c) India						(c) India						(c) India					
<i>From (j)</i>						<i>From (j)</i>						<i>From (j)</i>					
<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR
IP	19.3	20.17	18.27	0.22	2.73	IP	17.27	16.57	14.98	0.98	13.49	IP	2.03	3.6	3.29	-0.76	-10.76
CPI	11.34	12.79	16.69	1.11	5.56	CPI	16.46	17.51	12.89	2.1	17.03	CPI	-5.12	-4.72	3.8	-0.99	-11.47
(d) Japan						(d) Japan						(d) Japan					
<i>From (j)</i>						<i>From (j)</i>						<i>From (j)</i>					
<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR
IP	16.7	15.12	22.53	1.84	11.89	IP	15.06	12.77	17.03	0.75	18.01	IP	1.64	2.35	5.5	1.09	-6.12
CPI	10.78	14.02	18.95	2.1	13.22	CPI	14.69	14.82	14.98	0.21	19.41	CPI	-3.91	-0.8	3.97	1.89	-6.19
(e) South Korea						(e) South Korea						(e) South Korea					
<i>From (j)</i>						<i>From (j)</i>						<i>From (j)</i>					
<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR	<i>To (i)</i>	USEPU	EUEPU	EPU	BRENT	LR
IP	14.49	13.83	20	0.18	9.96	IP	17.53	19.02	15.8	1.32	0.5	IP	-3.04	-5.19	4.2	-1.14	9.46
CPI	15.47	14.53	16.05	2.5	10.38	CPI	10.88	17.41	9.06	0.67	8.95	CPI	4.59	-2.88	6.99	1.83	1.43

Figure 2. The spillover results from the lending rate to macroeconomic indicators under different cases for China



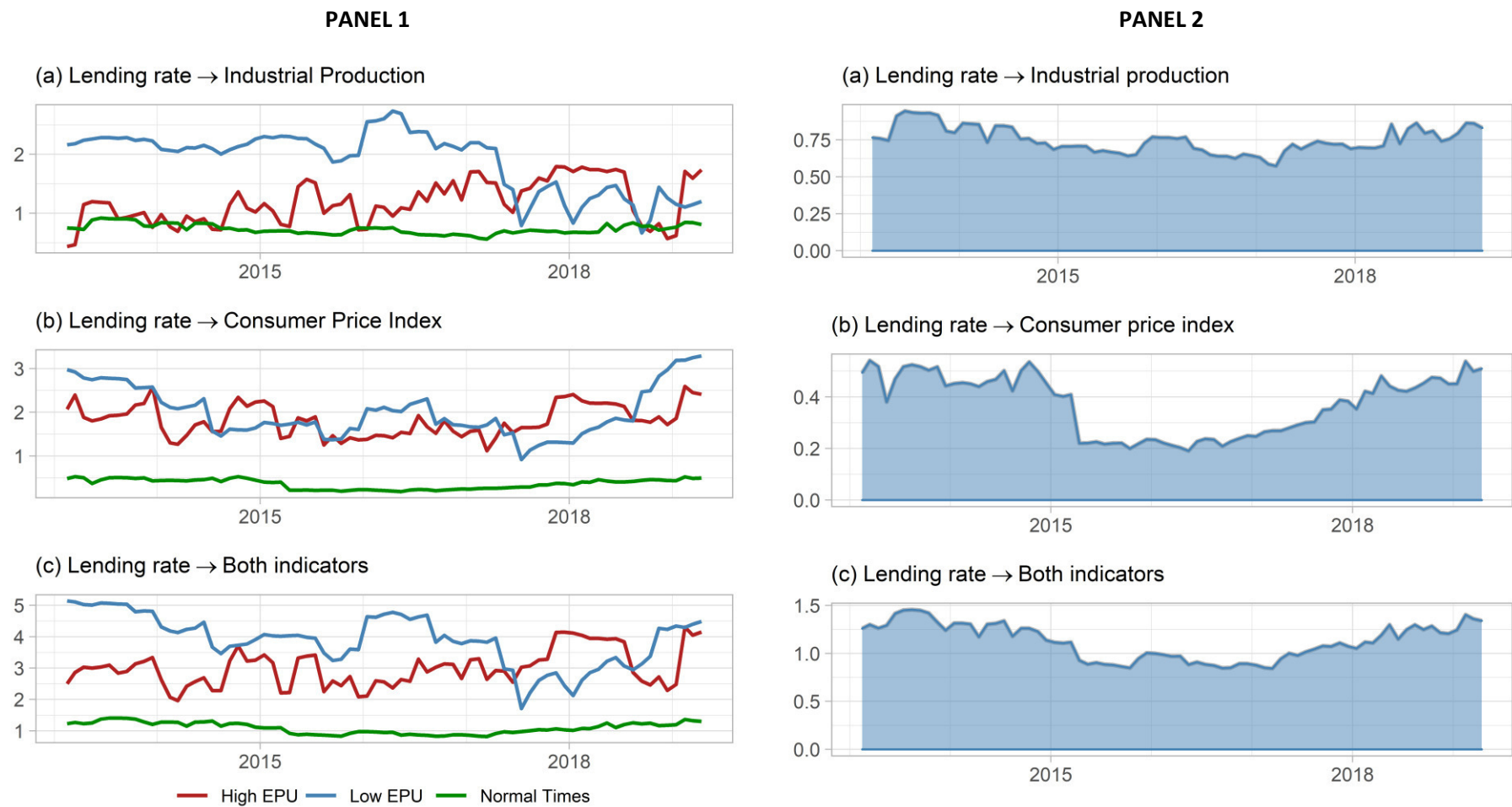
Note: Panel 1 reports rolling estimates of spillover from lending rate for high EPU (Case 1), low EPU (Case 2), normal case (Case 3), while Panel 2 reports rolling estimates for high external EPU (Case 4).

Figure 3. The spillover results from the lending rate to macroeconomic indicators under different cases for Hong Kong



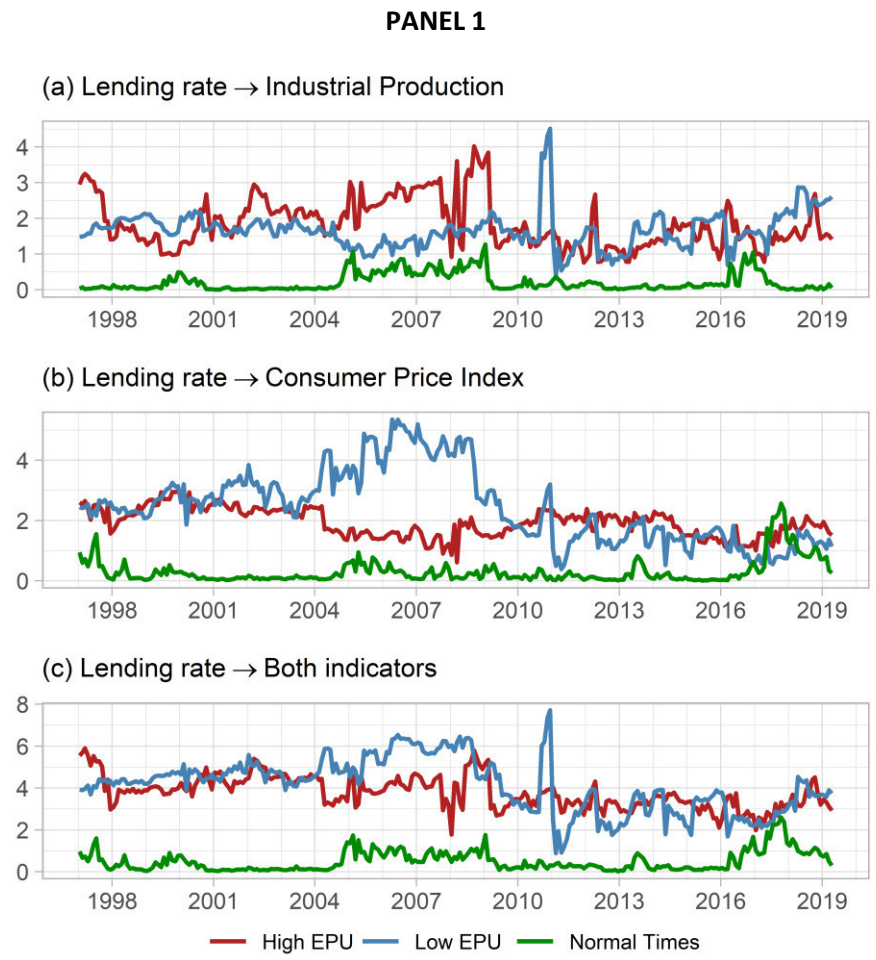
Note: See note to Figure 2.

Figure 4. The spillover results from the lending rate to macroeconomic indicators under different cases for India



Note: See note to Figure 2.

Figure 5. The spillover results from the lending rate to macroeconomic indicators under different cases for Japan



Note: See note to Figure 2.

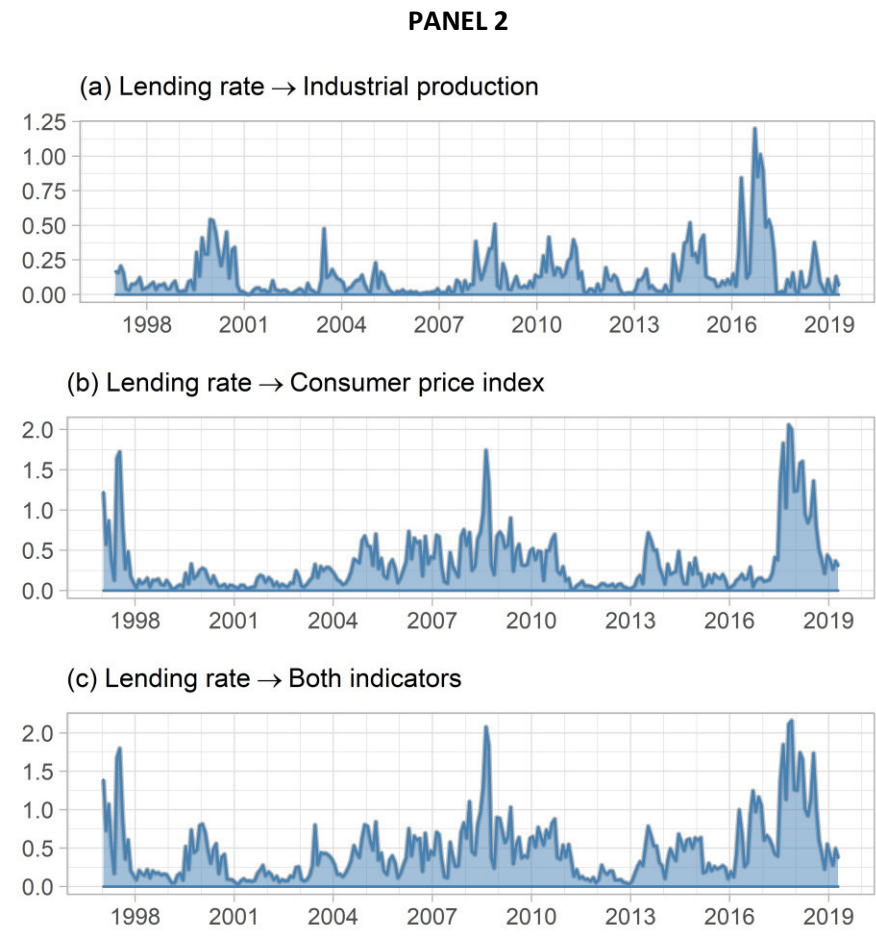
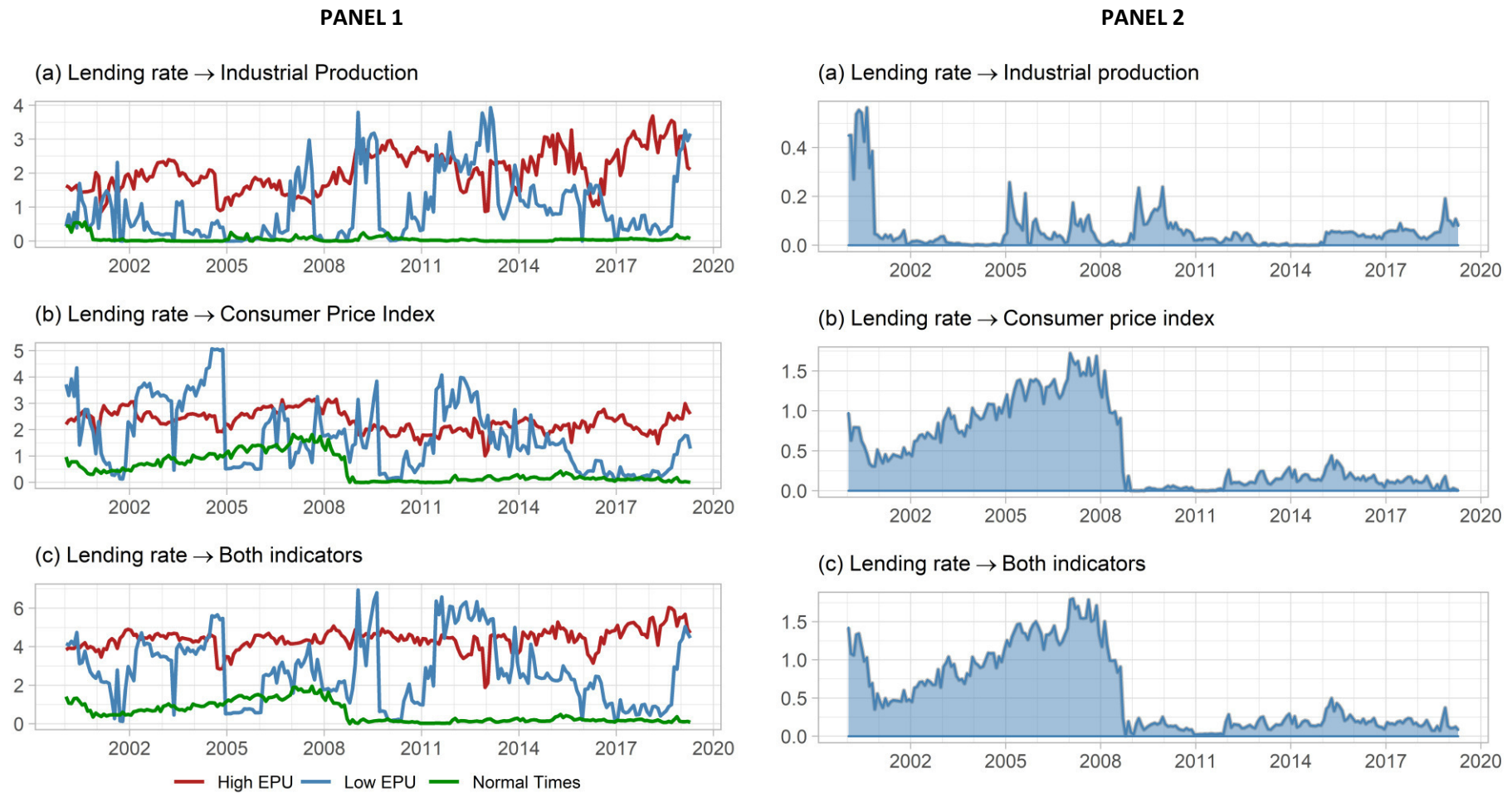


Figure 6. The spillover results from the lending rate to macroeconomic indicators under different cases for South Korea



Note: See note to Figure 2.