Interest Rate Pass-Through from the Weighted Average Call Rate to the Primary Commercial Paper Market in India using daily data: An empirical analysis

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Abstract

The paper aims to model the interest rate pass-through from the weighted average call rate (WACR) to the discount rate in the primary Commercial Paper market (CPDR) in India using daily data from March 12, 2010 to February 23, 2017. Both the daily CPDR and WACR series turned stationary at first differences and were cointegrated. Accordingly, an error correction model is estimated with both the long-run and the short-run equations adjusted for ARCH effects/volatility clustering. The long-run elasticity of CPDR with respect to the WACR was 0.584, that is, about 58 per cent of the change in the WACR gets passed on the CPDR. In the short run, while amount asymmetry, timing/pattern asymmetry and adjustment asymmetry were absent, there was evidence of shock asymmetry. The evidence of shock asymmetry may be due to the existence of 'search cost'. This explanation would, however, require further investigation.

Keywords: Commercial Paper, Money Market, Interest Rate Pass-Through, Monetary Policy Transmission, Weighted Average Call Rate, Error Correction Model (ECM), EGARCH models.
JEL Classification: E43, E44, E52.

I. Introduction

Monetary (policy) Transmission Mechanism refers to the 'channels' through which the monetary policy actions by the Central Bank impact the economic activity in the economy, in general and prices in particular (Eddie *et al*, 1999, Kuttner and Mosser, 2002, Ireland, 2006). Currently, seven major channels of monetary transmission have been identified in the literature: (i) Interest Rate Channel, (ii) Credit Channel/Bank Lending Channel, (iii) Exchange Rate Channel, (iv) Asset Prices Channel, (v) Expectations Chanel, (vi) Confidence Channel, and (vii) Risk-taking Channel (ECB, 2017).

The interest rate channel is one of the key channels of monetary policy transmission. Several studies have empirically assessed the effectiveness of various channels of monetary policy transmission in advanced and emerging economies. There are many studies on India also contributing to the current debate on the nature and extent of

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transmission of monetary policy to other interest rates in the economy (briefly reviewed in the next section). To the best of our knowledge, two studies have examined the transmission of monetary policy actions to the interest rates in the primary Commercial Paper (CP) market that is relevant from the perspective of this study. Ghosh and Pradhan (2008), using monthly data from April 2002 to September 2007, estimate that a 1 per cent increase in the Call Rate leads to an increase by 0.077 percentage points in the weighted average discount rate (WADR) in the CP market, keeping the 364-day T-bills cut-off yield, incremental bank credit, log of CP issue amount constant and including a February month seasonal dummy.

The second paper by Jayadev and Kumar (2012), studied the extent and nature of influence of announcement of the Bank Rate[2] changes on CP rates in India using daily data from the MoneyLine Telerate database for the period January 1999 to June 2003. Finding the CP discount rate and Bank Rate cointegrated, they estimate an error correction model (ECM) and report the speed of adjustment of the CP rate to be 'low' at -0.00049 indicating that deviation in the long-run equilibrium between the CP rate and Bank Rate is corrected by about 0.05 per cent on the next day. They also perform an event analysis by looking at the changes in the CP rates in a 14-days window 'before and after' a change in the bank rate announced in the monetary policy. They find that the changes in the Bank Rate explained nearly 67 per cent of the changes in the CP rate; and a 100 basis points (bps) increase in the Bank Rate is likely to increase the CP rates by 195 bps.

The main contribution of this paper to the literature is that we look at the interest-rate pass-through from the extant operating target of monetary policy (i.e., the WACR) to the discount rate in the primary CP market in India on a daily frequency.[3] This paper provides new evidence on the interest rate pass-through to the primary CP market using daily data from March 12, 2010 to February 23, 2017.

[2] Bank Rate is the rate at which RBI rediscounts bills of exchange presented by the commercial banks, which the RBI used as a major monetary policy instrument from 1935 to until about 2001.

[3] The weighted average overnight call money rate was explicitly recognized as the operating target of monetary policy on May 3, 2011.

The specific objectives of the paper are: (1) to measure the extent and speed of pass-through from the WACR to the discount rate in the primary CP market (CPDR) and (2) to test for the presence of various asymmetries (namely amount, timing/pattern, adjustment and volatility asymmetries) in the response of the CPDR to changes in the WACR. With CPDR and WACR stationary at first difference and co-integrated, the long-run equilibrium relationship and short-run adjustments between the two are modeled using an error correction model (ECM). Further, the paper tests for symmetry/asymmetry in the changes in CPDR under the ECM framework after adjusting for the presence of volatility clustering using an EGARCH(1,1) model. We find that the long-run elasticity of CPDR with respect to the WACR during the sample period was 0.584, which implies only about 58 per cent of the change in the WACR gets passed on the CPDR. In the short run, there was no amount asymmetry or timing/pattern asymmetry or adjustment asymmetry. However, the presence of shock asymmetry was observed indicating that the volatility process was asymmetric: a positive shock to the CPDR has a greater effect on the variance of the CPDR than the negative shock.

The remainder of the paper is structured as follows. The next section reviews some of the related literature. Section III presents some stylised facts on the primary CP market in India and Section IV describes the data. The empirical methodology and the results are given in Section V. Section VI concludes.

II Related Literature

Monetary policy transmission is an extensively researched subject for advanced as well as developing countries (See Mohanty (2012) for a comprehensive review). There are many empirical studies on the monetary policy transmission mechanism in India. Please see Annex 2 for a summary of the literature survey.

Among the recent studies, Das (2015) studied the transmission of monetary policy to the weighted average call money rate (WACMR), and further to two main bank interest rates, three-month certificates of deposits (CDs) and the prime lending rate (PLR) (the average of five major banks) using bi-weekly data for the period end-March 2002 to end-October 2014. Using stepwise estimation of vector error correction models, Das (2015) finds significant, *albeit* slow, pass-through of policy rate changes to bank interest rates in India. Further, they find evidence of asymmetric adjustment to monetary policy: the lending rate adjusts more quickly to monetary tightening than to loosening. In addition, the speed of adjustment of deposit and lending rates to changes in the policy rate has increased in recent years.

The CP market is an important segment of the money market and therefore an assessment of the transmission of the monetary policy rates to the discount rates in the CP market would be useful. The Commercial Paper is an unsecured promissory note issued at a discount by corporates with certain minimum ratings to raise short term funds, primarily as working capital, with tenor ranging from seven days to up to a year.

As indicated in the Introduction, a few studies earlier have looked at the interest rate pass-through to the Commercial Paper market, namely, Jayadev and Kumar (2012) find the speed of adjustment of the CP rate to be low using an Error Correction Model (ECM). Ghosh and Pradhan (2008) find the 'seasonally adjusted' weighted average discount rate (WADR) in the CP market to be determined by the call rate, cut-off yield of 364-day T-bills, incremental bank credit and the CP issue amount. Ray and Prabhu (2013) analyzing the nature of integration among different segments of Indian financial markets and the influence of monetary policy on different segments of financial markets in a SVAR framework find that the shocks in the monetary policy (using the effective policy rate) have expected immediate and persistent effects on the 3 month Certificate of Deposits (CD) rate and Commercial Paper (CP) rate.

Ongoing debate between daily data versus lower frequency data

There is an ongoing debate on the appropriate frequency of data to be used in financial markets analysis. While some prefer to analyse daily data over lower frequency data arguing that (i) analyzing lower frequency data might lead to an improper understanding of the pricing process when input prices are volatile (Bettendorf et al, 2009, page 385) and (ii) 'whose dynamics are by nature not affected by macroeconomic fundamentals, should have an advantage in identifying the spillovers in financial markets, where the news are priced rapidly, compared to lower frequency variables' (Belke et al, 2017, page 5). Geweke, (1978) indicates that from an econometric standpoint, inadequate temporal disaggregation could result in the omission of important short time lags, which may introduce significant bias to estimates. Using weekly and monthly data could have temporal aggregation bias (Bachmeier and Griffin, 2003; Balaguer and Ripolles, 2012). Others argue that daily data are contaminated by noise and anomalies such as days-of-the-week effect or non-synchronous trading bias (Ferrando et al, 2017).

III Primary Commercial Paper Market in India: some stylised facts

Commercial Paper is an unsecured money market instrument issued in the form of a promissory note. It was introduced in India in 1990 with a view to enabling highly rated corporate borrowers to diversify their sources of short-term borrowings and to provide an additional instrument to investors. Subsequently, PDs and All-India Financial Institutions (AIFIs) were also permitted to issue CPs to enable them to meet their short-term funding requirements for their operations. However, an issuer would be eligible to issue CP provided – (a) the tangible net worth of the company, as per the latest audited balance sheet, is not less than Rs. 40 million, (b) company has been sanctioned working capital limit by bank/s or all-India financial institution/s; and (c) the borrowal account of the company is classified as a standard asset by the financing bank(s) or institution(s). A scheduled bank can act as an issuing and paying agent (IPA) for the issuance of CP.

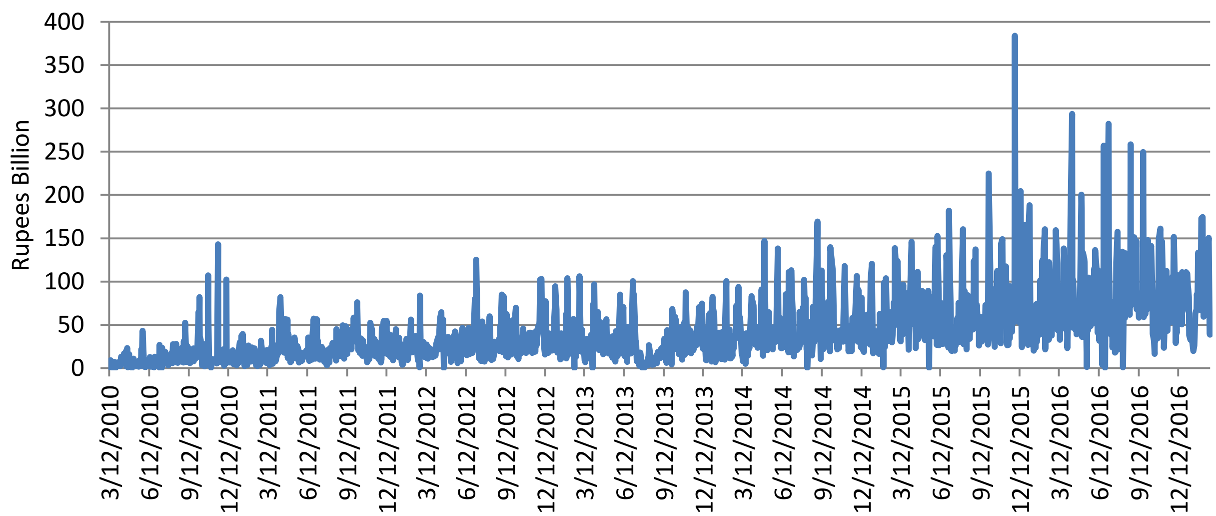
Furthermore, all eligible participants should obtain the credit rating for issuance of Commercial Paper from a credit rating agency (CRA) as may be specified by the Reserve Bank of India (RBI) from time to time, for the purpose. The minimum credit rating shall be P-2 of CRISIL or such equivalent rating by other agencies. The issuers need to ensure at the time of issuance of CP that the rating so obtained is current and has not fallen due for review and the maturity date of the CP should not go beyond the date up to which the credit rating of the issuer is valid.

CPs can be issued for maturities between a minimum of 7 days and a maximum of up to one year from the date of issue. CPs can be issued in denominations of Rs. 0.5 million or multiples thereof. CP will be issued at a discount to face value as may be determined by the issuer and the issue of CP cannot be underwritten or co-accepted. The aggregate amount of CP from an issuer shall be within the limit as approved by its Board of Directors or the quantum indicated by the Credit Rating Agency for the specified rating, whichever is lower. As regards FIs, they can issue CP within the overall umbrella limit fixed by the RBI, *i.e.,* issue of CP together with other instruments *viz.,* term money borrowings, term deposits, certificates of deposit and inter-corporate deposits should not exceed 100 per cent of its net owned funds, as per the latest audited balance sheet.

Individuals, banks, other corporate bodies (registered or incorporated in India) and unincorporated bodies, Non-Resident Indians and Foreign Institutional Investors (FIIs) are eligible to invest in CPs. Finally, every CP issue should be reported to the RBI through the Issuing and Paying Agent within three days from the date of completion of the issue. Currently, the reporting is to be made on the online returns filing system (ORFS) of the RBI. In this backdrop, this section presents some stylised facts about the primary CP market in India based on the daily data from the ORFS.

The average daily volume in the CP market has been increasing over the study period (Chart 1 and Table 1).

Chart 1: Daily Average Issue of Commercial Paper

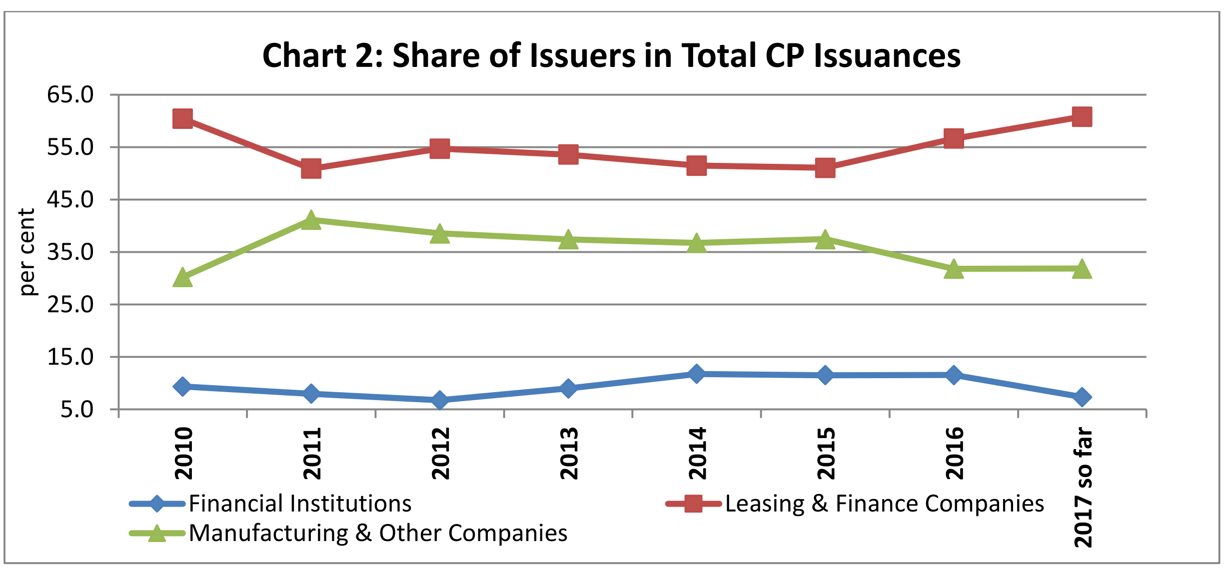


The increase in the daily average issue is particularly visible since 2014-15, perhaps on account of the declining interest rate regime (Table 1).

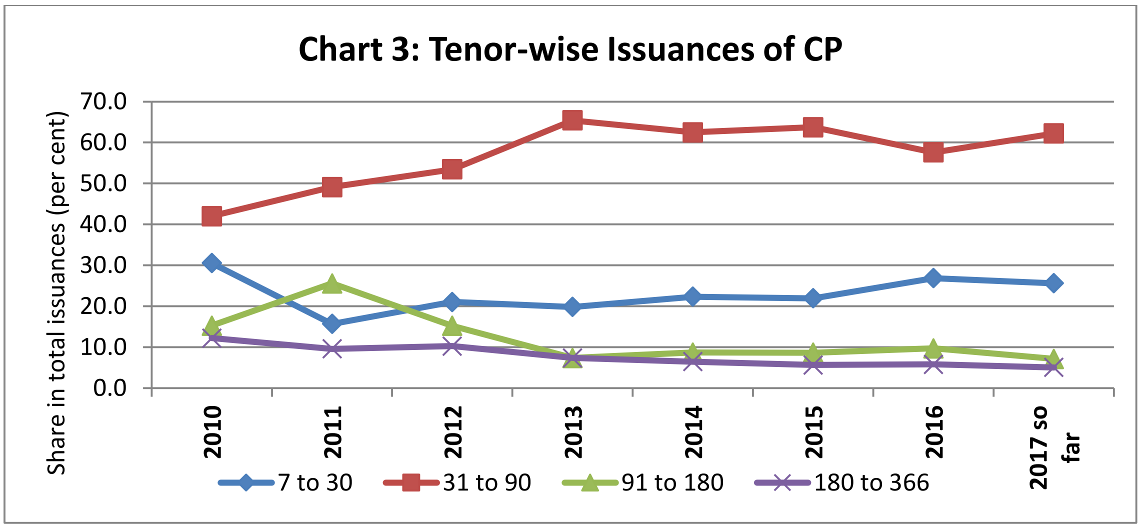
Table 1: Commercial Paper Primary Market				
Financial Year (April-March)	**Average Daily Volume (Rs. Billion)**	**Weighted Average Discount Rate**	**Min. Discount Rate (%)**	**Max Discount Rate (%)**
2010-2011	13.20	8.82	3.65	20.00
2011-2012	23.42	9.88	4.00	15.25
2012-2013	31.34	9.17	7.37	15.25
2013-2014	30.41	9.11	7.36	14.31
2014-2015	48.21	8.81	7.36	14.92
2015-2016	68.10	8.06	6.52	13.14
2016-2017 so far	81.77	7.39	5.68	14.21

Source: Reserve Bank of India.

Manufacturing companies accounted for only 30 per cent of the total issues, while leasing & finance companies and financial institutions garnered nearly 70 per cent of the amount raised through CPs (Chart 2). Interestingly, since 2015, there has been moderate increase of CP issuances by the leasing & finance companies with commensurate decrease in issuances by manufacturing & other companies. Also, participation of financial institutions in terms of CP issuance has gone up since 2013 (ignoring 2017 as the data point is very less).



The most popular tenor of the CP issued was of 31-90 days followed by 7-30 days (Chart 3). The share of CP issuances in the 31-90 days category has more or less remained around 60 per cent since 2013. In recent years, like 2015 and 2016, there has been a marginal upward trend in the share of CP issuances for the 7-30 days category. The average percentage share of more than 90 days category remained less than 10 per cent. This proves the preference of the issuers to issue CPs for short term (less than 90 days) as compared to longer term categories (more than 90 days).



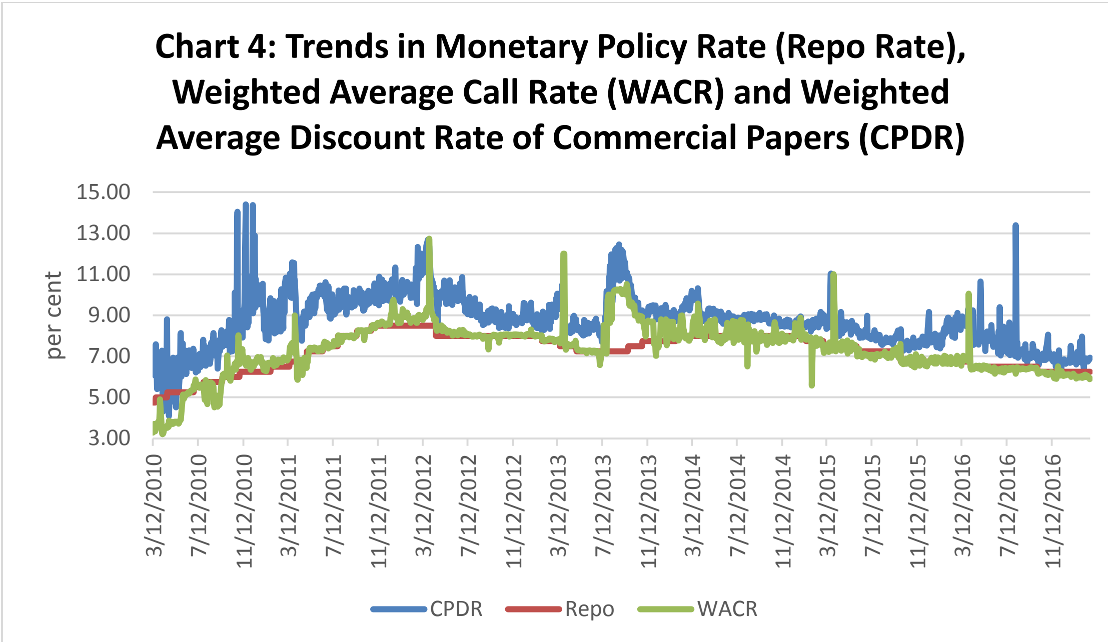
IV Data

The variables used for the empirical analysis are the weighted average discount rate in the CP market (CPDR) and overnight interbank call money market rate (WACR); the two variables are in daily frequency. The daily data on primary issue of CP and the discount rate for the period from March 12, 2010 to February 23, 2017 (totaling 1,689 observations) were obtained from the ORFS reporting platform. The starting date of the sample, i.e., March 12, 2010, was due to the availability of the data in the ORFS.

V Model Specification and Results

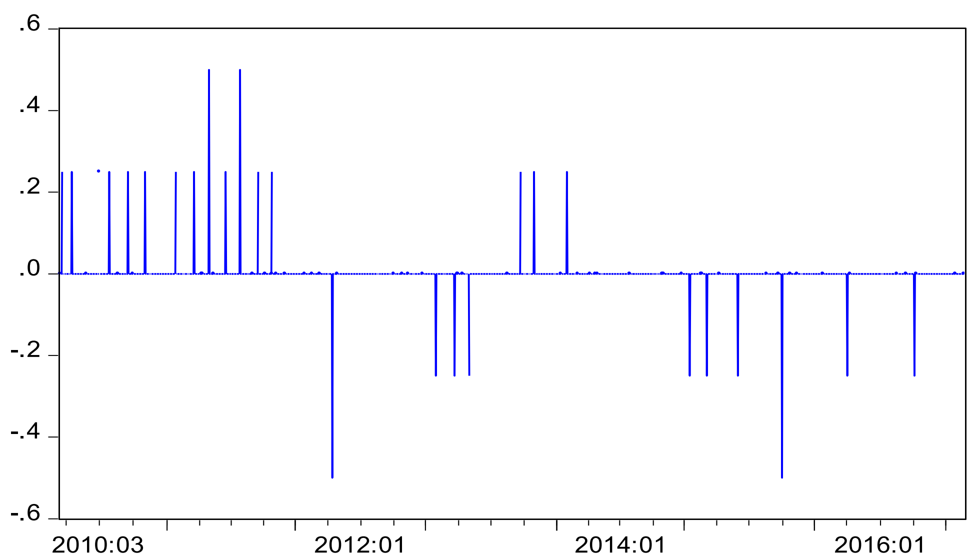
Interest rate trends

As observed in Chart 4, the CPDR has been generally tracking the monetary policy rate (Repo rate) and the operating target of monetary policy (WACR).



The study period has been characterized by alternate regimes of interest rate rise and fall as observed from the changes in the monetary policy rate (the repo rate) (Chart 5).

Chart 5: Change in Repo Rate



Descriptive Statistics

The descriptive statistics of the variables for the study period, March 2010 to March 2017, are presented in Table 2.

Table 2: Descriptive Statistics of all the variables

Variable	Mean	Median	Min.	Max.	Std. Dev	Skewness	Kurtosis
CPDR	8.69	8.72	4.10	14.41	1.28	0.18	4.13
WACR	7.35	7.51	3.21	12.73	1.22	-0.53	4.47
REPO RATE (RR)	7.24	7.50	4.75	8.50	0.87	-0.62	2.56
EFFECTIVE POLICY RATE (EPR)	7.11	7.50	3.25	8.50	1.08	-1.15	4.33

Stationarity Tests and Cointegration

We use three tests for analyzing the stationarity of the variables, namely, the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests whose null hypothesis is presence of non-stationarity, and the KPSS test whose null hypothesis is stationarity of the series. Literature suggests that the PP test is more powerful in the presence of heteroscedasticity and serial correlation (Bettendorf et al, 2009) which is generally the case with financial markets data on daily and weekly frequency.

The unit root test results for daily data are provided in Tables 3 and 4. All the test results generally indicated that the variables are non-stationary at levels and stationary at first difference, i.e., they are integrated of order 1.

Table 3: Results of Unit Root tests at levels

Variable	ADF Test (H0: Series is Non-Stationary)			PP Test (H0: Series is Non-Stationary)			KPSS Test (H0: Series is Stationary)	
	P-values			P-values			LM-Stat[4]	
	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept

[4]

			Intercept	Trend and Intercept
Asymptotic critical values*:		1% level	0.739000	0.216000
		5% level	0.463000	0.146000
		10% level	0.347000	0.119000
*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)				

CPDR	0.003	0.003	0.510	0.0000	0.0000	0.4889	1.22	0.61
WACR	0.029	0.127	0.756	0.0021	0.0148	0.8603	0.92	0.94
Repo Rate	0.054	0.251	0.852	0.0541	0.2279	0.8520	0.93	0.94
Effective Rate	0.010	0.029	0.705	0.0117	0.0724	0.7690	0.92	0.93

Note: Lag Length selected automatically based on SIC.

Table 4: Results of Unit Root tests at first difference

Variable	**ADF Test (H0: Series is Non-Stationary)**			**PP Test (H0: Series is Non-Stationary)**			**KPSS Test (H0: Series is Stationary)**	
	P-values			**P-values**			**LM-Stat**	
	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept
CPDR	0.00	0.00	0.00	0.0001	0.0001	0.0001	0.19	0.05
WACR	0.00	0.00	0.00	0.0001	0.0001	0.0001	0.33	0.04
Repo Rate	0.00	0.00	0.00	0.0000	0.0000	0.0000	1.66	0.16
Effective Rate	0.00	0.00	0.00	0.0001	0.0001	0.0001	0.89	0.10

Note: Lag Length selected automatically based on SIC.

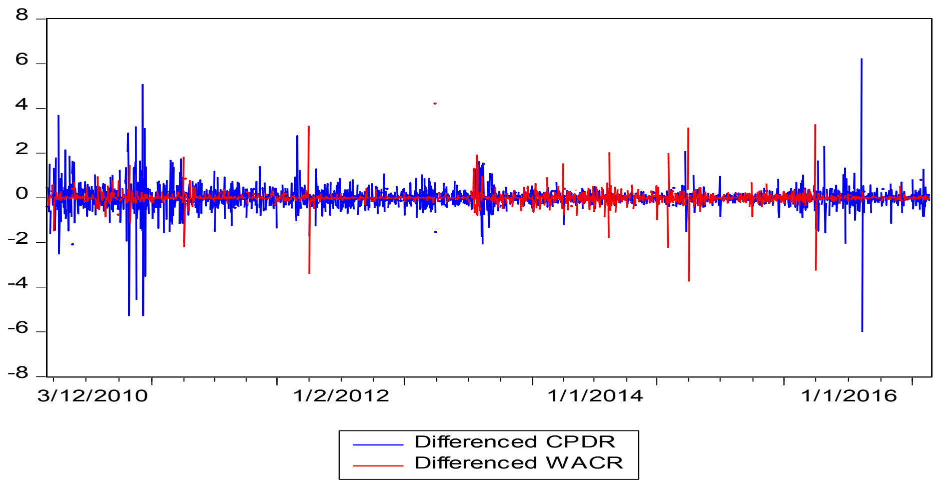
With the daily CPDR and WACR being I(1), we test for cointegration using the Bivariate Cointegration (Engle-Granger) and Johansen cointegration tests. In the former test, the ADF test was carried on the residual (without including the deterministic trend) from the OLS regression of CPDR on WACR and an intercept. The unit root null hypothesis (of 'no cointegration') is rejected which indicates that CPDR and WACR are co-integrated. The Engle–Granger test, however, has low power and can be misleading if there are structural breaks in the data. The latter test indicates one cointegrating vector at the 0.05 level with both the Trace test and the Max-eigenvalue test yielding consistent results (Annex1, Table 3).

In high frequency data (daily data), the presence of volatility clustering (i.e., ARCH effects) is expected. Hence, we test the residuals of both the long-run and short-run models for ARCH effects as adopted by de Haan and Sterken (2011).

Volatility Clustering

Apart from testing for stationarity, we also check for volatility clustering as this is a common feature of high frequency data, such as daily and weekly data used in this paper. Chart 4 above gives some indication of volatility clustering, which can be further observed in the charts for ΔCPDR and ΔWACR (Chart 6) and also confirmed by the autocorrelations for ΔCPDR, $[\Delta CPDR]^2$, ΔWACR and $[\Delta WACR]^2$. Therefore, assuming that the variance of the error term is constant, as is done in OLS regressions, may not be appropriate.

Chart 6: Change in CPDR and WACR



Error Correction Model (ECM)

As the CPDR and WACR are cointegrated, they are modelled in an Error Correction Model (ECM) Framework. The ECM has two equations: one, the long-run equation (in levels) that captures the long-run equilibrium between the two variables; and two, the short-run equation that models the short-run dynamics between the changes in the two variables. The ECM is estimated in two steps. First, the following long-run (LR) equation is estimated using the static OLS method (Table 5).

$$CPDR_t = \alpha_1 + \beta_1 WACR_t + \nu_t \qquad (1)$$

The model assumes that, in the long run, the buyers in the primary CP market set the discount rate as a mark-up on the interbank call money rate (the WACR). The residual from Equation (1), ν_t, may contain ARCH effects as a result of the daily frequency of the data. Therefore, the long-run parameters are to be estimated correcting for possible ARCH effects.

It is argued that the conventional (or static) OLS yields consistent estimates in the presence of cointegration and are also unaffected by volatility clustering (asymptotically). However, the conventional OLS standard errors are not consistent. Therefore, for testing the hypothesis related to the long-run equation, the Dynamic Least Squares (DOLS) method is adopted (Bettendorf et al, 2009). The DOLS method involves augmenting the cointegrating regression with lags and leads of ΔX_t so that the resulting cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations.

Table 5: Long Run (LR) Equation

	Static OLS Coefficient	***Dynamic OLS Coefficient*[1]**	**ARCH (1)**	**GARCH(1,1)**
	(1)	**(2)**	**(3)**	**(4)**
α_1 *(t-value)*	2.715 (49.5)	2.380 (8.36)	3.299 (z-value=116.98)	3.36
β_1 *(t-value)*	0.812 (22.2)	0.857 (22.46)	0.691 (79.22)	0.685
Observations	1689	1683	1689	1689
Adjusted R^2	0.592	0.62	0.521	0.528
S.E. of regression	0.821	0.792	0.888	0.882
F-Statistics (p-value)	2453.283 (0.000)			
DW	0.595		-	
ARCH-LM test (p-value)	177.300 (0.000)		2.657 (0.1033)	0.048 (0.8258)

1. *Automatic lead and lag selection based on SIC criterion.*

The long-run parameter from the long-run OLS is 0.812. This indicates that, in the long run, an increase in the WACR by one unit (one per cent) would cause an increase in the CPDR by 0.812 units (i.e., 0.812 percentage points). The static and dynamic OLS show that there is incomplete pass-through and a significant mark-up in the pricing of the CPDR. The results of the ARCH-LM test on the residuals showed the presence of ARCH-effects. Therefore, the model is re-estimated using an ARCH(1) specification following de Haan and Sterken (2011). As compared to the OLS results, the magnitude of the parameters from the ARCH(1) model has changed after the ARCH correction. The ARCH(1) model shows the pass-through parameter to be further lower and the mark-up is higher. As the correlogram of the standardized residuals squared showed a few significant correlations after four lags, we estimated GARCH(1,1) to correct for the correlations (Table 7, Column 4). This model showed a further reduction in the pass-through and a higher mark-up.

The coefficient on the WACR in the long run equation ranges between 0.685 and 0.857 (Table 7 above). From the ARCH(1) model, the long-run elasticity of CPDR with respect to the WACR is, η = $\beta_1 * \frac{mean(WACR)}{mean(CPDR)}$ = 0.691 * (7.35) / (8.69) = 0.584. This means that only about 58 per cent of the change in the WACR gets passed on the CPDR.

In the second step, the estimated Short-Run (SR) error correction model is as follows:

$$\Delta(CPDR_t) = \sum_{i=0}^{k} \lambda_i \Delta WACR_{t-i} + \omega \nu_{t-1} + \varepsilon_t \qquad (2)$$

where the error correction term, ν_{t-1}, is the one-period lagged residual from the LR Equation (1). In equation (2), ω is assumed to be negative.

The underlying assumption in this model is that WACR is weakly exogenous to CPDR, implying that there is no feedback from CPDR to WACR. This is a reasonable assumption in that the WACR is the operating target of monetary policy in India and is kept near the policy rate by the RBI. The coefficient (ω) on the error correction term (ν_{t-1}) gives the speed of adjustment of the CP discount rate to a deviation in the relationship between the CP discount rate and WACR.

First, Equation (2) was estimated by OLS using the one-period lagged residuals from the OLS/ARCH(1)/GARCH model as the error correction term (ν_{t-1}). However, the ARCH-LM test of the OLS estimates indicate that the volatility is serially correlated over time (i.e., indicating presence of heteroscedasticity), which implies that the OLS estimates are not efficient (Table 6).

Table 6: Short-run equation estimated using OLS

	OLS

Independent variable	Model 1	Model 2	Model 3	Model 4	Model 5
C	-0.000	0.098***	0.017	0.000	0.078***
DWACR	0.273***	0.237***		0.176	0.253***
R_OLS(-1)	-0.263***		-0.265***		
R_DOLS(-1)				-0.279	
R_ARCH(1) (-1)					-0.255***
DWACRp			0.153***		
DWACRn			0.401***		
R_OLSp(-1)		-0.363***			
R_OLSn(-1)		-0.034			
Residual autocorrelation	Y	Y	Y	Y	Y
Residual heteroskedasticity	Y	Y	Y	Y	Y

To correct for the volatility clustering, we estimated Equation (2) in a GARCH(1,1) framework. Further, to allow for asymmetry in the volatility process, an EGARCH(1,1) model is estimated. The exponential GARCH (EGARCH) model belonging to the family of GARCH models which includes logarithm and leverage term to detect asymmetry in volatility clustering (Nelson, 1990).

Asymmetric Transmission

In order to test for asymmetry in the transmission of policy to CPDR, both changes in the explanatory variable (WACR) and the error correction term (ν_{t-1}) in Equation 2, are split into their positive and negative components. The mean equation is given below:

$$\Delta(CPDR_t) = \sum_{i=0}^{m} \lambda_i^+ \, \Delta WACR_{t-i}^+ + \sum_{i=0}^{n} \lambda_i^- \Delta WACR_{t-i}^- + \omega^+ \nu_{t-1}^+ + \omega^- \nu_{t-1}^- + \varepsilon_t \qquad (4)$$

The specification of the conditional variance in the asymmetric EGARCH(1,1) model is given below.

$$ln\sigma_t^2 = \alpha_0 + \alpha_1 \left| \frac{\epsilon_{t-1}}{\sigma_{t-1}} \right| + \beta_1 \, ln\sigma_{t-1}^2 + \gamma_1 \left(\frac{\epsilon_{t-1}}{\sigma_{t-1}} \right) \qquad (3)$$

There are different types of asymmetries (Geweke, 2004). As CPDR and WACR are cointegrated, they will not drift apart in the long run, and thus, there will not be any major *amount asymmetry* in the long run. In the short-run, there could be *amount asymmetry*. The short run amount symmetry is present if

$$\sum \lambda_i^+ \neq \sum \lambda_i^-$$

There would be *timing or pattern asymmetry* if there are differences in the estimate of λ_i^+ and λ_i^- at the same lags. *Adjustment* asymmetry, that is asymmetry in the speed of adjustment, is present if $\omega^+ \neq \omega^-$. Finally, the effects of volatility to shocks can be asymmetrical. To allow for asymmetry in the volatility process, lags of the unconditional normalized standard deviations, $\left(\frac{\epsilon_{t-1}}{\sigma_{t-1}}\right)$, is introduced. Thus, *shock* asymmetry is present if $\gamma_1 \neq 0$ in the variance equation: negative shocks have an impact of $\alpha_1 - \gamma_1$ on the log of the conditional variance and positive shocks have an effect of $\alpha_1 + \gamma_1$ (Bettendorf *et al*, 2011). The different models estimated are given in Table 7 below.

Table 7: Short-run equation estimated using GARCH(1,1) and EGARCH(1,1)

	GARCH (1,1)			EGARCH(1,1) with error distribution as Normal (Gaussian)			EGARCH(1,1) with error distribution as Student's t-distribution	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Mean Equation								
C	0.011	0.018**	0.015	0.009	0.013	0.015	-0.003	-0.014
DWACR	0.172***			0.161***			0.115***	
R_ARCH(1) (-1)	-0.153***	-0.152***		-0.138***	-0.140***		-0.076	
DWACRp		0.119***	0.120***		0.098***	0.098		0.113***
DWACRn		0.208***	0.209***		0.174***	0.175		0.109***
R_ARCH(1)p (-1)			-0.147***			-0.142		-0.056***
R_ARCH(1)n (-1)			-0.162***			-0.134		-0.101***
DCPDR(-1)							-0.478***	-0.486***
DCPDR(-2)							-0.275***	-0.290***
DCPDR(-3)							-0.174***	-0.195***
DCPDR(-4)							-0.054***	-0.088***
DCPDR(-5)								-0.056***
Variance Equation								
C	0.001***	0.001***	0.001***	-0.186***	-0.188	-0.188	-0.183	-0.176
RESID(-1)^2	0.168***	0.168***	0.168***					
GARCH(-1)	0.864***	0.864***	0.864***					
$\left\lvert\frac{\epsilon_{t-1}}{\sigma_{t-1}}\right\rvert$				0.230***	0.234***	0.234***	0.162	0.161

$\left(\frac{\epsilon_{t-1}}{\sigma_{t-1}}\right)$				0.029***	0.025***	0.025**	0.099	0.094
$ln\sigma_{t-1}^2$				0.986***	0.986***	0.986***	0.973	0.975
Observations								1684
Adjusted R^2								0.240
S.E. of regression								0.519
Residual autocorrelation	Yes	Yes	Yes	Yes	Yes	Yes	No	P-values > 0.05 for 36 lags
Residual heteroskedasticity								ARCH test: F-stat = 0.002261; Prob. F (1,1681) = 0.9621 Obs R^2 = 0.002264
Normality								JB stat = 176810; Probability = 0.000
Wald Tests								
								H0: $\lambda_i^+ = \lambda_i^-$ t-stat = 0.087; p-value = 0.93
								H0: $\omega^+ = \omega^-$ t-stat = 1.205; p-value = 0.22
								H0: γ_1= 0 t-stat = 170.53 (p-value=0.00)

*** and ** indicates significance at 1 per cent and 5 per cent level of significance, respectively.

In the selected models (7 and 8), the serial correlation in the residuals was corrected by taking four lags of DCPDR as regressor and assuming that the errors have a Student's t-distribution (Table above, Column 8).

The selected model yields the following conclusions:

- First, in the selected ECM-EGARCH(1,1) model (Model 8), the coefficient β_1 is less than one indicating that the model is stationary, but its value close to one indicates volatility persistence.
- Second, the null of $\lambda_i^+ = \lambda_i^-$ cannot be rejected indicating that there are no amount and timing asymmetry in the short-run.
- Third, the null of $\omega^+ = \omega^-$ also cannot be rejected indicating that there is no a*djustment* asymmetry, that is no asymmetry in the speed of adjustment to positive or negative deviations from the long-run equilibrium. The speed of adjustment coefficient (ω) in Model 7 is -0.076. This indicates that, in case of any deviation

from the equilibrium between the CPDR and the WACR, the CPDR adjusts by about 7.6 per cent per time period towards the WACR to re-establish equilibrium.

- Finally, the hypothesis of γ_1 = 0 is rejected indicating the presence of *shock* asymmetry. Further, γ_1 > 0 indicates that positive shocks generate more volatility then negative shocks of the same size. While, negative shocks have an impact of $(\alpha_1 - \gamma_1) =$ 0.067 (i.e., 0.161 – 0.094) on the log of the conditional variance, positive shocks have an effect of $\alpha_1 + \gamma_1$ = 0.255. This evidence of shock asymmetry might have a 'search cost' explanation with borrower firms, who observe a volatile interest rate market, are reluctant to start a costly price comparison when faced with a price change. This explanation would, however, require further investigation.

VI Conclusion

This paper examines the interest-rate pass-through to the primary Commercial Paper market in India at a daily frequency for the period March 12, 2010 to February 23, 2017. In the sample period, the daily discount rate in the primary CP market and the weighted average call rate were observed to be stationary at first difference and were cointegrated. Accordingly, an error correction model (ECM) on the daily changes in the CPDR vis-à-vis daily changes in the WACR is estimated, taking care of the volatility clustering by estimating an EGARCH model.

The long-run elasticity of CPDR with respect to the WACR during the sample period was 0.584, which implies about 58 per cent of the change in the WACR gets passed on the CPDR. In the short run, while amount asymmetry, timing/pattern asymmetry and adjustment asymmetry were absent, there was evidence of shock asymmetry. Absence of amount asymmetry indicated that the CPDR adjusts almost evenly when there is an increase or a decrease in the WACR at various lags. Timing/pattern symmetry implies that the response of CPDR to positive or negative changes in WACR are similar at each period lag. Absence of adjustment asymmetry implied that the speed of adjustment of the CPDR to deviation from the long-run equilibrium was similar whether there was a positive or a negative deviation. Finally, the presence of shock asymmetry implied that a positive shock to the CPDR had a greater effect on the variance of the CPDR than a negative shock of the same size. This evidence of shock asymmetry might have a ‘search cost’ explanation with the corporates, who observe a volatile interest rate market, are reluctant to start a costly price comparison when faced with a price change. This explanation would, however, require further investigation.

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Annex 1: Some statistical test results

Table 1: Group Unit Root test results

A. Series: CPDR, REPO_RATE, WACR
Sample: 3/12/2010 2/23/2017
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.07356	0.0011	3	4992
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.41246	0.0003	3	4992
ADF - Fisher Chi-square	24.4782	0.0004	3	4992
PP - Fisher Chi-square	102.499	0.0000	3	5046

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

B. Series: CPDR, EFF_RATE, WACR
Sample: 3/12/2010 2/23/2017
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 3 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.43702	0.0003	3	4989
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-3.80282	0.0001	3	4989
ADF - Fisher Chi-square	27.8609	0.0001	3	4989
PP - Fisher Chi-square	105.571	0.0000	3	5046

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Table 2: Breakpoint Unit Root test

Null Hypothesis: CPDR has a unit root
Trend Specification: Intercept only
Break Specification: Intercept only
Break Type: Innovational outlier

Break Date: 8/11/2016
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 3 (Automatic - based on Schwarz information criterion,

maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.919171	0.0116
Test critical values:	1% level	-4.949133	
	5% level	-4.443649	
	10% level	-4.193627	

*Vogelsang (1993) asymptotic one-sided p-values.

Null Hypothesis: WACR has a unit root
Trend Specification: Intercept only
Break Specification: Intercept only
Break Type: Innovational outlier

Break Date: 3/31/2015
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 5 (Automatic - based on Schwarz information criterion, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.094244	0.1268
Test critical values:	1% level	-4.949133	
	5% level	-4.443649	
	10% level	-4.193627	

*Vogelsang (1993) asymptotic one-sided p-values.

Null Hypothesis: REPO_RATE has a unit root
Trend Specification: Intercept only
Break Specification: Intercept only
Break Type: Innovational outlier

Break Date: 6/01/2015
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 0 (Automatic - based on Schwarz information criterion, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.088668	0.1282
Test critical values:	1% level	-4.949133	
	5% level	-4.443649	
	10% level	-4.193627	

*Vogelsang (1993) asymptotic one-sided p-values.

Null Hypothesis: EFF_RATE has a unit root
Trend Specification: Intercept only
Break Specification: Intercept only
Break Type: Innovational outlier

Break Date: 1/14/2015
Break Selection: Minimize Dickey-Fuller t-statistic
Lag Length: 16 (Automatic - based on Schwarz information criterion, maxlag=24)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.934496	0.0108
Test critical values:	1% level	-4.949133	
	5% level	-4.443649	
	10% level	-4.193627	

*Vogelsang (1993) asymptotic one-sided p-values.

Table 3: Johansen cointegration test

Sample (adjusted): 3/22/2010 2/23/2017
Included observations: 1630 after adjustments
Trend assumption: No deterministic trend
Series: CPDR WACR
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.034570	57.34634	12.32090	0.0000
At most 1	1.36E-07	0.000221	4.129906	0.9920

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.034570	57.34612	11.22480	0.0000
At most 1	1.36E-07	0.000221	4.129906	0.9920

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Annex 2: Survey of Empirical Evidence on Monetary Transmission Mechanism (MTM) in India

Study	Sample Period (Frequency)	MTM Channel[1]	Model[2]	Some findings[3]
Ray et al (1998)	1970-71 to 1996-97 (Annual)	IRC and ERC	VAR	Transmission of monetary policy through both interest rate and exchange rate channels was found to be strong in the post-reform period vis-à-vis pre-reform period.
Dhal (2000)	1961-2000 (Monthly)	IRC and CC	Rolling Regression	Interest rate has emerged as a significant factor for explaining the variation in real activity in the 1990s.
Al-Mashat (2003)	1980:Q1 to 2002:Q4 (Quarterly)	IRC, ERC and CC/BLC	VECM	IRC and ERC important in the transmission of monetary policy shocks on key macroeconomic variables. BLC not an important channel due to the presence of directed lending under priority sector
Pandit et al (2006)	April 1993 to April 2002 (Monthly)	CC/BLC	VAR/SVAR	BLC operates in the Indian context. Response of big banks to monetary policy shocks differs from that of small banks, with the latter being more compliant.
Singh and Kalirajan (2007)		IRC	Cointegrated VAR with generalized restrictions	The long-run relationship and the short-run dynamics suggest an important role for the interest rate in the post-liberalised Indian economy.
Ghosh and Pradhan (2008)	April 2002 to Sept 2007 (Monthly)	IRC		WADR in the CP market determined by the call rate, 364-day T-bills cut-off yield, incremental bank credit and the CP issue amount
Aleem (2010)	1996:Q4 to 2007:Q4 (Quarterly)	CC, APC, and ERC	VAR	CC - only important channel of monetary transmission in India
Patra and Kapur (2010)	1996 to 2009 (Quarterly)	IRC and ERC	GMM and OLS	Explores theoretical foundations for the monetary policy framework in India, and empirically assess monetary transmission channels in the period 1996-2009 in a new-Keynesian framework. Aggregate demand responds to interest rate changes with a lag of at least three quarters, and the presence of institutional impediments in the credit market such as administered interest rates can lead to persistence of the impact of monetary policy up to two years Exchange rate pass through to domestic inflation in India has found to be credible and working. The forward looking response of monetary authorities in India to expected inflation and output has been found to be on the right track.
Singh and Pattanaik (2010)	1996 to 2001 (Quarterly)	APC	SVAR	Paper provides empirical evidence on the relevance of a policy of no direct use of the interest rate instrument for stabilising asset price cycles. Concerns on financial stability arising out of asset price bubbles could be addressed effectively through micro and macro-prudential measures.
Bhaumik et al (2011)	2000-07	CC	Panel	Considerable differences in the reactions of different types of banks (based on

				ownership) to monetary policy initiatives of the central bank, and that the bank lending channel of monetary policy is likely to be much more effective in a tight money period than in an easy money period
Pandit and Vashisht (2011)	January 2002 to August 2010	IRC	Panel data	Change in policy rate of interest is an important determinant of firms' demand for bank credit.
Khundrakpam (2011)	2001:M3 to 2011:M3	CC	OLS/Rolling Regression	Transmission of policy rate to nominal or real bank credit growth takes about seven months over the full sample period as well as across various sub-sample periods.
Singh (2011)	2001:M3 to 2012:M6	IRC, CC, ERC and APC	VAR	Transmission is instantaneous and large for money market as compared with the longer end of financial market. Longer lags in transmission to bank deposit and lending rates. Asymmetry in transmission between periods of banking system liquidity deficit and surplus scenarios.
Jayadev and Kumar (2012)	January 1999 to June 2003 (Daily)	IRC	ECM	Speed of adjustment of CP rate to Bank Rate is low.
Khundrakpam and Jain (2012)	1996-97:Q1 to 2011-12:Q1	IRC, CC, ERC and APC	SVAR	IRC, CC, APC are important, while ERC is weak.
Mohanty (2012)	1996-97:Q1 to 2010-11:Q4 (Quarterly)	IRC	SVAR	Policy rate increases have a negative effect on output growth with a lag of two quarters and a moderating impact on inflation with a lag of three quarters. The overall impact persists through 8-10 quarters
Ray and Prabhu (2013)	Jan 2005 to Dec 2011 (Daily)	IRC, CC, ERC and APC	SVAR	Shocks in the monetary policy (using effective policy rate) have expected immediate and persistent effects on the 3 month Certificate of Deposits (CD) rate and Commercial Paper (CP) rate.
Sengupta (2014)	April 1993 to March 2012 (Monthly)	IRC, CC, ERC and APC	VAR and Augmented VAR	BLC remains an important means of transmission of monetary policy in India, but it has weakened in the post-LAF period. The IRC and APC have become stronger and the ERC, although weak, shows a mild improvement in the post-LAF period.
Das (2015)	end-March 2002 to end-October 2014 (Bi-weekly)	CC	ECM	Asymmetry
Mishra et al (2016)	April 2001 to December 2014		VAR	Mixed message on the effectiveness of monetary policy in India, but perhaps one that is more favourable than is typical of many countries at similar income levels.
Bhoi et al (2016)	1996–1997:Q1 to 2013–2014:Q4 (Quarterly)	IRC, APC, CC and ERC	VAR and 'shutdown' methodology	IRC is found to be the most dominant channel of monetary policy transmission in India.
Salunkhe and Patnaik (2017)	January 2002 to December 2015	--	Granger Causality in the frequency Domain. SVAR	Bi-directional causality between policy rate and inflation and between policy rate and output. Output gap causes inflation only in the short-to-medium-run.

Rangarajan and Samantaraya (2017)	2011:Q1 to 2016:Q2 (Quarterly)	CC	OLS using Newey-West Standard Errors correcting for heteroscedasticity and autocorrelation in stochastic error terms.	Relatively weaker transmission of monetary policy action (repo rate) to medium-term interest rates (WALR) as compared to the operating target (Call Money Rate).

Note: IRC – 1. Monetary Transmission Channels: (i) Interest Rate Channel - IRC; (ii) Credit Channel/Bank Lending Channel - CC/BLC; (iii) Exchange Rate Channel - ERC; (iv) Asset Prices Channel - APC; (v) Expectations Chanel – EC; and (vi) Confidence Channel (CoC).

2. Econometric Models: (i) Ordinary Least Squares - OLS; (ii) Vector Auto-Regression - VAR; (iii) Structural Vector Auto-Regression – SVAR; (iv) (Vector) Error Correction Model – (V)ECM.

3. CP – Commercial Paper; WADR - weighted average discount rate; WALR – Weighted Average Lending Rate.