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Bond Markets - Dirt In The “Clean” Price

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Abstract

Bond market pricing follows age-old and time-honoured principles of corporate finance and present value. A dealer of fixed income securities focuses on yield, and the price is calculated by using the PV principle. Accuracy is taken for granted. However the whole concept of bond mathematics makes a number of assumptions, which are not necessarily realistic.

The author finds two discrepancies in the calculation of dirty price and accrued interest which causes the clean price to be distorted. He shows how and why the formulae used are incorrect, and that the present value factor is over-estimated by the use of inappropriate formulae. This results in over-payment of the dirty price to the seller. Within the dirty price, there is over-payment on account of accrued interest, with the issue being that often full accrued interest is paid instead of its present value. Both these factors distort the clean price leading to improper accounting of the transactions.

The author suggests a modified compounding formula to rectify the distortions. Both the existing and suggested formulae have been tested for their accuracy. The author concludes by discussing comparative advantages of using the modified compounding formula, and the practical implications for fixed income fund managers.

Persons dealing in fixed income securities will know that if the coupon matches the yield required by the market the price will be 'at par' (face value). Subsequent to the issue of a coupon bond, the price (clean price) will continue to be 'at par' as long as there is no change in the required yield. On the contrary, if the market yield rises, the clean price will fall below par and vice versa. Persons connected with fixed income securities market also know that the seller of a bond in the secondary market is entitled to receive accrued interest apart from the clean price. Even when there is no change in the market yield and clean price, the settlement price (dirty price) will undergo change because of accrued interest. While dealing in secondary market, the counterparties mainly look at the yield leaving the calculation of clean price, accrued interest and settlement price to the computer. Surprisingly, what is paid to the seller on account of accrued interest is on a higher side and more importantly the overall settlement price paid to the seller is always over-estimated. The purpose of this article is to analyze and explain as to how and why the calculations are incorrect leading to over-payment to the seller and how to rectify the distortions.

The discussions in this article are arranged in the following order:

- Identification of distortions in dirty price, accrued interest and consequently clean price and the reasons as to why and how the distortions arise.
- Suggested formula to rectify the distortions.
- Testing the existing and suggested formulae for their accuracy.
- Comparative advantages of the suggested formula.
- Implications for fund managers.
- For the benefit of uninitiated readers, basics of dirty price, accrued interest and clean price and underlying principles of simple and compound interest are explained in Appendix A.

Dirt In The Clean Price

Clean Price = Dirty Price – Accrued Interest

The basics of dirty price, accrued interest and clean price are discussed in Appendix A. Clean price is supposed to reflect the intrinsic value of a bond and only the change in the required rate of return based on market yield movement should change the clean price. However, at times clean price used to be distorted by certain market practices. One such market practice was 'voucher element' prevailing in India upto June 1997. The buyer used to deduct certain percentage of accrued interest as 'voucher' (tax) and pay lesser accrued interest to the seller but would not pass on tax deduction certificate to the seller for claiming tax credit. To compensate the loss, the seller used to increase the clean price of the bond by an amount equal to the voucher element (Boovendran 1992, 175-181). Clean price would increase steadily from one coupon payment date to the next coupon payment date on account of voucher element. Since voucher element got loaded into the price, the prices for government securities quoted in the secondary market were not clean and the calculation of yields on government securities got distorted. Abolition of Tax Deducted at Source (TDS) with effect from June 1997 ended distortion in the clean price and facilitated quotations at real 'clean price' (Rangarajan 1997, 25).

Even now clean price is not as clean as one would like it to be. It is still dirty and distorted because of two reasons viz. (1) over-payment on account of accrued interest and (2) over-estimation of dirty price.

1. Over-Payment On Account Of Accrued Interest

Accrued interest is calculated from the last coupon payment date till the settlement date on simple interest basis and deducted from dirty price to arrive at clean price (Fabozzi 2011, 31-32; Burghardt et al 1994, 9; and Choudhry 2006, chap.1, para 1.2.2). Deducting full accrued interest from the dirty price does not stand to logic for the following reasons:

a. The seller of a bond is entitled for the interest accrued from the last coupon payment date upto the settlement date. The interest has just accrued and it is due for payment only on the next coupon payment date. The concept of time value of money is well recognized in securities market. If the seller is to be paid accrued interest on the date of settlement itself, then present value (PV) of accrued interest can only be paid and not the full accrued interest.

b. Dirty price exchanged between buyer and seller is calculated from the future cash flows. Among the future cash flows, the immediate next coupon inflow belongs to seller and buyer in the proportion of their holding periods in the coupon period. Since dirty price is the PV of future cash flows, payment on account of accrued interest should be also PV of accrued interest and not its future value.

c. Paying discounted accrued interest does not mean that the seller will end up receiving less. Accrued interest component in the dirty price will be less and the clean price component will be more to that extent. The seller will in any case receive the full amount of dirty price.

d. When the settlement is on the coupon payment date, there is no accrued interest and the dirty price and clean price are one and the same. When the required rate of return remains the same, the dirty price increases every day due to increase in accrued interest. The increase in dirty price as on a settlement date over that of last coupon payment date is equal to the PV of accrued interest. The increase in dirty price only be logically paid to the seller as accrued interest.

e. By paying full accrued interest instead of its PV, the clean price is distorted. What is paid more in the name of accrued interest is adjusted by paying less clean price.

Over payment on account of accrued interest does not result in undue enrichment to the seller or undue loss to the buyer. However, accrued interest is accounted as revenue receipt by the seller and revenue expenditure by the buyer. Clean price is accounted as capital receipt by the seller and capital expenditure by the buyer. Therefore, for correct accounting, the accrued interest and clean price need to be calculated correctly.

Suggested Remedy

In order to get rid of the distortion in clean price due to over-payment on account of accrued interest, the computation of clean price be modified as under:

Clean Price = Dirty Price – PV of Accrued Interest

PV of Accrued Interest = Accrued Interest * PV factor

(The way in which market is calculating the PV factor is found to be defective as per the reasonings given in the forthcoming paragraphs. A new formula has been suggested to arrive at a correct PV factor and the same may be used to calculate the PV of accrued interest).

2. Over- Estimation Of Dirty Price

Over-estimation of dirty price not only distorts clean price but also results in over- payment to the seller by the buyer. It warrants a deep and careful analysis. Dirty price is the total of present values of future cash flows. Future cash flows multiplied by relevant PV factors will give present values of future cash flows. As coupon on government securities is paid on semi-annual basis, half-yearly compounding formula is used to calculate future value and PV factor (inverse of future value). The concept of simple interest and compound interest is discussed in detail in Appendix A.

PV factor (traditional compounding) $= 1 / (1 + R)^{N}$
where,

R = Required rate of return per Re.1 per Half-year (HY)
N = Period in HY

When the settlement takes place on coupon payment dates, the cash flow periods will be in whole number of half-years and the present value calculated using traditional compounding formula is perfectly alright. However, when a settlement date falls on a date other than the coupon payment date, the first cash flow after settlement date occurs at the end of a fractional half-year and the accepted method for computing the price of the bond is as follows (Fabozzi 2011, 29):

$$P = \sum_{t=1}^{n} \frac{c}{(1+r)^{v}(1+r)^{t-1}} + \frac{M}{(1+r)^{v}(1+r)^{t-1}}$$

where,
P = price of the bond
c = semi-annual coupon payment
M = maturity value
r = periodic interest rate (required annual yield divided by 2)
v = (days between settlement and next coupon) / (days in six-month period)
t = time period when the payment is to be received
n = number of periods (number of years times 2)

When the period from the settlement date and the maturity date is less than six months, the above equation reduces to equation as below:

$$P = \frac{c + M}{(1+r)^{v}}$$

$$P = (c + M) * \frac{1}{(1+r)^{v}}$$

$$(c + M) \text{ is cash flow and } \frac{1}{(1+r)^{v}} \text{ is PV factor.}$$

In the above formula 'v' is fractional half-year. Whether the period is in whole number of half-years or fractional half-year, the compound interest formula used for PV factor is the same. Use of traditional compounding formula is found to under-estimate the future value resulting in over-estimation of PV factor and present value of future cash flows (dirty price) (Illustration 3 and 4 in Appendix A). How the future value is under-estimated by the traditional compounding formula is explained below:

Illustration 5:

Required rate of return	= 7.2% p.a. or 3.6% per HY
Maturity date (MD)	= 09-04-2021
Last coupon date (LCD)	= 09-10-2019
Next coupon date (NCD)	= 09-04-2020
Settlement date (SD)	= 09-01-2020, 09-02-2020
For SD 09-01-2020, period from SD to NCD	= 3 months (½ HY)
For SD 09-02-2020, period from SD to NCD	= 2 months (⅓ HY)

First cash flow period is from settlement date to next coupon date and that is a fractional half-year. Future value of Re.1 invested on the settlement date 09-01-2020 will be Re.1 *plus* interest for 3 months. Since interest is capitalized once in six months, the question of capitalization of interest (compounding of interest) ought not arise. It may be noted that government bonds having residual maturity of less than six months are priced as money market instruments using simple interest formula.

Interest for 3 months will have to be calculated on simple interest basis and that will be Re. 0.018. However, interest calculated for 3 months by using compound interest formula is only Re. 0.0178409 and with principal, the future value at the end of 3 months is Rs. 1.0178409. If the period is 2 months (settlement date 09-02-2020) the simple interest is Re.0.012 but compound interest formula gives only Re.0.011859 as interest. Compounding of interest is supposed to give more interest than simple interest because of interest on interest but when the period is less than one, compounding of interest gives less interest than simple interest. Half-yearly compounding of interest does not mean interest at lesser rates for periods less than six months.

The root cause for the under-estimation of future value is that the compound interest formula considers a lower required rate of return. In the given case under illustration 5, the required rate of return to be considered is 7.2% p.a. or 3.6% per half-year. How the compound interest formula calculates interest for different periods which are less than six months is explained in Exhibit 1. When the period from settlement date (SD) to the next coupon date (NCD) is 3 months, traditional compounding formula rightly calculates:

(i) simple interest,
(ii) on a principal of Re.1 and
(iii) for a period of 3 months.

However, interest is calculated at the rate of 7.1363% p.a. instead of 7.2% p.a. What is the link between 7.1363% and 7.2% is also explained in column 6 to 9 of Exhibit 1. It is assumed that interest is capitalized every 3 months and interest on interest is calculated for a period of six months. The rate of interest considered by the formula is such that, at the end of six months the principal + interest (compounded every 3 months) is equal to the principal + interest at the rate of 7.2% p.a. (compounded half-yearly). To illustrate:

Principal	= Re.1
Simple interest for 3 months at 7.1363% p.a. on Re.1	= Re.0.017841
Principal after capitalization of interest	= Rs.1.017841
Interest for 3 months at 7.1363% p.a. on Re.1.017841	= Re.0.018159
Principal + interest at the end of 6 months	= Rs.1.036000
Half-yearly compound interest at 7.2% p.a. for 6 months	= Re.0.036000

Exhibit 1: How compound interest formula calculates interest for fractional half-year

Required rate of return: 7.2% p.a.								
Period from SD to NCD	Interest calculated			Principal + Interest At the end of period in (3)	How the rate is linked to 7.2% p.a			Principal + Interest @ 7.2% p.a (compounded half-yearly) at the end of period in (7)
	On principal of Rs.	For a period of	At a rate of (simple interest % p.a)		Capitalize interest every	Calculate interest on interest for a period of	Principal + Interest at the end of period in (7)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3 months	1.000000	3 months	7.1363	1.017841	3 months	6 months	1.036000	1.036000
2 months	1.000000	2 months	7.1153	1.011859	2 months	6 months	1.036000	1.036000
1 month	1.000000	1 month	7.0943	1.005912	1 month	6 months	1.036000	1.036000
1 day	1.000000	1 day	7.0741.	1.000197	1 day	6 months	1.036000	1.036000
4 months	1.000000	4 months	7.1575	1.023858	4 months	12 months	1.073296	1.073296
5 months	1.000000	5 months	7.1787	1.029911	5 months	30 months	1.193435	1.193435
6 months	1.000000	6 months	7.2000	1.036000	6 months	6 months	1.036000	1.036000
Note: Day count followed is 30/360 E								

Interest is assumed to be capitalized at different intervals (column 6 of Exhibit 1). Only when the settlement date is equal to the coupon payment date, the interest is assumed to be capitalized once in six months. Depending upon the assumed frequency of capitalization, the required rate of return considered by the formula varies (column 4 of Exhibit 1) and the rates considered are always less than the required rate. This is how traditional compounding formula considers lower required rates of return and under-estimates the future value when the periods from settlement date to the next coupon date are fractional half-years.

When interest is required to be received once in six months, the buyer gets the first interest in 3 months. Present value calculations should take cognizance of this fact. For that, it is not necessary to use compound interest formula. Simple interest formula can also do that and more appropriately. It may be noted that for calculating **accrued interest** for the period **from last coupon date to settlement date, simple interest formula** is used. For calculating interest for the period **from settlement date to next coupon date** so as to arrive at future value and PV factor, **compound interest formula** is used. The principle and logic followed presently are dichotomous.

Suggested Formula For Correct Calculation Of PV Factor

For bonds having cash flow periods in fractional half-years: When a settlement date falls on a date other than coupon payment date, the first cash flow will happen at the end of a fractional half-year like ⅓ HY(2 months), 7 /180 HY(7 days), etc. and subsequent cash flow periods will be also fractional half-years like 1⅓ HY, 2 ⅓ HY, etc. As discussed earlier, interest is not capitalized for periods upto one half-year and therefore, when the period is upto six months, future value ought to be calculated using simple interest formula.

Illustration 6:

If R is 7.2% p.a. or 3.6% per HY or 0.0002 per Re.1 per day; and the cash flow periods are in fractional half-years like ⅓ HY, 1 ⅓ HY, 2 ⅓ HY, etc.:

Future value at the end of ⅓ HY:

Future value (Simple interest) $= P * (1 + R * N)$ ---------- (1)

where,

P = Principal
R = Required rate of return per Re.1 per HY
N = Period in HY

Future value of Re.1 at the end of ⅓ HY (2 months) $= 1 * \left(1 + 0.036 * \frac{1}{3}\right)$

$= 1.012$

Future value at the end of 1 and ⅓ HY:

On the principal of $1 * \left(1 + 0.036 * \frac{1}{3}\right)$ at the end of ⅓ HY, simple interest will be calculated for 1HY.

Future value of Re.1 at the end of 1 and ⅓ HY $= 1 * \left(1 + 0.036 * \frac{1}{3}\right) * (1 + 0.036 * 1)$

$= 1 * \left(1 + 0.036 * \frac{1}{3}\right) * (1 + 0.036)$

$= 1.048432$

Future value at the end of 2 and ⅓ HY:

On the principal of $1 * \left(1 + 0.036 * \frac{1}{3}\right) * (1 + 0.036)$ at the end of 1 and ⅓ HY, simple interest will be calculated for 1HY.

Future value of Re.1 at the end of 2 and ⅓ HY $= 1 * \left(1 + 0.036 * \frac{1}{3}\right) * (1 + 0.036) * (1 + 0.036)$

$= 1 * \left(1 + 0.036 * \frac{1}{3}\right) * (1 + 0.036)^2$

$= 1 * (1 + 0.036)^2 * \left(1 + 0.036 * \frac{1}{3}\right)$

$= 1.086176$

When the cash flow periods are in fractional half-years, each period is to be bifurcated into a whole number period and a fractional period and future value is to be logically calculated using simple interest formula for the fractional half-year and compound interest formula for the whole number of half-years.

For bonds having cash flow periods in fractional half-years:

Future value $= P * ((1 + R)^{INT(N)}) * (1 + R * (N - INT(N)))$ ---------- **(5)**

PV factor $= 1/((1 + R)^{INT(N)}) * (1 + R * (N - INT(N)))$ ---------- **(6)**

where,

P = Principal
R = Required rate of return per Re.1 per HY
N = Period in HY
INT (N) = Integer of N (whole number)

The above suggested formula is a combination of half-yearly compounding and simple interest formulae. The formula is appropriate not only for bonds having cash flow periods in fractional half-years but also for bonds having cash flow periods in whole number of half-years. When the cash flow periods are in whole number of half-years, (N – INT(N)) becomes zero and future value is calculated by using only half-yearly compounding.

N = 3 HY

INT(N) = 3

Future value $= P * ((1 + R)^{INT(N)}) * (1 + R * (N - INT(N)))$

$= P * ((1 + R)^3) * (1 + R * (3 - 3))$

$= P * ((1 + R)^3) * (1 + R * 0)$

$= P * ((1 + R)^3) * 1$

$= P * (1 + R)^3$

When the cash flow periods are less than 1 HY, INT(N) becomes zero and future value is calculated by using only simple interest.

N = 117 days = 0.65 HY

INT(N) = 0

Future value $= P * ((1 + R)^0) * (1 + R * (0.65 - 0))$

$= P * 1 * (1 + R * 0.65)$

$= P * (1 + R * 0.65)$

In other cases, including bonds having odd coupon period at the beginning or at the end, future value is calculated by using both half-yearly compounding and simple interest formulae.

N = 25.7 HY

INT(N) = 25

Future value $= P * ((1 + R)^{25}) * (1 + R * (25.7 - 25))$

$= P * ((1 + R)^{25}) * (1 + R * 0.7)$

The suggested formula may be called as **'modified compounding'** formula and the traditional compound interest formula which is used at present may be called as **'traditional compounding'** formula.

Future value (traditional compounding) $= P * (1 + R)^N$ ---------- (3)

PV factor (traditional compounding) $= 1/(1 + R)^N$ ---------- (4)

Future value (modified compounding) $= P * ((1 + R)^{INT(N)}) * (1 + R * (N - INT(N)))$ ---------- (5)

PV factor (modified compounding) $= 1/((1 + R)^{INT(N)}) * (1 + R * (N - INT(N)))$ ---------- (6)

Cash flow * PV factor = Present value of cash flow

Total of present value of all cash flows = Dirty price

Instances of using compound interest and simple interest formulae for price calculation: Indiscriminate use of compound interest formula is the cause for distortion of clean price. It is prudent to modify the formula as warranted by the situation. A typical example is the definition given by ISDA for INR-FBIL-MIBOR-OIS-COMPOUND. MIBOR-OIS is an interest rate derivative product for exchanging floating rate (MIBOR) for a fixed rate. For pricing the interest rate swap, the floating leg interest is capitalized on daily basis (daily compounding). However, during week-end holidays and other holidays, only simple interest is calculated and capitalized at the end of holiday period (FIMMDA 2016, 35-36). Thus, interest is calculated both on compound interest basis and simple interest basis for valuing the 'daily compound interest investment'.

Similarly, for pricing bonds having cash flow periods in fractional half-years modified compounding formula as suggested above may be used.

Accuracy Test: Traditional And Modified Compounding Formulae

When the coupon rate is equal to the required yield, the price of the bond will be equal to its par value (Fabozzi 2011, 26 -27).

$$\text{Coupon Rate} = \text{Required Yield} \leftrightarrow \text{Price} = \text{At Par}$$

Both traditional and modified compounding formulae give some future value, PV factor and dirty price. To find out as to which formula is giving accurate results, the above rule is applied. Using traditional and modified compounding formula, clean price is calculated for various settlement dates for a bond having coupon equal to the required rate of return. If the coupon is more or less than the required rate of return, the clean price will be influenced by amortization of premium and accrual of discount and testing the accuracy of a pricing formula will become difficult.

Illustration 7:

Face Value	= Re.1
Coupon	= 7.2% p.a. or 3.6% per HY
Required rate of return (R)	= 7.2% p.a. or 0.036 per Re.1 per HY
Maturity date (MD)	= 09-04-2021
Last coupon date (LCD)	= 09-10-2019
Next coupon date (NCD)	= 09-04-2020
Settlement date (SD)	= 18 different dates

Dirty prices calculated using traditional compounding formula for a bond described in illustration 7 are given in Exhibit 2 in Appendix B. Cash flow dates, source of cash flow and amount of cash flow are given at the top. For each settlement date, the period (N) is calculated as cash flow date minus settlement date. Principal (P) is Re.1 for future value calculations. Using traditional compounding formula, the PVs of future cash flows are calculated and summed up to arrive at the dirty price. Exhibit 3 in Appendix B gives the dirty prices calculated using modified compounding formula. It may be observed from Exhibit 2 and 3 that the dirty prices calculated using traditional compounding formula are more as compared to that of modified compounding formula.

In Exhibit 4 in Appendix B, accrued interest for each settlement date has been calculated. Accrued interest multiplied by PV factor (modified compounding formula) gives PV of accrued interest. From the dirty prices calculated using traditional and modified compounding formulae, two clean prices each were calculated:

(i) Clean price by deducting full accrued interest from the dirty price.
(ii) Clean price by deducting PV of accrued interest from the dirty price.

Since the coupon is equal to the required rate of return, clean price is expected to be 'at par'. From Exhibit 4 it may be observed as under:

- When settlement takes place on coupon payment dates, the clean prices calculated using both the formulae are 'at par'.
- When the settlement dates are other than coupon payment dates (cash flow periods in fractional half-years):
    - Clean prices calculated using traditional compounding formula are below par if full accrued interest is deducted from dirty price and above par if PV of accrued interest is deducted.
    - Clean prices calculated using modified compounding formula are below par if full accrued interest is deducted from dirty price. Clean prices are below par to the extent of difference between accrued interest and PV of accrued interest.
    - If PV of accrued interest is deducted from dirty prices calculated using modified compounding formula, the resultant clean prices are always exactly 'at par'.

Thus, when tested by applying the rule that clean price will be 'at par' when coupon is equal to the required rate of return, the modified compounding formula passes the test while the traditional compounding formula fails.

It is, therefore, evident that **the clean price can be calculated accurately** and the existing **distortions can be rectified**, provided:

(i) dirty price is calculated using the suggested modified compounding formula; and
(ii) PV of accrued interest is deducted from the dirty price.

Comparative Advantages Of Using Modified Compounding Formula

a. Correct consideration of required rate of return

As seen in Exhibit 1, traditional compounding formula under-estimates the future value by considering lesser required rates of return. On the contrary, calculating future value by using modified compounding formula uniformly considers required rate of return of 7.2% p.a. and simple interest is calculated if the cash flow periods are less than six months (Exhibit 5).

Exhibit 5: How modified compounding formula calculates interest for fractional half-year

Required rate of return: 7.2% p.a.

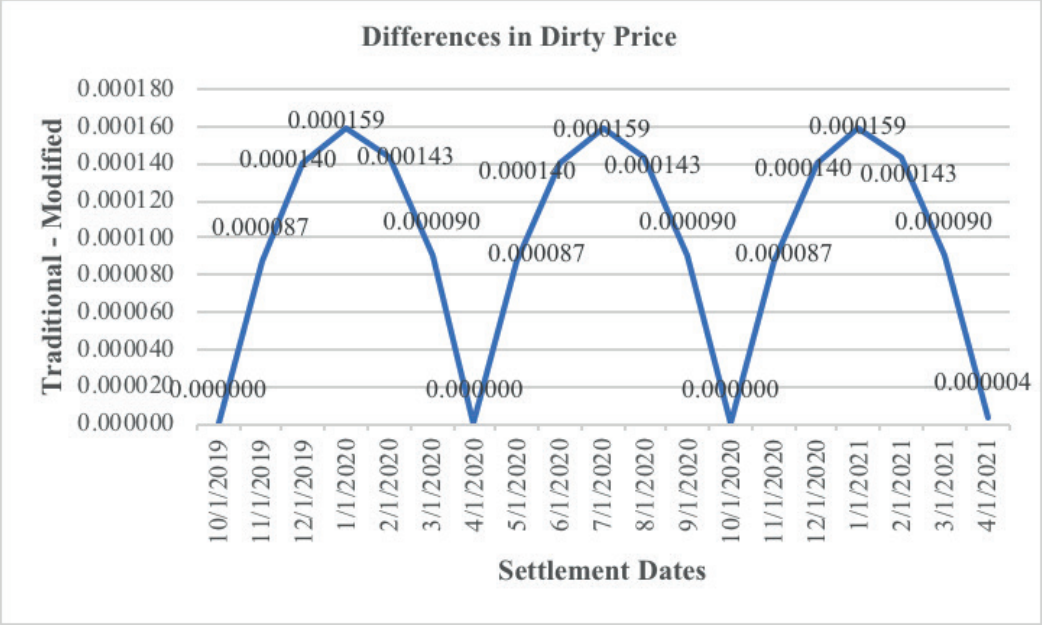
Period from SD to NCD	Interest is calculated			Principal + Interest at the end of period in (3)
	On principal of Rs.	For a period of	At a rate of (simple interest % p.a.)	
(1)	(2)	(3)	(4)	(5)
1 day	1.000000	1 day	7.2000	1.000200
1 month	1.000000	1 month	7.2000	1.006000
2 months	1.000000	2 months	7.2000	1.012000
3 months	1.000000	3 months	7.2000	1.018000
4 months	1.000000	4 months	7.2000	1.024000
5 months	1.000000	5 months	7.2000	1.030000
6 months (1 HY)	1.000000	6 months	7.2000	1.036000
6 months & 1 day	1.036000	1 day	7.2000	1.036207
9 months	1.036000	3 months	7.2000	1.054648
11 months & 29 days	1.036000	5 months & 29 days	7.2000	1.073089
12 months (2HY)	1.036000	6 months	7.2000	1.073296
13 months	1.073296	1 month	7.2000	1.079736
Note: Day count followed is 30/360 E				

Interest is capitalized at the end of six months and for periods above six months simple interest is calculated on the new principal but the required rate remains the same. Like this capitalization of interest takes place every six months and for in between periods simple interest is calculated at the required rate of return.

b. Arbitrage opportunity

An ideal pricing formula or methodology should be arbitrage free. Having established that the prices calculated using modified compounding formula are accurate, it may be observed from Exhibit 4 in Appendix B, that the dirty prices calculated using traditional compounding formula for different settlement dates are higher than that of modified compounding formula. The over-estimation of dirty price is uneven as depicted in Exhibit 6 below:

Exhibit 6: Differences in Dirty Prices calculated by using Traditional and Modified Compounding

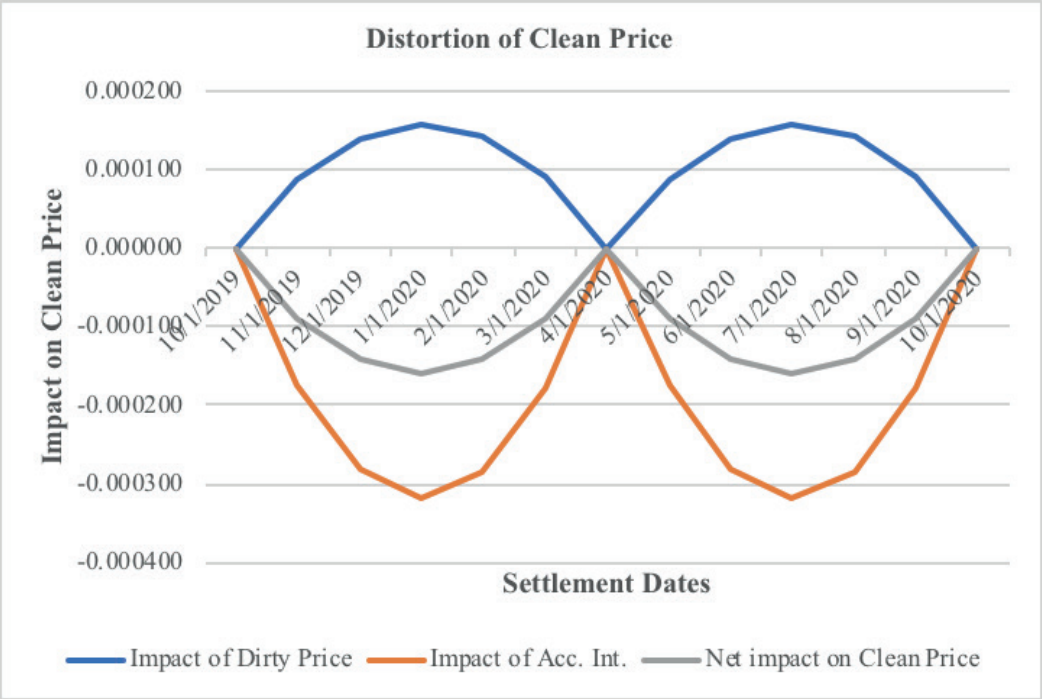


In a coupon period of 180 days, the difference will be Nil if the settlement date is at the start of the coupon period; will increase and reach its peak when the settlement date is 90 days from the coupon payment dates (LCD as well as NCD); will diminish and reach Nil level at the end of the coupon period. One can buy a bond nearer to coupon payment dates and sell around middle of the coupon period to take advantage of price difference. **Thus, traditional compounding formula not only over-estimates the dirty price but also provides an arbitrage opportunity.**

Combined Impact On Clean Price

Over-estimation of dirty price will artificially increase the clean price. Over-payment on account of accrued interest will decrease the clean price. The combined effect of both on the clean price is explained in Exhibit 7 in Appendix B and Exhibit 8 below:

Exhibit 8: Over-estimation of Dirty Price and Accrued Interest – Impact on Clean Price



When the coupon and required rate of return are 3.6% per HY, the net impact on clean price is negative and the impact is maximum when the settlement takes place around middle of the coupon period as shown in Exhibit 8. For other combinations of coupon and yield rates the differences will change as given in Exhibit 9 in Appendix B.

- For various combinations of coupon and yield, the dirty price is always overestimated by using traditional compounding formula.
- PV of accrued interest is always lower than the accrued interest for various combinations of coupon and yield.
- The combined net impact on clean price is negative, zero or positive for different combinations of coupon and yield.

Implications For Fund Managers

Thanks to the computerization of trading and settlement, the transaction costs have come down considerably. Traders are looking for a margin as narrow as less than Re.0.01. The 'tick' size of an order is 0.0025 for bonds having face value of Rs.100. When the coupon and yield are 7.2% p.a., over payment on account of accrued interest can go upto Rs.0.0318, which is more than 12 'ticks' and over payment to the seller due to over-estimation of dirty price can go upto Rs.0.0159, which is more than 6 'ticks. The existing distortions in clean price can, therefore, be considered as significant to a trader.

Materiality apart, there can be no justification:

(i) for using compound interest formula where simple interest formula is to be used.
(ii) for unduly enriching the seller.
(iii)for paying full accrued interest when the entitlement is only PV of accrued interest.

Besides, the traders will cease to get the arbitrage opportunities provided by the traditional compounding formula.

Conclusion

Bond pricing involves complex mathematical formulae. When bond prices and yields were calculated manually with the help of ready reckoners, compromising accuracy was understandable. When computers are available with every person dealing in bonds, there should not be any compromise with accuracy. The mathematical formulae used for calculating bond prices and yields ought to be accurate, appropriate, logical and arbitrage free. Traditional compounding formula which is widely used across various jurisdictions is found to over-estimate the dirty price. The clean price is positively impacted. Present practice of over-payment on account of accrued interest negatively impacts the clean price. As a result, the clean price is still distorted and not really clean. Modified compounding formula suggested in this article for calculating bond price will ensure distortion free clean price and payment of correct consideration to the seller by the buyer. Modified compounding formula can be used to calculate dirty price and clean price accurately for bonds paying periodic coupon and settled in between or on coupon dates. The same formula can be used for bonds with odd coupon periods and other fixed income securities having coupon payments at irregular intervals as well.

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Appendix A

Basics Of Dirty Price, Accrued Interest And Clean Price

Need For A Price

For settlement of a transaction involving transfer of ownership of any commodity or financial instrument, price is required. Price discovery, which is essential for orderly development of a market, is enabled by quotes of prices which are simple, transparent and indicative of the intrinsic value of the economic interest transferred. The discussions are based on government securities market in India but the principles are applicable in any other market.

Dirty Price And Accrued Interest

Total amount that the buyer of a bond must pay to its seller is called as consideration amount, settlement price, full price or all-in-one price. The settlement price is a function of (i) future cash flows (coupon and redemption amount) (ii) periods of future cash flows (coupon frequency and time to maturity) and (iii) required rate of return (market yield). For a given market yield, if more amounts are received in lesser periods the settlement price will be more and vice versa.

If the settlement day happens to be the coupon payment date, coupon upto the date of settlement would have been directly paid to the seller by the issuer. All future cash flows would belong to the buyer. For the settlements taking place in between coupon payment dates, the seller is the owner of the bond upto the date of settlement and hence he is entitled to receive the coupon from the last coupon date till the settlement date (accrued interest).

When the bonds are held in demat form and the settlement of funds and securities are carried out electronically, it is possible for an issuer to know who were all holding a bond during the coupon period and the period of holding by each holder. On coupon payment date, the issuer can pay the coupon to the holders in proportion to their period of holding. In that case, all the future cash flows will belong to the buyer only and the bond can be priced accordingly. However, the prevailing market practice is issuer paying coupon for the full coupon period to whosoever is holding the security on coupon payment date and the buyer paying accrued interest to the seller on settlement date. The buyer pays the accrued interest first and receives it subsequently on the next coupon payment date.

The settlement price paid by the buyer to the seller, therefore, consists of the actual price of a bond *plus* accrued interest. With every passing day, the accrued interest will increase and consequently the settlement price will also increase. The quantum of such increase is predictable. The actual price of the bond will also undergo change because of market forces like change in market yield, demand, supply, etc. Inclusion of accrued interest in the settlement price mars the actual price movement in a bond. Even when the market is steady and the actual price of the bond remains constant, the settlement price will steadily increase from the last coupon date to the next coupon date. The settlement price does not indicate to the seller whether the bond is 'in the money' or 'out of money'. The settlement price which has embedded accrued interest is, therefore, called as 'dirty price' also.

Clean Price:

Clean price (also known as flat price) of a bond is the price that does not take into account the accrued interest.

Clean Price = Dirty Price – Accrued Interest

Market participants prefer clean price for the following reasons:

(i) For coupon bonds, clean price will be 'at par' when the coupon is equal to the required rate of return (yield). If the coupon is more than the yield, the clean price will be above par (bond quoting at premium) and if the coupon is less than the yield the clean price will be below par (bond quoting at discount). Coupon higher than yield means that reinvestment of the coupons at the required rate of return may not be possible and that will adversely affect the total return on the bond. Traders consider this aspect also while negotiating price. From the clean price a trader will be able to know whether the coupon of the bond is more than the yield or otherwise.

(ii) Knowing the clean price of a bond is essential from the accounting point of view also. Out of the settlement price, interest accrued till the date of settlement is accounted for as interest income by the seller and interest expenditure by the buyer. The balance of the settlement price (clean price) is accounted for as investment by both. Settlement price, per se, does not indicate to the buyer and seller the revenue account component and capital account component.

(iii) Clean price provides pricing transparency in trading. It is easy for a trader to place order based on clean price because it can be readily compared with the holding price and the decision to sell can be taken if desired profit is achieved. The trading platform provider can calculate the accrued interest and settlement price and the same can be verified by the back office of counterparties.

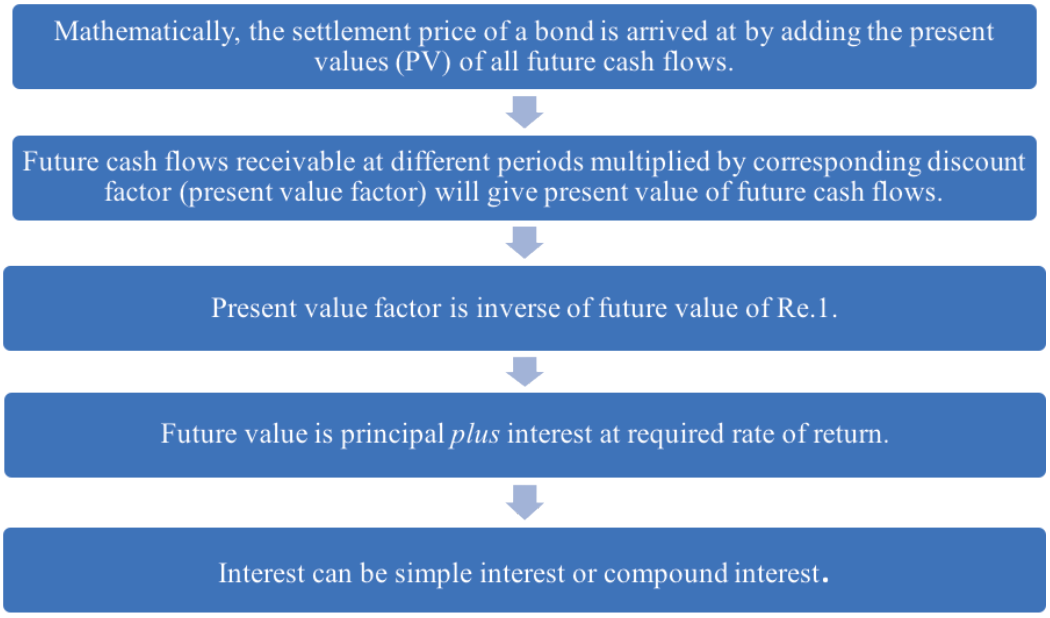
Most financial markets (including India) quote government bonds at their clean prices. Accrued interest is added back to the quoted price to determine the settlement price.

How Interest Is Expressed And Paid On Government Bonds

On zero coupon bonds and Treasury Bills interest is paid on maturity by way of difference between the issue price and redemption amount. For coupon bonds, the coupon rate is typically noted on an annual basis known as the annual percentage rate (APR). For example: Coupon of 7.2% per annum means interest will be paid at the rate of Rs.7.2 per Rs.100 of principal per year. It does not necessarily mean that interest is paid once a year. It is simply a rate at which the interest is paid on the bond. Hence, coupon of 7.2% p.a. is also expressed as 3.6% per half-year, 1.8% per quarter, etc. Coupon of 3.6% per half-year does not mean that the interest is payable every half-year. If that is the case, then half-yearly interest rate will be 3.6% per half-year and effective annual interest rate will be 7.2% plus interest on Rs.3.6 for a period of one half-year. Bond interest is not expressed and paid that way. Whether the coupon is paid once a year, half-year or month the expression of coupon rate will remain the same. Hence, 7.2% p.a. can be expressed as.0.60% per month, 0.02% per day, 72% per decade or 0.036 per Re.1 per half-year. Coupon is the agreed rate at which interest will be paid.

Periodicity of payment of coupon will be separately indicated for each bond. Coupon rate and periodicity of payment are different and they should not be mixed. Coupon at the rate of 7.2% p.a. means Rs.3.6 for a half-year when coupon payment is once in six months, Rs.1.8 for a quarter when coupon payment is once in three months, etc. Government bonds pay coupon on semi-annual basis. From the date of issue or date of last coupon payment, the interest accrues daily at coupon rate and on simple interest basis and is paid on the next coupon payment date. For odd maturity bonds, either the first or the last coupon period will be less than a full half-year. For such fractional half-years also, issuer pays interest at the fixed coupon rate agreed at the time of issue of the bond. Interest accrual per day per unit of principal for a fractional coupon period will not be less than that of a full coupon period.

Computation Of Settlement (Dirty) Price



Simple interest

Interest is the amount a borrower (issuer) pays to the lender (investor) for the use of funds. The amount of interest will vary in direct proportion to the quantum of funds used, rate of interest and period of use. This is simple interest.

Simple interest = PRN
where,
P = Principal
R = Rate of interest per Re.1 per period
N = Period

Compound interest

If simple interest is added to the principal (capitalized) periodically and further simple interest is calculated on the new principal, it becomes compound interest. Compound interest is a modified version of simple interest and the basis is simple interest only. If simple interest is calculated and added to the principal on daily basis, it is daily compounding. If it is done every six months, it is half-yearly compounding and so on. Compounding frequency is, in fact, the frequency of capitalization of interest. The quantum of compound interest is greater than simple interest not because of higher rate of interest but because of calculation of interest on higher and higher amount of principal.

Assumptions involved in price calculations

Various assumptions are possible while calculating dirty price. Assumptions which impact price of a bond are as follows:

(i) **Required rate of return (discount rate or market yield):** The discount rates can be different for different cash flow periods or only a single discount rate can be used for all the cash flows.
(ii) **Compounding frequency:** Any frequency like continuous, daily, monthly, quarterly, half-yearly, yearly, etc. can be assumed.
(iii) **Day count basis:** Actual/Actual, Actual/365, 30/360, etc.

In India, market participants follow a set of agreed market practices (FIMMDA 2016) while dealing in fixed income securities. For calculating price of government bonds,

(i) Only a single rate (yield curve rate corresponding to the residual maturity of the bond) is used to discount all the cash flows at different periods of time.
(ii) Half-yearly compounding is used.
(iii) Day count basis used is 30/360 E.

The discussions in this article are based on the above assumptions only.

Future Value And Present Value Factor Using Simple Interest Formula

Illustration 1:

If required rate of return (R) is 7.2% p.a. or 3.6% per half-year (HY) or 0.036 per Re.1 per HY:

Future value of Re.1 at the end of 1 month	=Principal+Interest =P+(P*R*N) =1+(1*0.036*1/6) =1.006
Future value of Re.1 at the end of 3 months	=1+(1*0.036*3/6) =1.018
Future value of Re.1 at the end of 6 months (1 HY)	=1+(1*0.036*6/6) =1.036

For bonds having cash flow periods upto six months

Since interest on government bonds is paid on half-yearly basis, capitalization of interest is done on half-yearly basis for future/ present value calculations. For periods upto one half-year interest is not capitalized. Therefore, when the period is upto six months, future value ought to be calculated using simple interest formula.

Future Value (simple interest)	=P+(P*R*N) =P*(1+R*N) ---------- (1)
Present Value factor (using simple interest)	=1/(1+R*N) ---------- (2)
Present value of future cash flow	= Cash flow * PV factor

Future Value And Present Value Factor Using Compound Interest Formula

Illustration 2:

If R is 7.2% p.a. or 3.6% per HY or 0.0002 per Re.1 per day; and the **settlement date falls on the coupon payment date:**

Future value at the end of 1 HY:

Future value of Re.1 at the end of 1 HY	=P*(1+R*N) =1*(1+0.0002*180) =1*(1+0.036) =1.036

Future value at the end of 2 HY:

Before calculating simple interest for the 2nd HY, interest for the 1st HY is capitalized. 1*(1+0.036) becomes principal on which simple interest is calculated for 2nd HY.

Future value of Re.1 at the end of 2nd HY	=1*(1+0.036)*(1+0.0002*180) = 1 * $(1 + 0.036)^2$ =1.073296

Future value at the end of 3 HY:

1 * $(1 + 0.036)^2$ becomes principal on which simple interest is calculated for 3rd HY.

Future value of Re.1 at the end of 3rd HY	=1*$(1+0.036)^2$*(1+0.0002*180) = 1 * $(1 + 0.036)^3$ =1.111935

For bonds having cash flow periods in whole number of half-years

When the settlement takes place on coupon payment dates, the periods upto each cash flow will be in whole number of half-years and the future value calculated using compound interest formula perfectly follows the principle of half-yearly capitalization of interest.

Future value (compound interest)	$=P*(1+R)^N$	---------- (3)
Present value factor (using compound interest)	$=1/(1+R)^N$	---------- (4)
Present value of future cash flow	= Cash flow * PV factor	

Relationship between simple interest and compound interest formula

As mentioned earlier, compound interest is nothing but capitalizing simple interest periodically and calculating further simple interest on the new principal. How they work is illustrated below:

Illustration 3:

P = Re.1; R = 0.036 per HY; N = 1 HY

S.No.	Simple interest formula	Compound interest formula
1	**Only simple interest is payable (e.g. during gestation period of a project)**	
1.1	Future value of Re.1 at the end of 4 HY $= P * (1 + R * N)$ $= 1 * (1 + 0.036 * 4)$ $= 1.144$	There is no capitalization of interest. So, compound interest formula is not applicable.
2	**Capitalization of interest every six months**	
2.1	Future value of Re.1 at the end of '0' HY $= P * (1 + R * N)$ $= 1 * (1 + 0.036 * 0)$ $= 1$ No interest; Only the principal will remain. FV $= 1$ $= P$	Future value of Re.1 at the end of '0' HY (using compound interest formula) $= P * (1 + R)^N$ $= 1 * (1 + 0.036)^0$ $= 1 * 1$ $= 1$ FV $= P$ Compound interest formula gives the same result as that of simple interest formula.
2.2	Future value of Re.1 at the end of 1 HY $= P * (1 + R * N)$ $= 1 * (1 + 0.036 * 1)$ $= 1.036$ Since N = 1, and P =1, the formula can be written as: FV $= (1 + R)$	Future value of Re.1 at the end of 1 HY (using compound interest formula) $= P * (1 + R)^N$ $= 1 * (1 + 0.036)^1$ $= 1.036$ Since N = 1, and P =1, the formula can be written as: FV $= (1 + R)$ Compound interest formula gives the same result as that of simple interest formula.

2.3	<u>Future value of Re.1 at the end of 2nd HY</u> Re.1 becomes $(1 + R)$ at the end of 1 HY. For the 2nd HY P becomes $(1 + R)$ because interest is capitalized. FV at the end of 2nd HY $= (1 + R)/1 * (1 + R)$ Future value of Re.1 at the end of 2 HY $= (1 + R)/1 * (1 + R)$ $= (1 + R) * (1 + R)$ $= 1.036 * 1.036$	Future value of Re.1 at the end of 2nd HY (using compound interest formula) FV $= (1 + R)^N$ $= (1 + R)^2$ $(1 + R)^2$ means $(1 + R) * (1 + R)$ So, simple interest formula and compound interest formula are one and the same.
2.4	<u>Future value of Re.1 at the end of 3rd HY</u> Re.1 becomes $(1 + R)$ at the end of 1 HY. FV at the end of 2nd HY is $(1 + R) * (1 + R)$ and that becomes P for the 3rd HY. FV at the end of 3rd HY $= (1 + R)/1 * (1 + R) * (1 + R)$ Future value of Re.1 at the end of 3rd HY $= (1 + R)/1 * (1 + R) * (1 + R)$ $= (1 + R) * (1 + R) * (1 + R)$ $= 1.036 * 1.036 * 1.036$	Future value of Re.1 at the end of 3rd HY (using compound interest formula) FV $= (1 + R)^N$ $= (1 + R)^3$ $(1 + R)^3$ means $(1 + R) * (1 + R) * (1 + R)$ So, simple interest formula and compound interest formula are one and the same.

3	**Interest is received before six months (capitalization of interest is every six months)**	
3.1	Future value of Re.1 at the end of ½ HY $= P * (1 + R * N)$ $= 1 * (1 + 0.036 * ½)$ $= 1.018$ FV $= P * (1 + R * N)$ Since P =1 and N = ½; $FV = 1 * (1 + R * ½)$ $= (1 + R * ½)$ Re.1 will become Re. (1 + R * ½) at the end of ½ N.	Future value of Re.1 at the end of ½ HY (using compound interest formula) $= P * (1 + R)^N$ $= 1 * (1 + 0.036)^{1/2}$ $= 1 * 1.017841$ $= 1.017841$ FV $= P * (1 + R)^N$ Since P =1, and N = ½ ; FV $= 1 * (1 + R)^{1/2}$ $= (1 + R)^{1/2}$ (1 + R * ½) is not equal to $(1 + R)^{1/2}$. Hence, compound interest formula does not give the result as given by simple interest formula.
4	**Capitalization of interest every 3 HY i.e. compounding frequency is less**	
4.1	Future value of Re.1 at the end of 3rd HY $= P * (1 + R * N)$ $= 1 * (1 + 0.036 * 3)$ $= 1.108$ Since N is not equal to 1 and P =1, the formula can be written as: FV $= (1 + R * N)$	Future value of Re.1 at the end of 3rd HY (using compound interest formula) $= P * (1 + R)^N$ $= 1 * (1 + 0.036)^3$ $= 1.111935$ Compound interest formula does not give the result as given by simple interest formula.

Whether interest on interest is calculated using simple interest formula or compound interest formula, the results are same when the periods are in whole numbers. When the periods are in fractional numbers and when the compounding frequency is in multiples of 'period', the compound interest formula does not give correct result.

What if compound interest formula is used for cash flow periods upto six months

In illustration 1, simple interest formula was used to calculate future value of bonds having cash flow periods upto six months. Future value calculations using half-yearly compounding are given below:

Illustration 4:

If R is 7.2% p.a. or 3.6% per HY or 0.036 per Re.1 per HY:

Future value of Re.1 at the end of 1 month (HY compounding	$=P*(1+R)^N$ $=1*(1+0.036)^{(1/6)}$ = 1.005912 (Simple interest 1.006)
Future value of Re.1 at the end of 3 months (HY compounding)	$=1*(1+0.036)^{(1/2)}$ = 1.017841 (Simple interest 1.018)
Future value of Re.1 at the end of 6 months (HY compounding)	$=1*(1+0.036)^1$ = 1.036 (Simple interest 1.036)

For bonds having cash flow periods less than six months, future values calculated using compound interest formula are less as compared to that of simple interest formula.

Computation Of Clean Price

When the future cash flows entirely belong to the buyer (settlement date is equal to coupon payment date), there being no accrued interest the total of present values of future cash flows will be the clean price. When the future cash flows include accrued interest belonging to the seller, dirty price minus accrued interest will be the clean price. Computation of dirty price has been discussed in the foregoing paragraphs.

Computation of accrued interest

Accrued interest is calculated on simple interest basis.

Accrued interest=F*C*A

where,
F = Face Value
C = Coupon per day
A = number of days from the beginning of the coupon period to the settlement date

Dirty Price – Accrued Interest = Clean Price

At present, dirty price is calculated using 'traditional compounding' formula described above and from the dirty price accrued interest is deducted to arrive at clean price. A different and correct way of calculating dirty price and clean price is discussed in the main article.

Appendix B

Exhibit 2: Dirty Price Calculated Using Traditional Compounding Formula

(Amount in Rs. & period in half-year)

Cash Flow Date	**09-04-20**		**09-10-20**		**09-04-21**		
Source	**Coupon**		**Coupon**		**Coupon + Redemption**		
Amount	**0.036**		**0.036**		**0.036 + 1.000**		
Settlement Date	**Period**	**PV (0.036* PV factor)**	**Period**	**PV (0.036* PV factor)**	**Period**	**PV (1.036* PV factor)**	**Total of PV (Dirty Price)**
09-10-19	6/6	0.034749	12/6	0.033542	18/6	0.931709	1.000000
09-11-19	5/6	0.034954	11/6	0.033740	17/6	0.937218	1.005912
09-12-19	4/6	0.035161	10/6	0.033939	16/6	0.942758	1.011859
09-01-20	3/6	0.035369	9/6	0.034140	15/6	0.948332	1.017841
09-02-20	2/6	0.035578	8/6	0.034342	14/6	0.953938	1.023858
09-03-20	1/6	0.035788	7/6	0.034545	13/6	0.959578	1.029911
09-04-20	0	0.000000	6/6	0.034749	12/6	0.965251	1.000000
09-05-20			5/6	0.034954	11/6	0.970957	1.005912
09-06-20			4/6	0.035161	10/6	0.976698	1.011859
09-07-20			3/6	0.035369	9/6	0.982472	1.017841
09-08-20			2/6	0.035578	8/6	0.988280	1.023858
09-09-20			1/6	0.035788	7/6	0.994123	1.029911
09-10-20			0	0.000000	6/6	1.000000	1.000000
09-11-20					5/6	1.005912	1.005912
09-12-20					4/6	1.011859	1.011859
09-01-21					3/6	1.017841	1.017841
09-02-21					2/6	1.023858	1.023858
09-03-21					1/6	1.029911	1.029911
08-04-21					1/180	1.035796	1.035796

Exhibit 3: Dirty Price Calculated Using Modified Compounding Formula

(Amount in Rs. & period in half-year)

Cash Flow Date	**09-04-20**		**09-10-20**		**09-04-21**		
Source	**Coupon**		**Coupon**		**Coupon + Redemption**		
Amount	**0.036**		**0.036**		**0.036 + 1.000**		
Settlement Date	**Period**	**PV (0.036* PV factor)**	**Period**	**PV (0.036* PV factor)**	**Period**	**PV (1.036* PV factor)**	**Total of PV (Dirty Price)**
09-10-19	6/6	0.034749	12/6	0.033542	18/6	0.931709	1.000000
09-11-19	5/6	0.034951	11/6	0.033737	17/6	0.937137	1.005825
09-12-19	4/6	0.035156	10/6	0.033935	16/6	0.942628	1.011719
09-01-20	3/6	0.035363	9/6	0.034135	15/6	0.948184	1.017682
09-02-20	2/6	0.035573	8/6	0.034337	14/6	0.953805	1.023715
09-03-20	1/6	0.035785	7/6	0.034542	13/6	0.959494	1.029821
09-04-20	0	0.000000	6/6	0.034749	12/6	0.965251	1.000000
09-05-20			5/6	0.034951	11/6	0.970874	1.005825
09-06-20			4/6	0.035156	10/6	0.976563	1.011719
09-07-20			3/6	0.035363	9/6	0.982318	1.017682
09-08-20			2/6	0.035573	8/6	0.988142	1.023715
09-09-20			1/6	0.035785	7/6	0.994036	1.029821
09-10-20			0	0.000000	6/6	1.000000	1.000000
09-11-20					5/6	1.005825	1.005825
09-12-20					4/6	1.011719	1.011719
09-01-21					3/6	1.017682	1.017682
09-02-21					2/6	1.023715	1.023715
09-03-21					1/6	1.029821	1.029821
08-04-21					1/180	1.035793	1.035793

Exhibit 4: Clean Price Calculated Using Traditional and Modified Compounding Formula

(Amount in Rs. & period in half-year)

				Traditional Compounding			Modified Compounding		
Settle-ment Date	**Accrual period**	**Accrued Interest**	**PV of Accrued Interest**	**Dirty Price**	**Clean Price (5 – 3)**	**Clean Price (5 – 4)**	**Dirty Price**	**Clean Price (8 – 3)**	**Clean Price (8 – 4)**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
09-10-19	0	0.0000	0.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
09-11-19	1/6	0.0060	0.005825	1.005912	0.999912	1.000087	1.005825	0.999825	1.000000
09-12-19	2/6	0.0120	0.011719	1.011859	0.999859	1.000140	1.011719	0.999719	1.000000
09-01-20	3/6	0.0180	0.017682	1.017841	0.999841	1.000159	1.017682	0.999682	1.000000
09-02-20	4/6	0.0240	0.023715	1.023858	0.999858	1.000143	1.023715	0.999715	1.000000
09-03-20	5/6	0.0300	0.029821	1.029911	0.999911	1.000090	1.029821	0.999821	1.000000
09-04-20	0	0.0000	0.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
09-05-20	1/6	0.0060	0.005825	1.005912	0.999912	1.000087	1.005825	0.999825	1.000000
09-06-20	2/6	0.0120	0.011719	1.011859	0.999859	1.000140	1.011719	0.999719	1.000000
09-07-20	3/6	0.0180	0.017682	1.017841	0.999841	1.000159	1.017682	0.999682	1.000000
09-08-20	4/6	0.0240	0.023715	1.023858	0.999858	1.000143	1.023715	0.999715	1.000000
09-09-20	5/6	0.0300	0.029821	1.029911	0.999911	1.000090	1.029821	0.999821	1.000000
09-10-20	0	0.0000	0.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
09-11-20	1/6	0.0060	0.005825	1.005912	0.999912	1.000087	1.005825	0.999825	1.000000
09-12-20	2/6	0.0120	0.011719	1.011859	0.999859	1.000140	1.011719	0.999719	1.000000
09-01-21	3/6	0.0180	0.017682	1.017841	0.999841	1.000159	1.017682	0.999682	1.000000
09-02-21	4/6	0.0240	0.023715	1.023858	0.999858	1.000143	1.023715	0.999715	1.000000
09-03-21	5/6	0.0300	0.029821	1.029911	0.999911	1.000090	1.029821	0.999821	1.000000
08-04-21	179/180	0.0358	0.035793	1.035796	0.999996	1.000004	1.035793	0.999993	1.000000

Exhibit 7: Combined Impact on Clean Price

Principal : Re.1 Required rate : 3.6% per HY Coupon : 3.6% per HY Last coupon date : 09-10-2019
Next coupon date : 09-04-2020 Next to next coupon date : 09-10-2020 Maturity Date : 09-04-2021
(Amount in Rs.)

	Dirty Price			Accrued Interest			
Settlement Date	Tradi-tional Compoun-ding	Modified Compoun-ding	Positive Impact on Clean Price (2 – 3)	Accrued Interest	PV of Accrued Interest	Negative Impact on Clean Price (6 – 5)	Combined Impact on Clean Price (4 + 7)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
09-10-19	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
09-11-19	1.005912	1.005825	0.000087	0.006000	0.005825	-0.000175	-0.000088
09-12-19	1.011859	1.011719	0.000140	0.012000	0.011719	-0.000281	-0.000141
09-01-20	1.017841	1.017682	0.000159	0.018000	0.017682	-0.000318	-0.000159
09-02-20	1.023858	1.023715	0.000143	0.024000	0.023715	-0.000285	-0.000142
09-03-20	1.029911	1.029821	0.000090	0.030000	0.029821	-0.000179	-0.000089
09-04-20	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
09-05-20	1.005912	1.005825	0.000087	0.006000	0.005825	-0.000175	-0.000088
09-06-20	1.011859	1.011719	0.000140	0.012000	0.011719	-0.000281	-0.000141
09-07-20	1.017841	1.017682	0.000159	0.018000	0.017682	-0.000318	-0.000159
09-08-20	1.023858	1.023715	0.000143	0.024000	0.023715	-0.000285	-0.000142
09-09-20	1.029911	1.029821	0.000090	0.030000	0.029821	-0.000179	-0.000089
09-10-20	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Table 9: Differences in dirty price, accrued interest, and clean price at different coupon / yield

Settlement date : 09-01-2020 Last coupon date : 09-10-2019
Next coupon date : 09-04-2020 Next to next coupon date : 09-10-2020 Maturity Date : 09-04-2021
(Amount in Rs.)

		Dirty Price			Accrued Interest			
Coupon p.a.	**Yield p.a.**	**Tradi-tional Compoun-ding**	**Modified Compoun-ding**	**Positive Impact on Clean Price (3 – 5)**	**Accrued Interest**	**PV of Accrued Interest**	**Negative Impact on Clean Price (8 – 7)**	**Combined Impact on Clean Price (6 + 9)**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.80%	1.80%	1.004490	1.004480	0.000010	0.004500	0.004480	-0.000020	-0.000010
7.20%	7.20%	1.017841	1.017682	0.000159	0.018000	0.017682	-0.000318	-0.000159
28.80%	28.80%	1.069579	1.067164	0.002415	0.072000	0.067164	-0.004836	-0.002421
28.80%	7.20%	1.325229	1.325021	0.000207	0.072000	0.070727	-0.001273	-0.001066
7.20%	28.80%	0.803187	0.801373	0.001814	0.018000	0.016791	-0.001209	0.000605
9.00%	7.20%	1.043456	1.043293	0.000163	0.022500	0.022102	-0.000398	-0.000235
7.20%	7.20%	1.017841	1.017682	0.000159	0.018000	0.017682	-0.000318	-0.000159
3.60%	7.20%	0.966610	0.966458	0.000151	0.009000	0.008841	-0.000159	-0.000008
3.40%	7.20%	0.963763	0.963613	0.000151	0.008500	0.008350	-0.000150	0.000000
0.10%	7.20%	0.916801	0.916658	0.000143	0.000250	0.000246	-0.000004	0.000139
7.20%	18.00%	0.901322	0.900486	0.000836	0.018000	0.017225	-0.000775	0.000061
7.20%	16.33%	0.918034	0.917328	0.000706	0.018000	0.017294	-0.000706	0.000000
7.20%	16.20%	0.919354	0.918657	0.000697	0.018000	0.017299	-0.000701	-0.000004
7.20%	14.40%	0.937913	0.937347	0.000566	0.018000	0.017375	-0.000625	-0.000059
7.20%	0.50%	1.101374	1.101373	0.000001	0.018000	0.017978	-0.000022	-0.000022
7.20%	0.10%	1.106670	1.106670	0.000000	0.018000	0.017996	-0.000004	-0.000004
7.20%	0.01%	1.107867	1.107867	0.000000	0.018000	0.018000	-0.000000	0.000000