Monetary Policy Reaction Functions of the TICKs: A Quantile Regression Approach

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I. Introduction (1)

- On January 28, 2017, the Financial Times reported that the BRIC is being replaced by TICKs.
  - Two commodity-centric countries, Brazil and Russia, are replaced by two tech-heavy countries, Korea and Taiwan.
- Even though TICKs are firstly introduced for investment purposes with emphasis on their industry-level edges, it would be also useful to investigate the monetary policy of these countries.

I. Introduction (2)

- TICKs countries share some common characteristics.
  - First, all of four countries are located in Asia and have IT industries as their engines of economic growth.
  - Second, one of the major monetary objectives of these economies is price stability.
  - Third, these countries have achieved relatively high and stable economic growths in the past decade.

I. Introduction (3)

- However, there are some differences in these countries.
  - First, they are at different stages of development and have different economic scales as shown by differences in real GDP growth, per capita GDP and nominal GDP
    - For example, regarding the economic scales, nominal GDP growth rates between 1980 and 2016 are 3,581% (from $304 billion to $11,181 billion) for China, 1,096% (from $189 billion to $2,260 billion) for India, 2,071% (from $65 billion to $1,411 billion) for Korea, and 1,155% (from $42 billion to 530 billion) for Taiwan.
  - Second, those countries show different inflation rates. For example, average inflation rates between 2010 and 2016 are 2.8% for China, 8.3% for India, 1.9% for Korea, and 1.1% for Taiwan.

Table 1: Economic growth rates and inflation rates of TICKs countries

Category	Year	China	India	Korea	Taiwan
Real GDP growth rate (Average, %)	1980-1989	9.8	5.8	8.8	8.3
	1990-1999	9.9	5.7	7.1	6.6
	2000-2009	10.3	6.9	4.7	3.8
	2010-2016	8.1	7.2	3.5	3.6
Per capita GDP (Nominal US dollars)	1980	311	271	1,735	2,362
	1990	343	379	6,501	8,167
	2000	953	451	12,155	14,923
	2010	4,536	1,356	22,296	19,291
	2016	8,088	1,703	27,942	22,520
Nominal GDP (Billion US dollars)	1980	304	189	65	42
	1990	410	330	279	167
	2000	1,210	475	562	331
	2010	6,082	1,669	1,095	446
	2016	11,181	2,260	1,411	530
Inflation rate (Average, %)	1980-1989	8.0	8.8	8.4	4.6
	1990-1999	7.8	9.5	5.7	2.9
	2000-2009	1.9	5.6	3.1	1.0
	2010-2016	2.8	8.3	1.9	1.1

I. Introduction (4)

- There are also differences in the monetary policy objectives in these countries.
  - For example, Central Bank of the Republic of China (Taiwan) appears to emphasize the stability of exchange rate (external value of the currency) while Reserve Bank of India seems to emphasize the economic growth.
- Therefore, it would be interesting to see how central banks in TICKs countries react to different macroeconomic conditions using Taylor-type rule. The current inflation targets for central banks in TICKs countries are: China around 3.00%, India 4.00%±2%, Korea 2.00%±0.5% and Taiwan 2.00%.

1. Introduction (5)

- The most common form of monetary policy reaction functions typically assume that interest rates relate linearly to the gap between actual and desired values of inflation and output (see e.g. Taylor, 1993, Clarida et al., 2000, and Swamy et al., 2005).
- Nonlinear policy rules emerge from either asymmetric central bank preferences (e.g. Nobay and Peel, 2003, and Cukierman and Muscatelli, 2008) or a nonlinear (convex) aggregate supply or Phillips curve (e.g. Dolado et al., 2005), or still when central banks follow the opportunistic approach to disinflation (Aksoy et al., 2006).
  - Dolado et al. (2004) discuss a model, which comprises both asymmetric central bank preferences and a nonlinear Phillips curve.
  - Another strand of the monetary policy literature, dynamic stochastic general equilibrium models (see e.g. Smets and Wouters, 2003) make use of linear policy reaction function.

1. Introduction (6)

- Empirical studies on nonlinear monetary policy reaction functions abound in the literature for both developed and developing countries.
- However most of these studies have focussed on estimates only at the central mean of the policy rate with recent few exceptions that offer quantile regression method to generate estimates of the response to inflation at each of the points (quantiles) of the interest rate distribution.
  - For instance, Chevapatrukul et al. (2009) employed quantile regression to Taylor rules for Japan and the USA.
  - Miles and Schreyer (2012) apply quantile regression to Taylor estimations for four South East Asian economies, viz., Indonesia, Korea, Malaysia, and Thailand.

1. Introduction (7)

- The main crux of this study is to investigate how Taiwan, India, China and South Korea set interest rates in the context of Taylor-type rule models.
- A significant point of departure from previous studies on these economies is that the empirical estimates are conducted not only at the central mean of interest rate, but we also take into account the response of interest rate to inflation, output and exchange rate at various points on the conditional distribution of interest rates.

2. Methodology (1)

- Clarida et al. (1998; 2000) measure monetary policy by the short-term interest rate. This allows the central bank to choose the level of the interest rate from period to period and conduct policy.
  - They end up with the following modified forward-type of monetary rule

    $$i_t = (1-\rho)\left[\alpha + \beta\pi_{t+k|t} + \gamma y_t\right] + \rho i_{t-1} + \varepsilon_t \qquad (1)$$

    where ε_t is a policy shock, y_t is the output gap,$\pi_{t+k|t}$ is a k-period-ahead inflation forecast, and $0 \leq \rho \leq 1$ is the degree of interest rate smoothing
- However, in our case, all interest rate time series appear to be near to unit root processes and estimates of ρ are very close to unity.
  - It is well known that values of ρ in the vicinity of unity cause parameter estimates to diverge (Chevapatrakul et al.; 2009).

2. Methodology (2)

- To solve this problem, we follow Chevapatrakul et al. (2009) and we adopt Taylor's original rule specified by

$$i_t = \alpha + \beta\pi_{t+k|t} + \gamma y_t + \varepsilon_t. \qquad (2)$$

- For the purpose of this study, equation (2) can be modified and extended to capture the reaction of monetary policy to exchange rate movement:

$$i_t = \alpha + \beta\pi_{t+k|t} + \gamma y_t + \theta ER_t + \varepsilon_t, \qquad (3)$$

where ER_t is the exchange rate return against the US dollar.

2. Methodology (3)

- The standard approach of estimating a forward-looking Taylor rule is to estimate the model parameters at the mean by GMM due to endogeneity, with a limited number of lagged variables included in the instrument set.
  - However, parameter estimation at the mean of the interest rate distribution conditional on inflation and output gap is an incomplete description of monetary policy reactions.
- Several quantile estimation and inference methods that account for endogeneity are recently proposed in the literature.

2. Methodology (4)

- Chernozhukov and Hansen (2013) review the main three quantile modeling frameworks:
  - (1) the inverse quantile regressions (IVQR) methodology developed by Chernozhukov and Hansen (2005, 2006, 2008),
  - (2) the local quantile treatment effects with binary treatment and instrument approach of Abadie, Angrist, and Imbens (2002), and
  - (3) the instrumental variables quantile regression in triangular systems.
- The three approaches are not nested in general.
  - The second approach is not suitable for estimating the interest rate rule (equation (2)) since it requires both a binary endogenous variable and a binary instrument.
  - Chernozhukov and Hansen (2013) argue that the key difference of the other two approaches is the conditions that allow identification.
    - Specifically, the methodology of Chernozhukov and Hansen (2005, 2006, 2008) uses an unrestricted reduced form but imposes restrictions on the structural equation.
    - On the other hand, the instrumental variables quantile regression in triangular systems approach requires monotonicity of the reduce form disturbance.
    - However, Torgovitsky (2012) shows that under certain conditions the two approaches can be made compatible.

2. Methodology (5)

- However, Lee (2016) argues that conventional quantile regression (QR) econometric techniques are not valid when regressors are highly persistent.
  - Lee (2016) developed quantile econometric methods for robust inference in the presence of persistent and endogenous regressors.
  - Specifically, Lee (2009) develops a new QR methodology (called IVX-QR) which corrects size distortions arising from regressors' persistence by adopting the IVX filtering method proposed by Magdalinos and Phillips (2009).
- In this paper, we use the IVX-QR methodology of Lee (2016) in order to account of the endogeneity end persistence of monetary rule given in equation (3).

The IVX-QR approach (1)

- Consider a simple predictive model in mean:

$$\Upsilon_t = \delta_0 + \delta_1' \mathcal{X}_t + u_{0t}, \quad (4)$$

with $E(u_{0t}/I_t) = 0$, where $\mathcal{X}_t$ is a mx1 vector of regressors, δ_1 is a mx1 vector of parameters, and I_t is the natural filtration.

- Now consider a linear QR model.
  - Given the natural filtration and $I_t = \sigma\{u_j = (u_{0j}, u_{\mathcal{X}j}'), j \leq t\}$, the predictive QR regression model is

$$Q_{\Upsilon_t}(\tau/I_t) = \delta_{0,\tau} + \delta_{1,\tau}^{'} \mathcal{X}_t, \quad (5)$$

where $Q_{\Upsilon_t}(\tau/I_t)$ is the conditional quantile of Υ_t such that $P(\Upsilon_t \leq Q_{\Upsilon_t}(\tau/I_t)/I_t) = \tau \in (0,1)$.

- Model (5) analyzes other quantile predictability as well as the median of Υ_t.

The IVX-QR approach (2)

- We further assume that the regressors follow an autoregressive form:

$$\mathcal{X}_t = R_n \mathcal{X}_{t-1} + u_{xt}, \tag{6}$$

where $R_n = I_K + \frac{C}{n^\alpha}$, for some $\alpha > 0$.

- In this specification the pair (α, C) represents persistence of the regressors.
  - Lee (2016) shows that in the case of persistent (local to unity or unit root) regressors, the limit distribution of the slope coefficient (ordinary QR) estimator is nonstandard and nonpivotal. Specifically, the t-ratio becomes:

The IVX-QR approach (3)

- Lee (2016) shows that in the case of persistent regressors, the limit distribution of the slope coefficient (ordinary QR) estimator is nonstandard and nonpivotal.
  - Specifically, the t-ratio becomes:

$$t_{\widehat{\delta}_{1,\tau}} = \frac{\widehat{\delta}_{1,\tau} - \delta_{1,\tau}}{SE(\widehat{\delta}_{1,\tau})} \sim [1 - \lambda(\tau)]^{0.5}\ Z + \lambda(\tau)\,\eta(C) \qquad (7)$$

Where Z and $\eta(c)$ stand for standard normal distribution and nonstationary statistics, respectively, and $\lambda(\tau) = -Corr(1(u_{0t\tau} < 0)u_{xt})$. The first term of the asymptotic distribution in equation (7) corresponds to standard inference, while the second term, $\lambda(\tau)\,\eta(C)$, introduces nonstandard distortions.

Clearly, the magnitude of nonstandard distortions depends firstly, on the degree of persistence through the nonstationary distortion component $\eta(C)$ and secondly, on the endogeneity of regressors through the QR endogeneity component $\lambda(\tau)$.

The IVX-QR approach (4)

- Lee (2016) adopts the IVX filtering technique of Magdalinos and Phillips (2009) to correct the asymptotic distribution (equation (7)) for the nonstandard distortion.
  - The main idea of IVX filtering is to filter x_t to generate $\tilde{z}_t$ with mild persistence – intermediate between first differencing and the use of levels data.

Data(1)

- We use data for the 1994:M1 to 2016:M2 period for the four economies: Taiwan, India, China and South Korea (TICKs).
  - The choice is partly driven by period over which the respective Central Banks have been operating and is also partly driven by data availability at the time of writing this paper.
- Data on the policy rate, consumer price index used to compute the month-on-month inflation rate, industrial production used to create the measure of output-gap based on the Hodrick-Prescott filter, the US dollar-based exchange rates
- Data are all derived from the Global Insight database maintained by IHS.

Data(2)

- One discernible pattern is that the distributions have heavy masses in the upper tail, i.e., the distribution is positively skewed with excess kurtosis (to the extent that the normality is rejected at the highest level of significance based on the Jarque-Bera test).
  - Our results based on the quantile regressions tend to confirm such patterns for the reaction of the interest rate to inflation rates, in the sense, that stronger responses are observed at higher quantiles.

Figure A5. Histogram of Interest Rate for Taiwan:

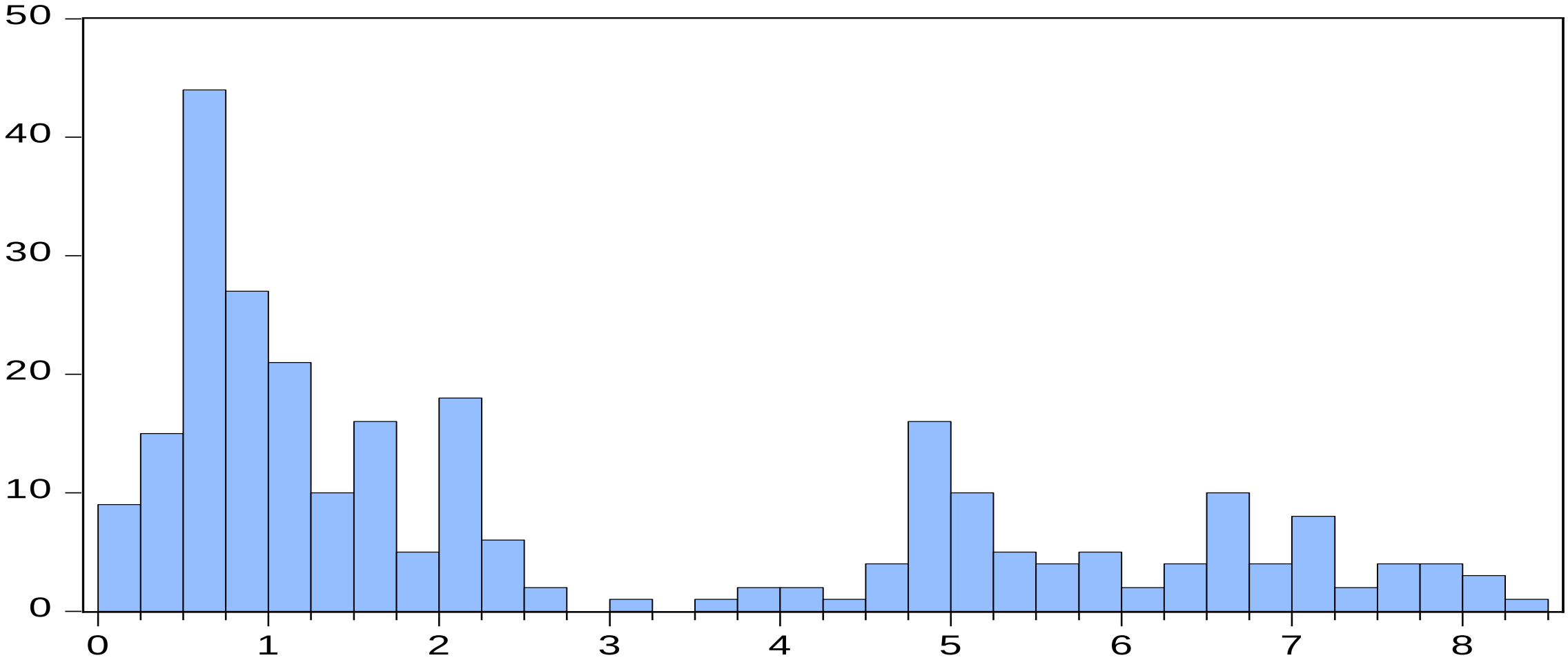


Figure A6. Histogram of Interest Rate for India:

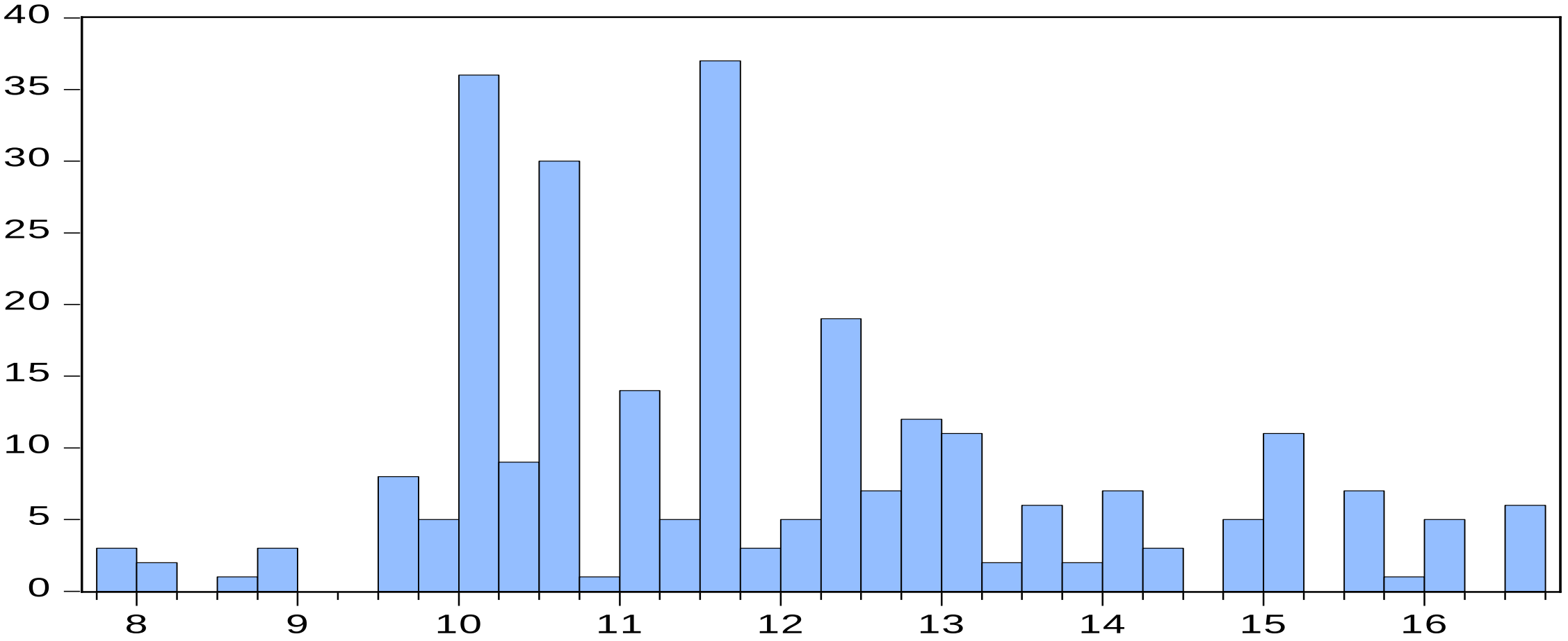


Figure A7. Histogram of Interest Rate for China:

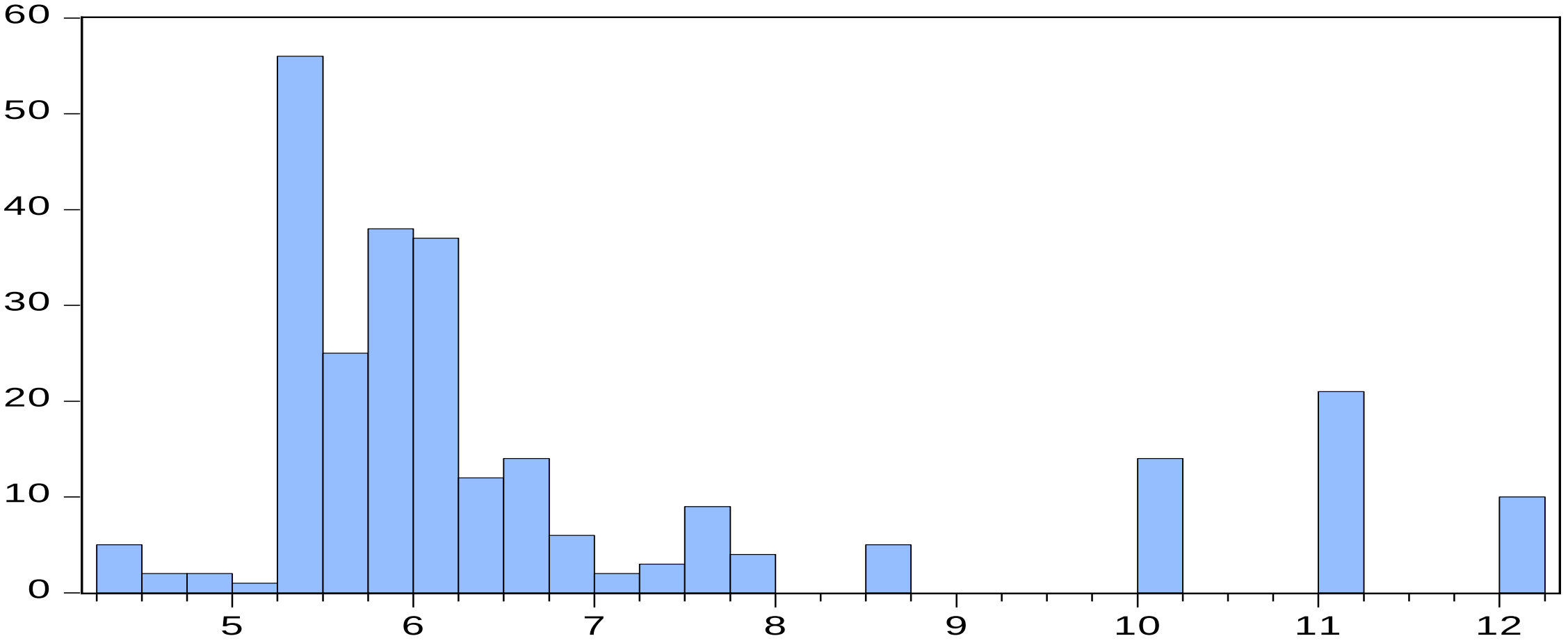
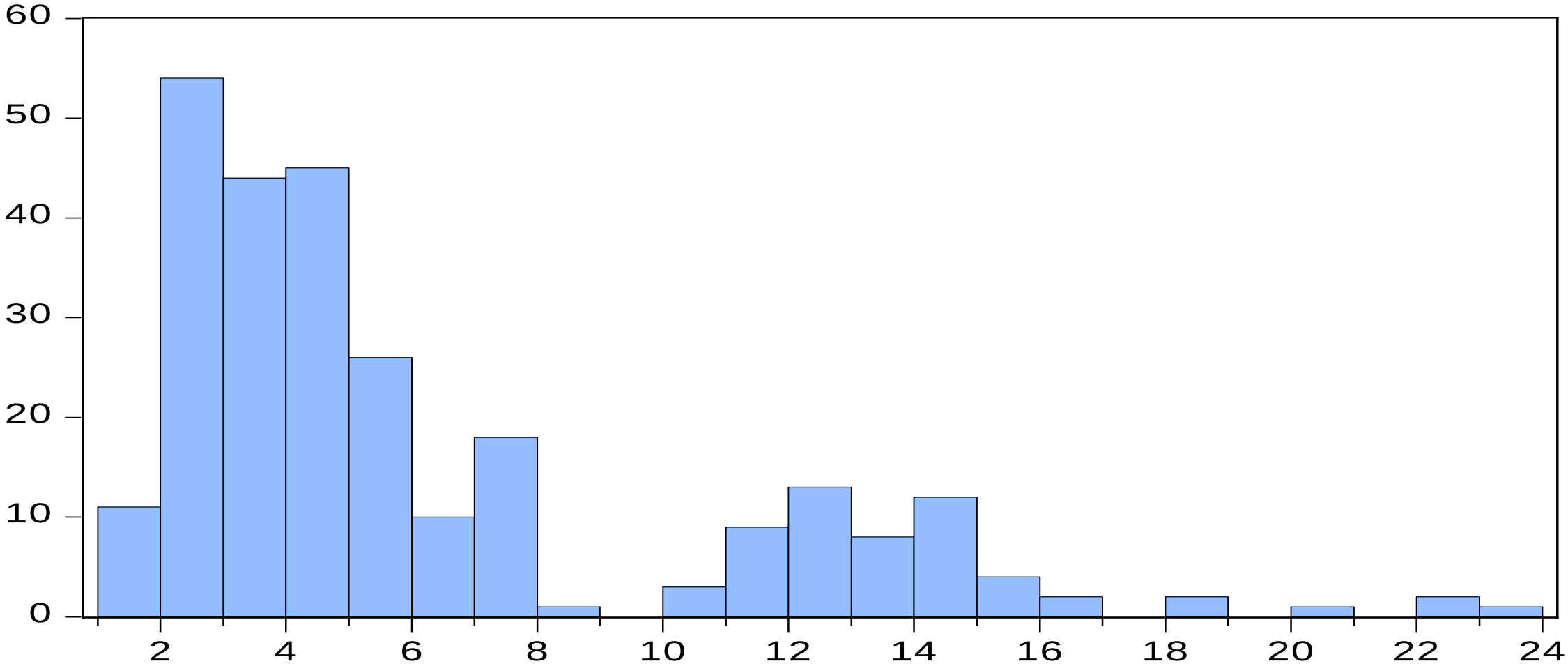


Figure A8. Histogram of Interest Rate for Korea:



Estimates at the Central Conditional Mean (1)

- Table 2 reports GMM estimates of the Taylor rule equation (3)
  - Inflation, output gap and exchange rate growth are instrumented using appropriately chosen lags of these variables.
  - The set of instruments are determined by choosing lags that are sufficiently long to avoid correlation with the error term
  - We use the *J*-test (Hansen; 1982) for the validity of overidentifying restrictions for each set of chosen instruments.
- The specification for equation (3) allows for a forward-looking rate of inflation 12 months ahead, k=12 for inflation, a contemporary output gap
  - (the dependence of these countries monetary policy on current rather than expected output gaps agrees with general consensus as for e.g., with Miles and Schreyer (2016) study of Asian economies or the Euro Area Wide Model in Dieppe et al., (2004)), and contemporaneous exchange rate growth.

Estimates at the Central Conditional Mean (2)

- Our results show that the set of instruments includes a constant, 4 lagged values of inflation, the output gap and exchange rate growth rate.
- In all cases and except for South Korea, the inflation (β) effect is statistically insignificant and China seems to respond to both the output gap (γ) and exchange rate (θ). The inflation effect β is much higher than one for South Korea, satisfying the "Taylor principle" that inflation increases trigger an increase in the real interest rate.
  - This result echoes Miles and Schreyer (2012) results for South Korea to some extent and Jawadi et al. (2014) results for the response of the Bank of China to the exchange rate.

Table 2: GMM estimation of the monetary rule at the conditional mean

	Taiwan	India	China	Korea
β	0.1513	0.6099	0.3499	6.1605**
γ	0.0434	0.1412	0.3166**	-0.0155
θ	-0.2361	-0.0850	0.6935***	-0.3895
J statistic	**3.0420*** **	**7.6238*** **	**15.3589** **	**10.0968*** **

Notes: Estimated monetary rule: $i_t = \alpha + \beta\pi_{t+12} + \gamma y_t + \theta ER_t + \varepsilon_t$. J-statistic refers to Hansen's (1982) test for overidentifying restrictions.

The Taylor Rule at Various Quantiles (1) - Inflation

- Table 3 reports the estimated coefficients at each quantile using Lee (2016) IVX-QR
- The coefficient on the inflation rate variable for China is significantly different from zero at the upper end of the range, more precisely from the 80^{th} to the 95^{th} quantile.
  - The response is greater than unity, supporting the Taylor principle.
  - This suggests that that the Bank of China responded more aggressively to inflation and hence shows evidence of a deflation bias to monetary policy.
- South Korea on the other hand seems to respond to inflation rate at all quantiles except at the very end of the 95^{th} quantile and is above unity at every point from the 20^{th} quantile, hence supporting the Taylor principle.
- The response of the Reserve Bank of India to inflation rate, though positive, does not seem to adhere to the Taylor principle.
- As for Taiwan, its managed floating currency regime for the New Taiwanese Dollar, together with tepid economic growth in the last few years reinforces the argument that the Central Bank is preoccupied mainly in keeping the currency rate once it gets out of range.

The Taylor Rule at Various Quantiles (2) - Output Gap

- The response to output gaps for China and India is variable over the quantiles and of a smaller magnitude from the figure that Taylor proposed.
- For South Korea, there is rather strong response to the output gap when inflation and interest rate are high with the output response being insignificant at low inflation and interest rates.
  - One could possibly argue that the Bank of Korea places high importance on inflationary pressures of output during periods of rising inflation.
- Taiwan does not respond to the output gap at any quantile.

The Taylor Rule at Various Quantiles (3) - Exchange Rate

- China does raise the interest rate at the 60^{th} and 70^{th} quantiles in response to yuan depreciation where inflation is likely to be higher.
- The Bank of Korea does take account of the exchange rate at almost all interest rate quantiles
- India and Taiwan do not respond to their currencies value at all.
- In the sense that a failure to find significance of the exchange rate on the interest rate movements may simply mean that another instrument is employed to deal with the currency value.
  - A strong possibility would be foreign currency reserves especially for China and Taiwan, with Aizenman et al. (2011) discussing the role that currency reserves play in Asian emerging economies seeking to limit exchange rate movements.

Table 3: Monetary rule using IVX-QR estimation

Country	Parameters	Quantiles										
		Q=5	Q= 10	Q=20	Q=30	Q=40	Q=50	Q=60	Q=70	Q=80	Q=90	Q=95
Taiwan	β	0.0460	0.0768	0.0926	-0.0221	-0.0394	-0.0832	-0.0196	0.0025	0.1260	-0.0595	0.1822
	γ	0.0082	0.0082	0.0086	0.0139	0.0239	0.0346	-0.0164	0.0155	-0.0581	0.0214	0.0133
	θ	-0.0421	-0.0700	-0.0802	-0.1233	-0.1664	-0.1958	0.0004	-0.0706	-0.1712	-0.1332	0.0160
India	β	0.0652	0.1885	0.1668	0.1389	0.5281***	0.6423***	0.7291***	0.6975***	0.6189**	0.7609**	0.2140
	γ	-0.0805**	-0.0565	0.0001	0.0134	0.0501*	0.0517**	0.0359**	0.0376*	0.0368	0.0450	0.1559**
	θ	0.0305	0.0175	0.0134	0.0146	0.0113	0.0038	-0.0100	-0.0092	-0.487	-0.0049	-0.0034
China	β	-0.0000	0.0000	-0.3418***	-0.3255***	-0.3740***	-0.1077	-0.3044	-0.2097	1.6050*	1.7964***	1.1094**
	γ	0.0000	-0.0000	0.0636*	0.0549	0.0773*	0.0437	0.1097*	0.1477*	-0.1508	-0.2233***	-0.0022
	θ	0.0000	0.0000	0.0565	0.0916*	0.0650	0.0215	0.1363*	0.3731***	-0.4349***	-0.2152*	-0.0176
Korea	β	0.5507*	0.7704**	1.0915***	2.7796***	1.9947***	1.8898***	2.8011***	3.0393***	4.3835**	3.1741**	1.7956
	γ	0.0082	0.0010	-0.0007	-0.0222	-0.0165	-0.0316	-0.1126	-0.1707	0.7594	0.6120***	0.3943***
	θ	0.0036	-0.0071	0.0054	0.2483***	0.1726***	0.1690***	0.4863***	0.5720**	1.5644**	0.7305**	0.1727*

Notes: Estimated monetary rule: $i_t = \alpha + \beta\pi_{t+12} + \gamma y_t + \theta ER_t + \varepsilon_t$. *, **, *** denote statistical significance at 10%, 5% and 1%, respectively.

Robustness Analysis (1)

- We assess the sensitivity of our findings firstly, using different model specification secondly, using different inflation horizon, and thirdly repeating the analysis using quarterly data.
- An important part of the paper is that the central banks in our study take the exchange rate into account when setting interest rates as generally found for the case of China and South Korea.
- To assess the usefulness of the exchange rate variable, we estimate the model without including the exchange rate in Table 4.
  - We find that the qualitative robustness of the quantile estimates does not change that much with respect to the response of the monetary authorities vis-a-vis the inflation rates for China, India and South Korea while still maintaining insignificant responses for Taiwan.

Table 4: IVX-QR estimation W/O Exchange Rate

Country	Parameters	Quantiles										
		Q=5	Q= 10	Q=20	Q=30	Q=40	Q=50	Q=60	Q=70	Q=80	Q=90	Q=95
Taiwan	β	0.0342	-0.0088	0.0452	-0.0249	-0.0622	-0.0071	-0.0161	0.0210	0.2258	0.2530	0.1909
	γ	0.0105	0.0045	0.0067	0.0120	0.0209	0.0307	-0.0182	0.0203	-0.0457	0.0220	0.0278
India	β	0.1634	0.1520	0.1898	0.1535	0.5310***	0.6455***	0.7376***	0.6995***	0.5242***	0.7791**	0.1494
	γ	-0.1173***	-0.0590	-0.0122	-0.0048	0.1085*	0.1422**	0.1400**	0.1262*	0.0577	0.1883*	0.1848**
China	β	0.0001	-0.0001	-0.3749***	-0.3715***	-0.4300***	-0.1248	-0.4051**	-0.3257	1.6758*	1.2146***	1.0113**
	γ	0.0001	0.0001	0.0346	0.0430	0.0598*	0.0370	0.0917**	0.2143***	0.2270	0.2033**	0.1411
Korea	β	0.4637	0.8031**	1.1929***	2.4650***	2.4596***	2.0641***	2.7778***	3.4868***	5.3421*	1.2428	-0.8338
	γ	0.0277	0.0026	0.0066	0.0233	0.0363	0.0485	0.0801	0.0457	-0.1731	-0.3311***	-0.4328***

Notes: Estimated monetary rule: $i_t = \alpha + \beta\pi_{t+12} + \gamma y_t + \varepsilon_t$. *, **, *** denote statistical significance at 10%, 5% and 1%, respectively.

Robustness Analysis (2)

- The results with the shorter horizon for inflation at one-month ahead in Table 5 show the robustness of the quantile estimates for inflation and somewhat different estimates for output and exchange rate.
  - Hence, we can conclude that inflation has a noticeable larger effect on higher quantiles of interest rates (where inflation is presumably higher than desired) than at lower quantiles of interest rates (where inflation is likely relatively low).
  - This is especially true for China and South Korea, as found in Section 4, the Taylor principle is usually adhered to.

Table 5 IVX-QR estimation with Shorter Horizon (T+1)

Country	Parameters	Quantiles										
		Q=5	Q= 10	Q=20	Q=30	Q=40	Q=50	Q=60	Q=70	Q=80	Q=90	Q=95
Taiwan	β	0.0151	-0.0162	0.0564	0.0187	0.2075	0.0584	0.0591	0.2609	0.2868	0.2984	0.2788
	γ	0.0088	0.0121	0.0052	0.0109	0.0080	0.0262	0.0289	0.0593	-0.0172	0.0093	0.0040
	θ	-0.0393	-0.0451	-0.0511	0.0706	-0.1247*	-0.2480**	-0.0551	-0.0343	-0.1504	-0.0779	-0.0273
India	β	0.0774	0.2326**	0.2554*	0.3665**	0.5345***	0.5215***	0.6433***	0.6764***	1.0851***	1.4165	1.1477
	γ	-0.1432***	-0.0519	-0.0578	-0.0098	0.0161	0.0413	0.0416*	0.0426*	-0.0105	-0.0729	-0.0285**
	θ	0.0648	0.0210	0.0281	0.0214	-0.0069	-0.0217	-0.0020	0.0022	-0.0112	-0.0035	-0.0100
China	β	-0.0000	-0.0000	-0.0800	-0.1540	-0.1346	-0.1078	-0.2349	0.3537	1.7299***	1.9164***	1.8547***
	γ	0.0000	0.0000	0.479	0.0793**	0.0621	0.0325	0.0678	0.0549	-0.0506	-0.1675	-0.2047**
	θ	0.0000	0.0000	0.0582	0.0793	0.1124*	0.0206	0.0415	0.1862***	-0.3327**	-0.4922***	-0.4205***
Korea	β	1.8871***	1.5051***	1.6866***	2.1073***	2.4962***	2.2082***	2.9915***	2.9158***	7.4939***	5.7674***	3.7814***
	γ)	-0.0168	-0.0032	-0.0146	-0.0352	-0.0179	0.0100	-0.0159	-0.0451	0.5170	1.2285***	1.4204***
	θ	0.0888***	-0.0052	-0.0058	0.0859*	0.2607***	0.1752***	0.2974**	0.1628	-1.1607	0.0419	0.0500

Notes: Estimated monetary rule: $i_t = \alpha + \beta\pi_{t+1} + \gamma y_t + \theta ER_t + \varepsilon_t$. *, **, *** denote statistical significance at 10%, 5% and 1%, respectively.

Robustness Analysis (3)

- Table 6 reports the results calculated using quarterly data.
- The coefficient on the inflation rate variable for China is significantly different from zero and greater than unity at the upper end of the range, more precisely from the 90^{th} quantile.
- In the case of South Korea, on the other hand, interest rate seems to positively respond to inflation rate at a sequence of quantiles, from the 10^{th} to the 90^{th}.
  - Specifically, the response appears to be greater the unity, except the response at the 10th quantile.
- The response of the Reserve Bank of India to inflation rate, though positive, does not seem to adhere to the Taylor principle.
- As for Taiwan, we do not observe any statistically significant reaction of interest rate to inflation.

Robustness Analysis (4)

- The response to output gaps for China and India is variable over the quantiles and of a smaller magnitude from the figure that Taylor proposed.
- For Taiwan and South Korea, there is no statistically significant (at least at 5% level) response of interest rate to output gap at any quantile.
- In the case of India, we observe significant reaction of interest rate to output gap only at the tails of the interest rate distribution.
  - Specifically, interest rate response negatively at the 5^{th} and 10^{th} quantiles, and positively at the 90^{th} and 95^{th} quantiles.
- Lastly, for China, our results suggest statistically significant response to output gap most quantiles, from the 10^{th} to the 90^{th}.
- For South Korea, there is rather strong response to the output gap when inflation and interest rate are high with the output response being insignificant at low inflation and interest rates.
  - One could possibly argue that the Bank of Korea places high importance on inflationary pressures of output during periods of rising inflation.
- Taiwan does not respond to the output gap at any quantile.

Table 6 IVX-QR Estimation with Quarterly Data

Country	Parameters	Quantiles										
		Q=5	Q= 10	Q=20	Q=30	Q=40	Q=50	Q=60	Q=70	Q=80	Q=90	Q=95
Taiwan	β	0.0525	0.1243	0.0034	0.0416	-0.0142	-0.0891	0.2805	1.0443	-0.1893	0.3901	-0.0428
	γ	0.0336	0.0488	0.0762	0.1142*	0.1544*	0.1585	0.1537	-0.0172	0.1048	-0.1614*	0.1765
	θ	-0.0382	-0.0421	-0.0130	-0.0964	-0.1146	-0.0758	-0.2061	0.0117	-0.2502	-0.0917*	-0.2374*
India	β	0.1375	0.2875**	0.5298***	0.6242***	0.6558***	0.6533***	0.7977***	0.9666***	0.9189***	0.5443***	0.1509
	γ	-0.1549**	-0.1672**	-0.0341	0.0086	0.0288	0.0302	0.0242	0.0080	0.0225	0.3296***	0.6133***
	θ	-0.0146	0.0025	0.0009	-0.0068	-0.0041	-0.0074	-0.0172	-0.0024	-0.0049	-0.0403	0.0006
China	β	-0.0000	-0.1694*	-0.2717***	-0.3138***	-0.0826	-0.1201	-0.3436***	-0.2852**	-0.2787	1.6692***	1.0538***
	γ	0.0000	0.1956	0.6179***	0.4413***	0.3618***	0.3757***	0.5108***	0.6578***	1.3355**	-1.1950***	-0.0824***
	θ	0.0000	-0.0087	0.0219	0.0021	-0.0020	0.0047	0.0498	0.0711	0.2050	-0.1387*	-0.0137**
Korea	β	0.1390	0.7956***	1.1495***	-0.1796	0.0131	1.0131***	1.4735***	0.7715	2.7320	2.3369**	-1.2028*
	γ	0.1142*	0.0219	-0.0496***	0.1743	0.1724	-0.0020	-0.1338*	0.0912	0.1470	0.5196	-1.7739*
	θ	-0.0223	-0.0011	0.0059	-0.0191	-0.0211	-0.0001	-0.0064	-0.0088	0.2960	0.0853***	-0.2250*

Notes: Estimated monetary rule: $i_t = \alpha + \beta\pi_{t+4} + \gamma y_t + \theta ER_t + \varepsilon_t$. *, **, *** denote *statistical significance at 10%, 5% and 1%, respectively.*

Conclusion

- This paper provides findings that support non-linearities in central bank responses to policy determinants in the emerging economies of China, India and South Korea.
  - Interestingly, for China and India, there is no response of interest rate at the mean.
  - While all these three central banks respond significantly to inflation at a number of quantiles (the exception is Taiwan which does not respond to inflation at all quantiles), yet the magnitude of the response varies, widely, not just across the countries but also across the quantiles within each country.
  - These results clearly show that relying on linear models to investigate monetary policy reaction functions might be misleading for these emerging economies .
- Estimating the response of interest rates to its determinants not only at various quantiles on the conditional distribution of interest rates but also at the various quantiles of its determinants is what we intend to address in future research.