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Abstract

This paper presents the empirical results of the volatility transmission of money market overnight repo rate along the yield curve in Pakistan. The results indicate that the transmission of volatility of overnight repo rate is higher at the shorter end of the yield curve compared to the longer end. These results are in line with empirical findings of volatility transmission of interest rates found in other countries. The results also suggest that the pass-through level of transmission of volatility from overnight repo rate to short and long term interest rates has decreased after State Bank of Pakistan (SBP) adopted the interest rate corridor framework in August 2009. The empirical findings show that the subsequent changes introduced in the current operational framework of SBP has further improved the signaling mechanism of SBP's monetary policy stance to financial markets. These results indicate the smooth transmission of changes in SBP policy rate to short and long term market interest rates without spreading the unwarranted volatility across the yield curve.

JEL Classification: E4, E5, G1
Keywords: monetary policy, volatility, yield curve, GARCH

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Non-technical summary

This paper empirically investigates the transmission of volatility in the money market overnight repo rate to short and long-term market interest rates in Pakistan. In contemporary economic world, central bank's ability to control short-term interest rates with high precision is necessary for credible monetary policy implementation. Today, most of the central banks use overnight interest rate – the starting point of the yield curve – as an operational target for signaling the monetary policy stance. State Bank of Pakistan (SBP) also uses short-term interest rate to provide monetary policy signals in the economy. However, given the uncertainties related to liquidity situation in the money market, at times short-term interest rates exhibit unwarranted volatility which could impair the process of monetary transmission mechanism.

To counter the unnecessary volatility at the short end of the yield curve, SBP adopted the interest rate corridor framework for its monetary policy operations in August 2009. Under this new framework, SBP established an overnight deposit facility in addition to already available overnight lending facility for the money market. The Bank also designated the money market overnight repo rate as its operational target. The spread between both the overnight standing facilities was initially set at 300 basis points. This spread was reduced to 250 basis points in February 2013 and then further to 200 basis points in May 2015. The subsequent changes made in SBP's operational framework aimed to reduce the volatility in overnight repo rate to improve the signaling of SBP's monetary policy stance. Recently, in May 2015, in line with best international practices and to further improve the signaling mechanism, SBP introduced a new target rate within the interest rate corridor which now serves as its policy rate.

In this backdrop, the objective of this paper is to empirically investigate the transmission of volatility from money market overnight repo rate to short and long-term interest rates. For this purpose, the study has used rigorous econometric technique for empirical estimations. In line with evidences found in other countries, the empirical results found in this study suggest that the transmission of volatility of money market overnight repo rate is higher at the shorter end of the yield curve compared to the longer end. The transmission of unwarranted volatility spillover across yield curve has reduced after SBP adopted the interest rate corridor (IRC) framework. The empirical findings also show that the subsequent changes introduced in this framework have further improved the signaling mechanism of SBP's monetary policy stance to financial markets. Significant decline is observed in estimated volatility of each market interest rate after implementation of IRC framework by SBP. These results also suggest the smooth transmission of SBP policy rate changes at shorter end of the yield curve to longer end after the implementation of IRC framework.

1. Introduction

In modern economic world, central bank ability to control short-term interest rate with high precision is necessary for credible monetary policy implementation. Today, most of the central banks employ overnight interest rate – the starting point of the yield curve – as an operational target of monetary policy framework. Besides signaling the monetary policy stance, the overnight rate also helps in anchoring the term structure of interest rates. Hence, central banks try to avoid excessive volatility in overnight rate because; (1) any erratic volatility in these rates may prove to be unfavorable for efficient market functioning through ineffective policy signals; and (2) this unwarranted volatility in overnight rates may be transmitted to long-term rates which are more relevant from the perspective of consumption and investment decisions in the economy.

State Bank of Pakistan (SBP), like most other central banks use short-term interest rate to provide monetary policy signals. However, given the uncertainties related to liquidity situation in the money market, at times short-term rates depict unnecessary volatility. This excessive volatility at the short end of the yield curve not only complicates the monetary policy implementation process but may also lead to volatility in other important macroeconomic variables in the economy. In August 2009, to counter this unwarranted volatility at the short end of the yield curve, SBP adopted the interest rate corridor (IRC) framework and established an overnight deposit facility in addition to already available overnight lending facility for the money market. The foremost reason behind this change in SBP's operational framework is to avoid excessive volatility in the money market overnight repo rate as this may create disconnect between short and long-term interest rates in the economy.[1]

In this backdrop, the objective of this paper is to empirically investigate, for the first time in a developing country context, the transmission of volatility in money market overnight repo rate to short and long-term interest rates in the term structure. For this purpose, ARCH model is used in this study for empirical investigations. In line with evidences found in other countries, the empirical results found in this study suggest that the transmission of volatility of money market overnight repo rate is higher at the shorter end of the yield curve compared to the longer end. The transmission of unwarranted volatility spillover across yield curve has reduced after SBP has adopted the interest rate corridor framework. We also find that the subsequent changes introduced in the IRC framework have improved the signaling mechanism of SBP's monetary policy stance to financial markets.

The rest of the paper is organized as follows. Section 2 reviews the international evidences about the transmission of volatility of overnight interest rates along the yield curve. Section 3 briefly describes the SBP's operational framework for monetary policy implementation. Section 4 provides the results

[1] Money market overnight repo rate is the weighted average collateralized overnight interest rate for interbank transactions. See Monetary Policy Statement, July-September 2009 for details.

of the empirical model for overnight repo rate. Section 4 presents the results of transmission of volatility of overnight repo rate along the yield curve in Pakistan. Section 5 makes the concluding remarks.

2. Global empirical evidences about the transmission of volatility of overnight interest rate

According to Bindseil (2004a) "There is little debate, at least among central bankers, about what a central bank decision on monetary policy means: it means to set the level of short-term money market interest rate that the central bank aims at in its day-to-day operations during the period until the next meeting of the central bank's decision-making body." Today, most of the central banks of both advanced and emerging economies are implementing their monetary policy by influencing the overnight interest rate, commonly recognized as the operational target. For effective policy signaling, they also try to keep the deviation in the overnight rate from the target (policy) rate at minimum. An effective way to limit this deviation in overnight rate can be achieved through the implementation of IRC system for monetary policy operations [see Bindseil (2004b) and Kahn (2010) for theoretical and practical considerations of IRC approach].

Most of the central banks of both advanced and emerging economies are currently operating under the IRC framework with different kind of arrangements.[2] However, the studies on the behavior of market interest rates and the effects of transmission of volatility along the term structure are mostly limited to the financial markets in advanced economies. In case of emerging economies such studies are almost non-existent. One of the main reasons which could explain this dearth in literature is that the depth and size of financial markets in emerging economies are still very low relative to advanced economies.[3] This may have implications for transmission mechanism of monetary policy and could impair the central bank's signaling of monetary policy stance [Krause and Rioja (2006)].

While ample empirical evidences found in advanced economies, vast literature deals with the theoretical structure of money market and transmission of volatility in market interest rates.[4] The core finding of all these studies is that the transmission of volatility of overnight rate is higher at the shorter maturities and tends to fall as move along the yield curve. For example, Ayuso et al (1997) found significant transmission of volatility from overnight to longer term money market rates for four advanced economies. The volatilities are found to be highest at the shortest end of the yield curve than the longer end. They also found the significance of calendar effects in modeling the short-term rates. Similar results were found by Moschitz (2004), Nautz and Offermanns (2007) and Cassola and

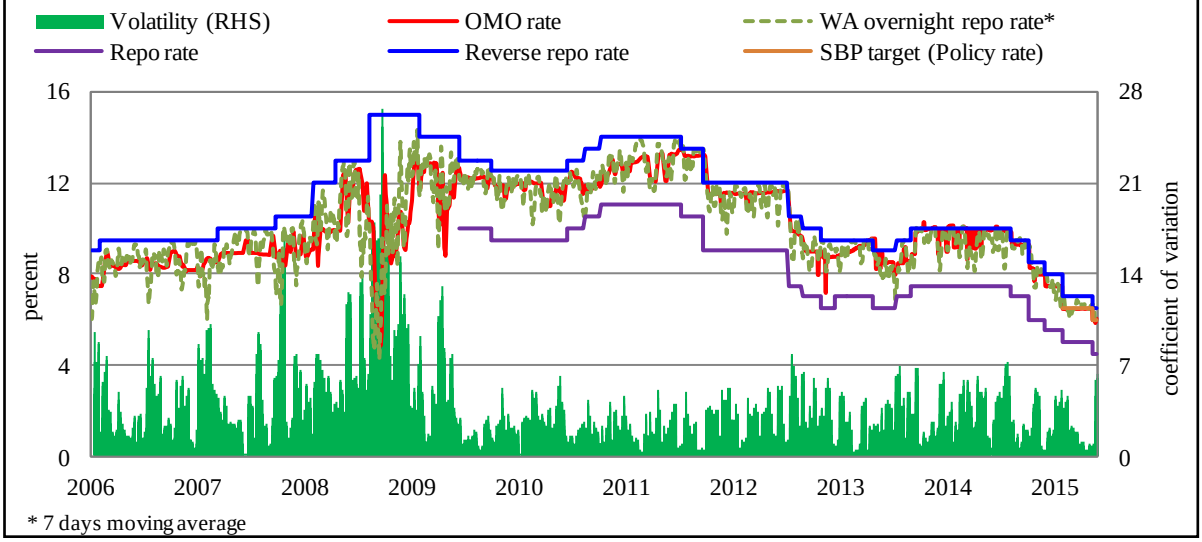
[2] See **Table A1** in annexure for cross-country comparison of selected central banks' arrangement of operational framework for monetary policy.
[3] According to latest statistics of Bank for International Settlements (BIS), the bond market in advanced economies explains around 81 percent of global bond market as of end-March 2015.
[4] See for example Ewerhart et. al. (2004), Ewerhart et. al. (2005) and Christensen and Prabhala (1998) among others.

Morana (2006) for European money market.[5] This study is first attempt of its kind for a developing country.

3. SBP operational framework for monetary policy implementation

Like most other central banks, SBP implements monetary policy by steering short-term interest rates in the interbank money market. In particular, the overnight repo rate (being the operational target) signals the stance of monetary policy. However, prior to August 2009, unlike many other central banks, there was no designated operational target under the SBP's operational framework. SBP used one of the rates on its standing facilities i.e. SBP reverse repo rate as policy rate to give overall direction of monetary policy in the economy.[6] Hence, there were periods where large deviations between overnight repo rate and SBP's policy rate could be observed. These deviations not only caused high volatility at the shorter end of the yield but also at the longer end.

Figure 1: Trend in SBP's Key Interest Rates



In absence of any desired level for operational target, it is evident from **Figure 1** that the deviations in policy rate and money market overnight repo rate is largely explained by the movements in SBP's intervention (interest) rate in open market operations (OMOs).[7] This suggests that what matters more for monetary policy implementation is the interest rate at which market expects to transact in substantial volume with the central bank.[8] Though dependent upon the market liquidity situation, SBP

[5] For more empirical work, see Demiralp et. al. (2006). Prati et. al. (2003) and Bartolini and Prati (2006) for cross-country studies of the behavior of overnight market rates in several advanced economies.
[6] Before the implementation of interest rate corridor framework in August 2009, the policy rate was defined as 3-day repo rate (discount rate).
[7] Besides the overnight repo rate, other interest rates also closely follow the changes in SBP's OMO rate (see **Figure A1** in annexure).
[8] See Bindseil (2004a and 2004b) and Disyatat (2008) for more on this operational aspect of monetary policy.

normally conducts OMOs for 7 days at the start of reserve maintenance period.[9] So, any liquidity shock in the remaining weekdays that might be emanated from the developments in autonomous factors (including; changes in government accounts, SBP's forex market activities, public demand to hold currency over deposits, or weekly reserve requirements) normally generates high variation in overnight repo rate.

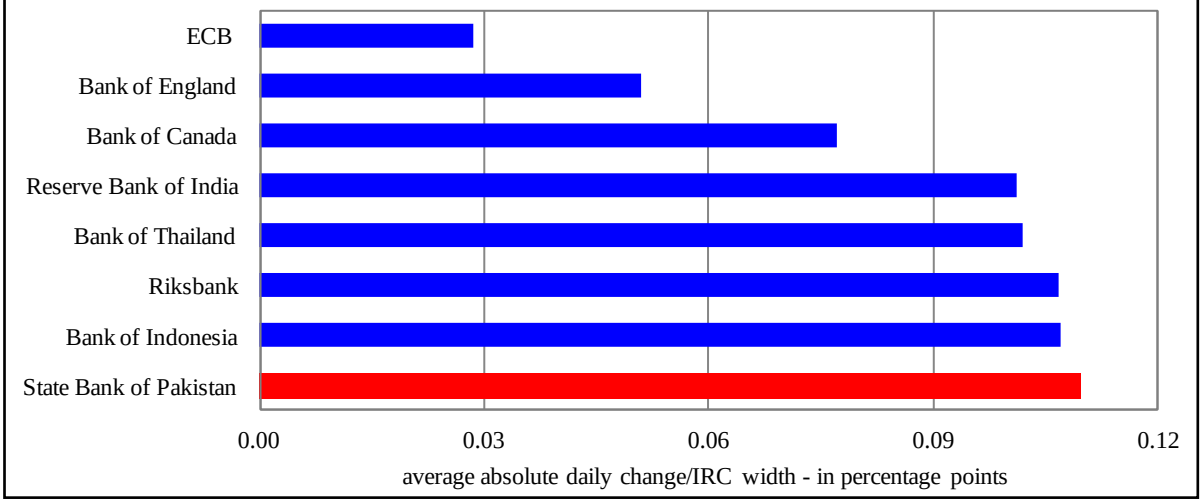
Furthermore, in addition to period average reserve requirements, banks are also required to meet daily reserve requirements obligation in Pakistan. Hence, a shortfall or surplus in any of large bank's reserve position may also cause high volatility in money market overnight repo rate. The interbank market in Pakistan, like other emerging markets, tends to deal mostly in shorter tenors, specifically in the overnight. Around 80 to 85 percent of the total transactions in both repos (secured) and call (unsecured) markets are being held on overnight basis only. Any erratic volatility in the prices of this market may prove to be unfavorable for efficient functioning of this market segment, in general, and for overall monetary transmission mechanism, in particular. Therefore, with the objective to reduce the excessive volatility in overnight repo rate, SBP introduced the IRC approach in August 2009. Under this approach, SBP established a new overnight deposit facility for excess funds in the money market in addition to already available discount or overnight lending facility. Also, Bank designated the money market overnight repo rate as its operational target.

The spread between both the overnight standing facilities was initially set at 300 basis points (bps). This spread was reduced to 250 bps in February 2013 and then further to 200 bps in May 2015. The subsequent changes made in SBP's operational framework have reduced the volatility in overnight repo rate. Recently, in May 2015, in line with best international practices, SBP introduced a new target rate within the IRC which now serves as its policy rate. This change has further reduced the volatility in the money market overnight repo rate. Nonetheless, when normalized to corridor width, **Figure 2** shows that the volatility in overnight repo rate under SBP's operational framework is slightly high when compared to the level found in selected regional and advanced economies with similar sort of monetary policy operational framework.

Is this volatility at the very short end of the yield curve is transmitting to other short-term and long-term interest rates or not? Given the objective of this paper and the rationale to adopt IRC, this is an important empirical question from the perspective of smooth transmission of changes in SBP's monetary policy stance. Thus, next sections will discuss this issue in detail for the first time in case of Pakistan.

[9] Currently, the reserve maintenance period starts from Friday and comprises two weeks which was changed from one week in October 2012. Also, the statistics suggest that around 1/3 of total OMOs conducted during July 2006 and September 2015 had a maturity period of 7 days.

Figure 2: Volatility in Operational Targets
(during August 2009 - September 2015)



4. Volatility in the overnight repo rate

The sample period for this study covers the daily data of money market overnight repo rate and Pak rupee revaluation rates (PKRV) for 1-month, 3-month, 6-month, 12-month, 1-year, 3-year, 5-year and 10-year tenors from 3rd July 2006 to 30th September 2015 (2486 observations).[10] The major reason behind the selection of this data sample is the absence of reliable data series for certain PKRV rates and more importantly overnight repo rate before July 2006.[11]

For estimation purposes, since money market interest rates display periods of volatility and periods of calm, this suggests the use of well-known generalized autoregressive conditional heteroskedasticity (GARCH) model.[12] Hence, based on Ayuso et. al. (1997), following GARCH (1, 1) model is used for regression analysis;[13]

$$\Delta r_t = \alpha + \beta (r - o)_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta r_{t-j} + \sum_{j=1}^{q} \eta_j \Delta o_{t-j} + \varepsilon_t \quad (1)$$

$$\varepsilon_t \sim N(0, \sigma^{2,ON})$$

$$\sigma_t^{2,ON} = \pi + \delta \varepsilon^{2,ON}_{t-1} + \rho \sigma^{2,ON}_{t-1} + \omega DX_t \quad (2)$$

[10] Since the data for repo rates is not readily available, PKRV rates were used in this study. These rates are based on collateralized transactions, quoted as end day values for different tenors of the term structure. The data on PKRV rates is taken from Financial Markets Association of Pakistan. Simple statistics for each PKRV data series are shown in **Table A2** in the annexure.

[11] There is another strand of limited literature which has used the measure of realized volatility for transmission of volatility in market interest rates [see Andersen and Bollerslev (1998) and Durre and Nardelli (2007) for details]. However, like most of the studies on this topic, this study preferred to use the model based volatility from ARCH-type models to answer the empirical question.

[12] See Engle (1982) and Bollerslev (1986) for the seminal contribution.

[13] The exponential (EGARCH) model used by Ayuso et. al. (1997) was also experimented and found not to add much to what is presented in this paper.

In the mean equation (1) r_t denotes the nominal overnight repo rate, o_t is the SBP's OMO intervention rate and Δ is the first difference operator since each series turned out to be I(1). In the variance equation (2) DX_t consists of several dummies to get an effect of end of reserve maintenance period, end quarter, and period of interest rate corridor implementation and reduction in its width to 250 bps and 200 bps on volatility of overnight repo rate.[14] Moreover, an error correction term (ECT) type variable i.e. the spread between the overnight repo rate and OMO rate is also introduced in equation (1). In the context of changes introduced in SBP's operational framework, the ECT helps in capturing the behavior of market participants which take the lead from changes in SBP's OMO intervention rate while transacting in the overnight money market.[15]

Table 1: Estimation Results for Overnight Repo Rate

Mean equation			Variance equation		
Parameter	**Coefficient**		**Parameter**	**Coefficient**	
α	0.2404	***	π	0.0316	***
β	-0.1624	***	δ	0.1562	***
γ_1	1.7857	***	ρ	0.8192	***
γ_2	-1.2727	**	ω_{EMP}	0.0058	*
γ_3	0.3978	***	ω_{EEMP}	0.0320	**
η_1	0.1277	***	ω_{EEEMP}	0.0108	*
η_2	-0.0401	**	ω_{EQ}	-0.1287	*
η_3	0.1711	***	ω_{CORR}	-0.0285	***
			ω_{250}	-0.0105	**
			ω_{200}	-0.0156	**

Note: Sample period is based on daily data from 3rd July 2006 to 30th September 2015; *, ** and *** denote statistical significance at 10, 5 and 1 percent (level of significance) respectively.

Table 1 presents the estimation results for modeling overnight repo rate volatility in case of Pakistan.[16] In the mean equation, the results show that a 1 percentage point increase in OMO rate translates into a 25 bps increase in overnight repo rate. The remaining differential between overnight rate and OMO rate is adjusted, on average, by 16 bps per day (the ECT coefficient). In the variance equation, the value for persistence of volatility ($\delta + \rho$) is 0.98. This value is quite high and indicates that the variance process of overnight repo rate does not tend towards a mean value in a predictable way.

[14] End quarter dummy is used to capture adjustments in government budgetary accounts and banks deposits. The dummy variables for a) IRC and b) changes in corridor width take value of 0 for the period before the adoption of IRC framework (change in corridor width) and 1 otherwise.

[15] Not necessarily but after the SBP introduced the target policy rate in May 2015, the spread between overnight repo rate and SBP OMO intervention rate has become a kind of reflective of how credibly SBP implements its communicated monetary policy stance.

[16] See **Figure A2** for estimated conditional variance of overnight repo rate.

It is also evident from **Table 1** that all the dummies included in the variance equation for overnight repo rate are significant. The results reveal that near the end of reserve maintenance period (EMP), volatility in overnight repo rate on average increases as the financial institutions try to fulfill their reserves averaging obligation. The coefficients for IRC dummies (CORR) are found to be significant with negative sign. This describes the decline in levels of volatility in overnight repo rate after the introduction of IRC framework, and subsequent changes made in the IRC width by SBP.

5. Transmission of volatility of overnight repo rate along the yield curve

As mentioned earlier that unlike other regional and advanced economies central banks which are having the interest rate corridor framework, the statistics suggest that the level of realized volatility is relatively high in case of SBP. Is this volatility in money market overnight repo rate is transmitting to other interest rates in the term structure or not? To answer this question, similar to the model for overnight repo rate, following GARCH (1,1) model is estimated for 1-month, 3-month, 6-month, 12-month, 3-year, 5-year and 10-year PKRV rates;

$$\Delta r_t^i = \alpha^i + \sum_{j=1}^{p} \gamma_j^i \Delta r_{t-j}^i + \sum_{j=1}^{q} \eta_j^i \Delta o_{t-j} + \varepsilon_t^i \quad (3)$$

$$\varepsilon_t^i \sim N(0, \sigma^{2,i})$$

$$\sigma_t^{2,i} = \pi^i + \delta^i \varepsilon_{t-1}^{2,i} + \rho^i \sigma_{t-1}^{2,i} + \omega^i DX_t + \lambda^i \sigma_t^{2,ON} \quad (4)$$

In the mean equation (3) r_t^i denotes the nominal interest rate with maturity i = 1-month, 3-month, 6-month, 12-month, 3-year, 5-year and 10-year PKRV rates. In the variance equation (4) the fitted GARCH variance ($\sigma_t^{2,ON}$) from the money market overnight repo rate model is used as an explanatory variable for other market interest rates. The coefficient values for parameter λ^i captures the pass-through effect of volatility in overnight repo rate along the yield curve, which is the main objective of this study. Positive values for the coefficient confirm the translation of volatility in overnight repo rate to other interest rates of the term structure.

It is evident from the **Table 2** that in the mean equation, the impact of changes OMO rate is found to be significant for all maturities but with different magnitudes at different tenors.[17] However, the main focus of this study is the results of the variance equation for the selected market interest rates. In line with expectations, the dummies for calendar dates effects found to be mostly insignificant at longer tenors. However, the effect of IRC related dummies is quite visible at all tenors with high level of significance. Importantly, it can be observed from **Table 2** that the pass-through coefficient of

[17] In the initial estimations, the conditional variance of overnight repo rate obtained from the equation (2) is also included in equation (3) as an explanatory variable. However, the coefficient at each maturity is found to be insignificant which simply implies no role of conditional volatility in the overnight repo rate in determining the level of short and longer term market interest rates.

volatility from money market overnight repo rate along the yield curve (i.e. λ values) is found to be significant for all tenors. The results suggest that the magnitude of volatility transmission from overnight repo rate decreases for each high tenor on the yield curve.[18]

Table 2: Estimation Results for Other Interest Rates in the Term Structure

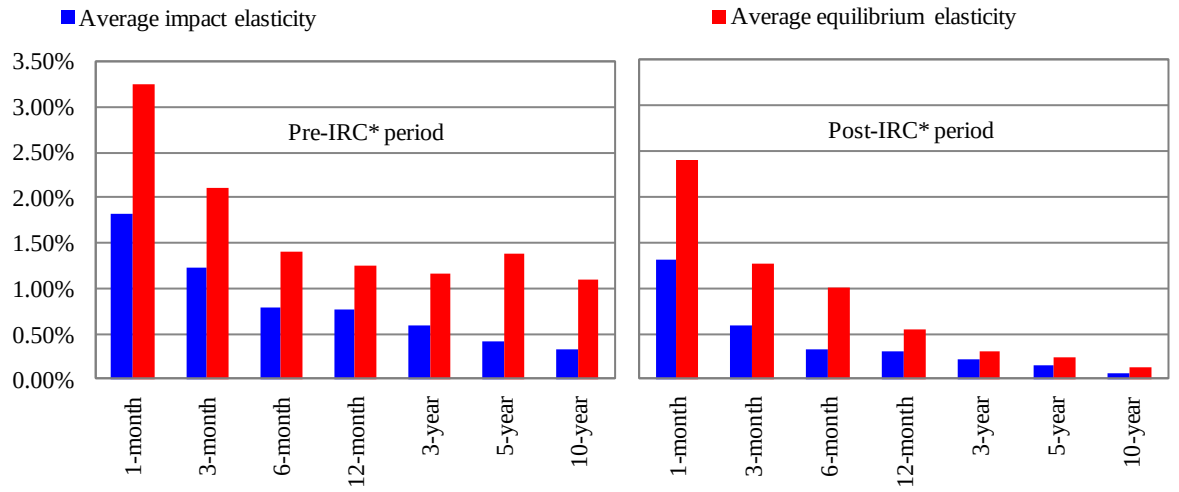
Parameter	1-month	3-month	6-month	12-month	3-year	5-year	10-year
Mean equation							
α	0.0866 ***	-0.0113 ***	0.0010 ***	0.0463 ***	0.0173 ***	0.0140 *	0.0925 *
γ_1	1.3694 ***	1.2914 **	1.3434 **	1.3259 **	1.5132 **	1.4641 **	1.3161 **
γ_2	-0.4925 ***	-0.2197 **	-0.4491 ***	-0.4382 ***	-0.7128 **	-0.5496 ***	-0.4601 **
γ_3	0.0622 **	-0.0752 ***	0.0422 **	-0.0100 ***	0.1382 *	0.0515 **	0.0267 **
η_1	-0.0640 **	0.0228 ***	0.0191 ***	0.0188 ***	0.0123 **	0.0109 **	-0.0004 **
η_2	0.1190 *	0.0020 **	-0.0046 ***	0.0334 ***	0.0061 **	-0.0099 **	0.0093 **
η_3	0.0500 ***	-0.0056 ***	0.0143 *	-0.0239 **	-0.0076 *	-0.0025 **	-0.0138 *
Variance equation							
π	0.2850 ***	-0.0008 ***	0.0592 ***	0.1422 ***	0.0182 ***	0.0643 **	0.0982 ***
δ	0.2484 ***	2.5410 ***	1.2396 ***	0.2492 ***	2.2156 ***	1.8536 ***	0.5354 ***
ρ	0.5122 ***	0.1128 ***	0.4006 ***	0.5743 **	0.0854 **	0.1199 ***	0.4810 ***
ω_{EMP}	0.0737 **	-0.0339 *	-0.0127 *	-0.0615	-0.0212	-0.0027	0.0006
ω_{EEMP}	-0.0575 *	0.0331	0.0115	-0.0421	-0.0954	0.0208	0.0063
ω_{EEEMP}	-0.0477	-0.0011	0.0000	0.0303	0.1426	0.0055	0.0271
ω_{EQ}	-0.0616	-0.0019 *	0.0023 *	0.0694 *	0.0798	-0.0076	0.0195
ω_{CORR}	-0.0515 ***	0.0073 **	-0.0478 ***	-0.0173 **	-0.0107 **	-0.0544 **	-0.0537 ***
ω_{250}	-0.0494 ***	0.0108 ***	0.0011 **	-0.0151 **	0.0845 **	0.0851 **	0.0107 *
ω_{200}	-0.0596 **	0.0455 **	-0.0053 *	-0.0135 **	-0.0258 *	-0.0383 *	-0.0203 *
λ	0.0085 ***	0.0071 **	0.0064 ***	0.0021 ***	0.0009 ***	0.0005 ***	0.0004 ***
$\delta + \rho$	0.7606	2.6539	1.6402	0.8235	2.3010	1.9735	1.0164

Note: Sample period is based on daily data from 3rd July 2006 to 30th September 2015; *, ** and *** denote statistical significance at 10, 5 and 1 percent (level of significance) respectively.

[18] However, the pass-through coefficients found in this study depict higher values even at longer end of the yield curve when compared to results of other countries following the same IRC framework for monetary policy implementation. For example, see Alonso and Blanco (2005), Bartolini and Prati (2006), Prati et. al. (2003), etc. As highlighted in the introduction, these differences might exist due to under developed nature and structure of money market in Pakistan compared to the more developed and efficient money markets in advanced economies.

Due to relatively higher volatility in overnight interest rates compared to other market rates, however, the estimated λ values are not considered as good measure for overnight volatility transmission along the yield curve.[19] Hence, two other adjusted measures were also calculated for getting the pass-through effect of overnight repo rate volatility transmission. The first calculates the average impact elasticity of overnight repo rate volatility and volatility of any particular tenor, computed as $\text{AIE} = \lambda^{i} \frac{\bar{\sigma}^{2,ON}}{\bar{\sigma}^{2,i}}$. The second measure calculates the average equilibrium elasticity and computed as $\text{AEE} = \frac{\lambda^{i}}{1-\rho^{i}} \frac{\bar{\sigma}^{2,ON}}{\bar{\sigma}^{2,i}}$.

Figure 3: Transmission of Volatility of Overnight Repo Rate along the Yield Curve - Pass-through Coefficient

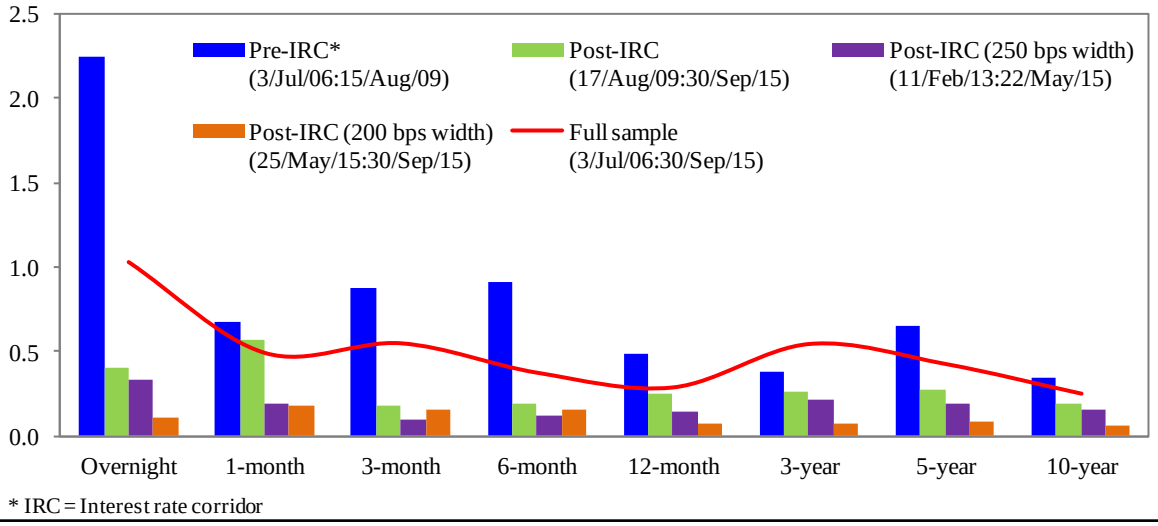


* IRC = Interest rate corridor

The results obtained from the computations of two adjusted measures of pass-through effect for both pre and post IRC are presented in **Figure 3**. The figure depicts that when both variances are at the average level, according to average impact elasticity approach in the pre IRC period, 1 percent increase in the variance of overnight repo rate increases the variance of 1-month PKRV rate by 1.8 percent compared to 1.3 percent in the post IRC period. Similarly, equilibrium elasticity approach suggest that due to a 1 percent increase in the variance of overnight repo rate in the pre IRC period, the variance of 1-month PKRV rate increases by 3.3 percent compared to 2.4 percent in the post IRC period. The pass-through impact decreases at longer maturities.

[19] See Colarossi and Zaghini (2009) for details.

Figure 4: Mean of Conditional Variance



* IRC = Interest rate corridor

Moreover, it can be observed from **Figure 4** that the average estimated conditional volatility in each selected market interest rate has significantly declined after the IRC framework implemented in August 2009 by SBP. In addition, the empirical results found after the reduction of IRC width from 300 bps to 250 bps in February 2013 and then to 200 bps in May 2015 also shows further decline in volatility in interest rates along the yield curve. These results are consistent with the objective of IRC implementation and have contributed in the reduction of unwarranted volatility spillovers across the yield curve. Our finding also suggest the smooth transmission of policy rate changes at shorter end of the yield curve to longer end after adoption of IRC framework.

6. Concluding remarks

Like most other central banks, SBP steers the short-term interest rates to give monetary policy signals in the economy. To achieve its objectives, the Bank tries to minimize the unnecessary volatility in the short-term rates by using its monetary policy instruments as excessive volatility in overnight repo rate may be transmitted along the yield curve and could impair the process of monetary transmission mechanism. In August 2009, SBP adopted the interest rate corridor (IRC) framework for its monetary policy implementation. The Bank also announced the money market overnight repo rate as its operational target with the purpose to avoid excessive volatility in the overnight repo rate. Since August 2009, subsequent changes have been introduced in the IRC framework to further reduce the unwarranted volatility in the overnight repo rate.

In this backdrop, this paper presents the empirical results of the volatility transmission of overnight repo rate along the yield curve in Pakistan. We find that, the transmission of unwarranted volatility spillover across yield curve has reduced after SBP adopted the IRC framework. In line with evidences found in other countries, we find that the volatility transmission of money market overnight repo rate in Pakistan is higher at the shorter end of the yield curve compared to the longer end. Also,

subsequent changes introduced in the SBP operational framework (for monetary policy) have improved the signaling mechanism of SBP's monetary policy stance to financial markets. Now, SBP policy rate changes are transmitted smoothly from shorter end to longer end of the yield curve.

References

Alonso, F. and Blanco, R. (2005) "Is the Volatility of the EONIA Transmitted to Longer-term Euro Money Market Interest Rates?", *Documentos de Trabajo* No. 541, Banco de Espagna.

Andersen, T. and Bollerslev, T. (1998) "Answering the Skeptics: Yes, Standard Volatility Models Do Provide Accurate Forecasts", *International Economic Review,* Vol. 39, pp. 885-905.

Ayuso, J., Haldane, A. G. and Restoy, F. (1997) "Volatility Transmission along the Money Market Yield Curve", *Weltwirtschaftliches Archive*, Vol. 133, pp. 56-75.

Bartolini, L. and Prati, A. (2006) "Cross-country Differences in Monetary Policy Execution and Money Market Rates' Volatility", *European Economic Review*, Vol. 50, pp. 349-376.

Benjamin H. C. (1999) "Monetary Policy Procedures and Volatility Transmission along the Yield Curve", CGFS Papers chapters, in: Bank for International Settlements (ed.), Market Liquidity: Research Findings and Selected Policy Implications, Vol. 11, pp. 1-22, *Bank for International Settlements*.

Bindseil, U. (2004a) "The Operational Target of Monetary Policy and the Rise and Fall of Reserve Position Doctrine", *ECB Working Paper* No. 372.

Bindseil, U. (2004b) "Monetary Policy Implementation: Theory-Past-Present", Oxford University Press, Oxford.

Bollerslev, T. (1986) "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, Vol. 31, pp. 307-327.

Cassola N. and Morana, C. (2006) "Volatility of Interest Rates in the Euro Area: Evidence from High Frequency Data", *The European Journal of Finance,* Vol. 12, pp. 513–528.

Christensen, B. and Prabhala, N. (1998) "The Relation between Implied and Realized Volatility", *Journal of Financial Economics*, Vol. 50, pp.125-150.

Colarossi, S. and Zaghini, A. (2009) "Gradualism, Transparency and the Improved Operational Framework: A Look at the Overnight Volatility Transmission", *Banca D'Italia Working Paper* No. 710.

Demiralp, S., Preslopsky, B. and Whitesell, W. (2006) "Overnight Interbank Loan Markets", *Journal of Economics & Business*, Vol. 58, pp. 67-83.

Disyatat, P. (2008) "Monetary Policy Implementation: Misconceptions and their Consequences", *BIS Paper* No. 269, Bank for International Settlements.

Durre, A. and Nardelli, S. (2008) "Volatility in the Euro Area Money Market: Effects from the Monetary Policy Operational Framework", *International Journal of Finance & Economics*, Vol. 13, pp. 307-322.

Engle, R. (1982) "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation", *Econometrica,* Vol. 50, pp. 987-1007.

Ewerhart, C., Cassola, N., Ejerskov, S. and Valla, N. (2004) "Sporadic Manipulation in Money Markets with Central Bank Standing Facilities", *ECB Working Paper* No. 399.

Ewerhart, C., Cassola, N. and Valla, N. (2005) "Equilibrium and Inefficiency in Fixed Rate Tenders", *ECB Working Paper* No. 554.

Gaspar, V., Perez-Quiros, G. and Sicilia, J. (2001) "The ECB Monetary Policy Strategy and the Money Market", *International Journal of Finance and Economics,* Vol. 6, pp. 325-342.

Kahn, G. A. (2010) "Monetary Policy under a Corridor Operating Framework", Federal Reserve Bank of Kansas City *Economic Review*, Fourth Quarter 2010, pp. 5-34.

Krause, S. and Rioja, F. (2006) "Financial Development and Monetary Policy Efficiency", *Emory University Working Paper,* September 2006.

Moschitz, J. (2004) "The Determinants of the Overnight Interest Rate in the Euro Area" *ECB Working Paper* No. 393.

Nautz, D. and Offermanns, C. J. (2007) "The Dynamic Relationship between the Euro Overnight Rate, the ECB's Policy Rate and the Term Spread", *International Journal of Finance and economics*, Vol. 12, pp. 287-300.

Perez-Quiros, G. and Mendizabal, H. R. (2006) "The Daily Market for Funds in Europe: What Has Changed with the EMU?", *Journal of Money, Credit, and Banking*, Vol. 38, pp. 91-118.

Prati, A., Bartolini, L. and Bertola, G. (2003) "The Overnight Interbank Market: Evidence from the G-7 and Euro Zone" *Journal of Banking and Finance*, Vol. 27, pp. 2045-2083.

Sarkar, S. and Ariff, M. (2002) "The Effect of Interest Rate Volatility on Treasury Yields", *Applied Financial Economics,* Vol. 12, pp. 667-672.

Sill, K. (1996) "The Cyclical Volatility of Interest Rates" Federal Reserve Bank of Philadelphia, *Business Review*, January 1996, pp. 15-29.

State Bank of Pakistan (2009) "Monetary Policy Statement: July-September 2009", *State Bank of Pakistan*, Karachi.

Whitesell, W. (2006) "Interest Rate Corridors and Reserves", *Journal of Monetary Economics*, Vol. 53, pp. 1177-1195.

Woodford, M. (2005) “Central Bank Communication and Policy Effectiveness”, *NBER Working Paper* No. 11898. Massachusetts: NBER.

Appendices

Table A1: Cross-country Comparison of Selected Central Banks' Operating Frameworks

Central bank	Policy rate	Operational target rate	Width of interest rate corridor (IRC)
Reserves Bank of Australia	Interbank cash rate	Interbank cash rate	50 basis points (bps)
Central Bank of Brazil	Selic rate	Selic rate - interest rate on overnight interbank loans collateralized	160 bps
Bank of Canada	Overnight rate	Overnight rate on collateralized transactions	50 bps
European Central Bank (ECB)	Minimum bid rate in MRO*	Euro Overnight Index Average (EONIA)[#]	50 bps
Reserve Bank of India	Repo rate	Weighted average call money rate	200 bps
Bank of Japan	Uncollateralized overnight call rate	Uncollateralized overnight call rate	-
Bank of Korea	Base rate	Overnight call rate	200 bps
Bank of Mexico	Interbank overnight rate	Interbank overnight rate	-
Riksbank	Repo rate	Interbank overnight rate	150 bps
Swiss National Bank	CHF 3-month Libor	Target range for 3-month Libor	-
Bank of England	Bank rate	Overnight rate	75 bps
Federal Reserve System	Federal Funds rate	Federal funds rate – uncollateralized	-
Bank of Thailand	1-day repurchase rate	1-day repurchase rate	100 bps
Central Bank of Turkey	1-week repo rate	No formal operational target	300 bps
Central Bank of Philippines	Rates on standing facilities	No formal operational target	200 bps
Bank Indonesia	Bank Indonesia (BI) rate	Interbank overnight rate	200 bps
State Bank of Pakistan	**SBP target rate****	**Money market overnight repo rate**	**200 bps**

* main refinancing operations; [#] Not formally announced operational target

** up till May 2015, the SBP used reverse repo rate (ceiling rate of IRC) as a policy rate without any target rate

Source: Central banks' websites, BIS

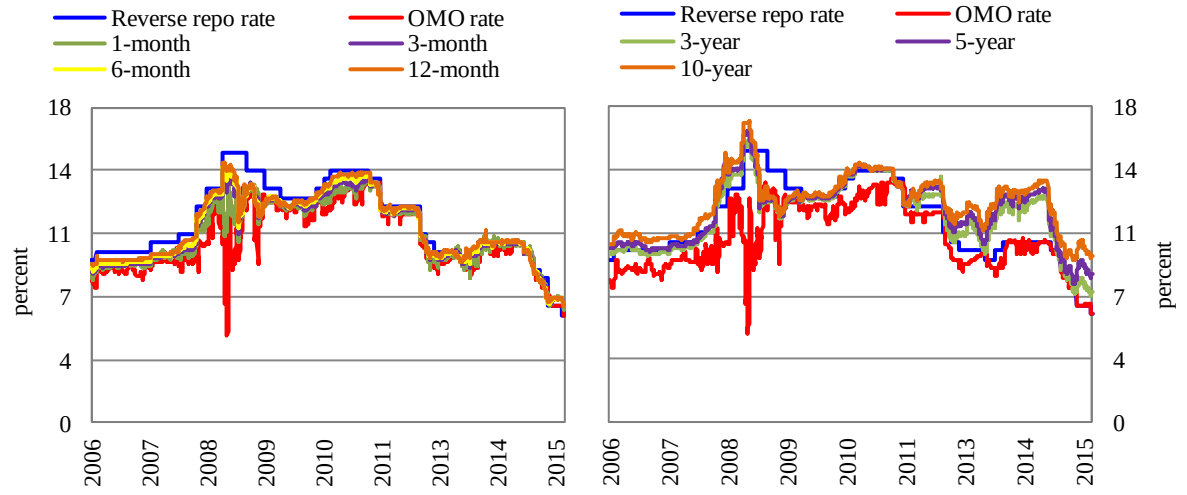
Table A2: Simple Statistics of Selected Interest Rates

Series	Mean	Median	Maximum	Minimum	Standard Deviation
OMO rate	10.17	9.89	13.51	4.88	1.81
Overnight repo rate (ONR)	10.11	9.74	14.28	4.26	1.89
1-month	10.54	10.04	13.53	6.33	1.75
3-month	10.66	9.98	13.83	6.46	1.83
6-month	10.76	10.01	14.22	6.50	1.89
12-month	10.87	10.11	14.48	6.53	1.92
3-year	11.49	12.00	15.62	7.00	1.84
5-year	11.80	12.33	16.11	7.65	1.76
10-year	12.19	12.48	16.65	8.94	1.58
Spread (ONR-OMO rate)	-0.07	-0.02	3.24	-5.21	0.75

Data sample: 2486 observations (3rd July 2006 to 30th September 2015)

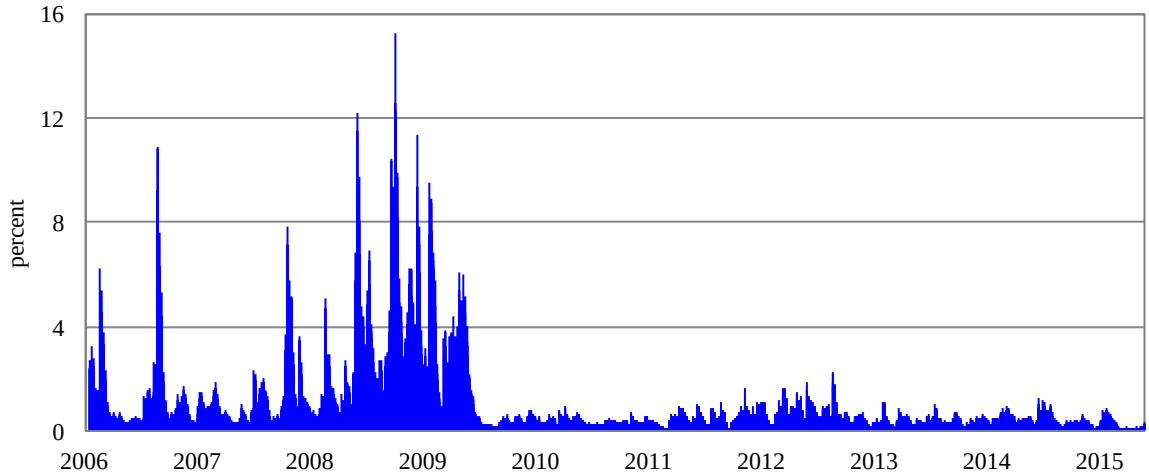
Source: SBP, Financial Markets Association of Pakistan, author's calculations

Figure A1: SBP's Key Interest Rates and PKRV Rates



Source: SBP, Financial Markets Association of Pakistan, author's calculations

Figure A2: Overnight Repo Rate - Conditional Variance



Author's calculations