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1. Introduction

Irving Fisher as one of the leading economists of the twentieth century claimed that nominal interest rates incorporate expected inflation rates, without affecting real interest rates. To this aim, Fisher (1930) empirically tested this hypothesis in his study[1] and detected very strong correlations between inflation rates and nominal interest rates for the USA and UK. According to Fisher (1930), a change in inflation causes a *one-for-one* change in nominal interest rates. In other words, nominal interest rates follow the changes in inflation closely. This effect of inflation on the nominal interest rate is known as the Fisher effect and is tested in an equation called the Fisher equation:

$$i_t = r_t^e + \pi_t^e + \varepsilon_t \tag{1}$$

where, i_t is the nominal interest rate, r_t^e is the *ex-ante* real interest rate and π_t^e is the expected rate of inflation. ε_t is the error term. Under rational expectations, the Fisher equation can be re-written in the following form since the rate of expected inflation equals the actual inflation ($\pi_t^e = \pi_t$).

$$i_t = \alpha + \beta\pi_t + \varepsilon_t \tag{2}$$

In Eqn. 2, if β is equal 1 this implies a full Fisher effect in the long-run which is defined as a *one-for-one* relationship between the nominal interest rate and inflation by Fisher (1930). If β is higher[2] or lower[3] than 1 this implies a partial Fisher effect. In this linear form of the equation, it is expected that while a rise in inflation leads to an increase in nominal interest rate, a fall leads to a decrease, implying either full or partial Fisher effects since the sign of β is positive.

However, the empirical methodology of this study differs from the previous ones using the above common linear representation of the Fisher equation in Eqn.2. This study applies the nonlinear ARDL model recently developed by Shin et al. (2014). This model allows us to decompose the changes in inflation (π_t) from one series (variable) to two new series (variables) as increases (π_t^+) and decreases (π_t^-) in inflation derived π_t. Therefore, the model technically enables us to examine the Fisher effect in increases (π_t^+) and decreases (π_t^-) in inflation separately. This usage of the nonlinear ARDL model when testing the Fisher effect provides us a number of potential advantageous outputs.

First, with decomposed variables (π_t^+, π_t^-) we will be able to monitor how an increase and decrease in the inflation rate affect the nominal interest rates separately. For instance, an increase in the inflation rate (π_t^+) may lead to a higher effect on the nominal interest rate than a decrease (π_t^-) or vice versa.

Second, this model enables us to reveal whether π_t^+ and π_t^- have symmetric or asymmetric effects on the nominal interest rates. Here, the rationale of using the nonlinear model in this study is based on the asymmetric information in borrowing and lending markets. Hence, the

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[1] *The Theory of Interest* Fisher (1930).

[2] According to Darby (1975), Feldstein (1976), when the nominal interest rates are taxed, the changes in nominal interest rates adjust higher than the changes in expected inflation to maintain the constant ex-ante real interest rate. This is referred to as the Darby-Feldstein effect or the tax adjusted effect.

[3] According to Mundell (1963) and Tobin (1965), nominal interest rates adjust lower than *one-for-one* since the lenders shift from nominal to real assets when there is an increase in expected inflation. This is referred to as the Mundell-Tobin effect.

responses of borrowers and lenders on the changes in inflation and interest rates may not be in the same direction and size.

For instance, while an increase in the inflation rate (π_t^+) may increase the nominal interest rate, a decrease (π_t^-) may also increase it asymmetrically if the signs of π_t^+ and π_t^- are different (positive and negative respectively). Similarly, asymmetry will also be valid if the effects (sizes) of π_t^+ and π_t^- on the nominal interest rates are different. Because, if π_t^+ and π_t^- are same in sign and size this will imply symmetric effects on the nominal interest rates.

Third, decomposed π_t^+ and π_t^- may also enable us to mathematically-technically describe and introduce a different version of the partial Fisher effect if either π_t^+ or π_t^- is significantly positive. For instance, significantly positive π_t^+ will imply that an increase in the inflation rate will lead to an increase in the nominal interest rate, supporting the evidence of a partial Fisher effect unilaterally (partially) by π_t^+ only. Likewise, significantly positive π_t^- will imply that a decrease in the inflation rate will lead a decrease in the nominal interest rate, supporting the evidence of a partial Fisher effect unilaterally (partially) by π_t^- only. In this approach, the concept of partiality is considered on an individual parametric manner of π_t^+ and π_t^- separately. In other words, partiality is based on each decomposed variable's (π_t^+, π_t^-) individual impact on the nominal interest rates. Therefore, the nonlinear ARDL model may bring a different perspective to the partiality of the Fisher effect technically, hypothetically, and conceptually.

In this study, Fisher effect is tested for Canada from this nonlinear methodological perspective. Canada is one of the countries adopting inflation targeting policy by using interest rates as an operational target. This policy was adopted by the Bank of Canada in 1991 and has been renewed every five years. The last renewal will conclude at the end of 2021. In other words, this country has a long and ongoing experience in monitoring the relationship between inflation and nominal interest rates in the long-run. In this respect, Canada appears to be one of the unique sample countries for testing the Fisher effect empirically.

The rest of this study is organized as follows. Section 2 presents a literature review. Section 3 describes the empirical methodology. Sections 4 and 5 present the empirical results and concluding remarks respectively. The data set of the study is presented in appendix.

2. Literature Review

After Fisher's (1930) pioneering original study investigating the relationship between nominal interest rates and inflation, many researchers have been testing the Fisher effect empirically for Canada as well as other countries by using different methodologies. However, the findings of these studies are ambiguous and do not provide a clear picture of the validity of the Fisher effect for Canada or other countries.

Several researchers have found evidence of the Fisher effect for at least Canada. For instance, Mishkin (1984) used the Johansen methodology for some countries and found evidence of the Fisher effect only for Canada, UK, and USA. Similarly, MacDonald and Murphy (1989) used cointegration and found the evidence of the Fisher effect for Canada, USA, Belgium and the U.K. Crowder (1997) used cointegration and the vector error correction model (*VECM*) and found evidence of the Fisher effect for Canada. Atkins and Sun (2003) used wavelets and found evidence of the Fisher effect for Canada and USA. Berument et al. (2007) used the GARCH specification for the G7 countries and found evidence supporting the Fisher effect for all countries including Canada. Westerlund (2008) applied panel cointegration and found support for the Fisher effect for 20 OECD countries including Canada. Argyro (2010) tested the Fisher effect using cointegration analysis for Canada, Belgium and Korea but found the effect only for Canada. Ozcan and Ari (2016) applied panel ARDL and found the Fisher effect for all G7 countries including Canada.

Nevertheless, other researchers have tested for the Fisher effect and found conflicting evidence for its existence in relation to Canada. For example, Dutt and Ghosh (1995) applied the Johansen-Juselius (JJ) multivariate cointegration methodology for Canada and found no evidence of the Fisher effect. Similarly, Yuhn (1996) used the unit root test and cointegration for the USA, Germany, Japan, the UK and Canada and found no the evidence of the Fisher effect for Canada and UK. Atkins and Coe (2002) used the autoregressive distributed lag (ARDL) model and found no evidence of the Fisher effect for Canada and the USA. Ghazali and Ramlee (2003) applied the Autoregressive Fractionally Integrated Moving Average (ARFIMA) model and found no evidence of the Fisher effect for the G7 countries including Canada. Atkins and Serletis (2003) used the ARDL model for some countries including Canada and found little evidence of the Fisher effect for these countries. Koustas and Lamarche (2010) applied the unit root and cointegration tests for Canada, France, Italy and Japan and found no evidence of the Fisher effect for any of the sample countries.

3. Empirical Methodology

In order to test the Fisher effect, we first decompose the changes in inflation (π_t) in Eqn.2 into increases (π_t^+) and decreases (π_t^-) in inflation as two new variables. The decomposition is constructed with the following concept of the partial sum process:

$$\pi_t^+ = \sum_{j=1}^{t} \Delta\pi_j^+ = \sum_{j=1}^{t} \max(\Delta\pi_j, 0) \tag{3}$$

$$\pi_t^- = \sum_{j=1}^{t} \Delta\pi_j^- = \sum_{j=1}^{t} \min(\Delta\pi_j, 0) \tag{4}$$

where π_t^+ and π_t^- are the partial sum process of increases and decreases in π_t.

In the second step, before the nonlinear ARDL model, we apply linear ARDL model since the nonlinear model asymmetrically extends the linear model of Pesaran et al. (2001). Therefore, the model in Eqn.2 transforms to the following linear ARDL model in Eqn.5.

$$\Delta i_t = \alpha_0 + \sum_{j=1}^{p} \alpha_{1j}\Delta i_{t-j} + \sum_{j=0}^{q} \alpha_{2j}\Delta\pi_{t-j} + \alpha_3 i_{t-1} + \alpha_4\pi_{t-1} + \varepsilon_t \tag{5}$$

Here in this equation, the short-run effect of the change in inflation on the nominal interest rate is determined by the sign and significance of α_{2j}. Similarly, the long-run effect of the change in inflation on the nominal interest rate is determined by the sign and significance of α_4. Hence, the Fisher effect is supported both in short-run and long-run if α_{2j} and α_4 are both significantly positive.

When we apply the model by Shin et al. (2014), the model in Eqn. 5 transforms to the following nonlinear form in Eqn.6. The nonlinear model adds asymmetry and nonlinearity to the linear model while reserving all merits of the linear model. In other words, the nonlinear model extends the linear model.

$$\Delta i_t = \alpha_0 + \sum_{j=1}^{p} \alpha_{1j} \Delta i_{t-j} + \sum_{j=0}^{q} \alpha_{2j} \Delta \pi_{t-j}^{+} + \sum_{j=0}^{n} \alpha_{3j} \Delta \pi_{t-j}^{-} + \alpha_4 i_{t-1} + \alpha_5 \pi_{t-1}^{+} + \alpha_6 \pi_{t-1}^{-} + \varepsilon_t \quad (6)$$

Here in nonlinear ARDL model (Eqn. 6), in order to decide the short-run effects of increases (π_t^+) and decreases (π_t^-) in inflation on the nominal interest rate, we will consider the signs and significances of α_{2j} and α_{3j} respectively. Similarly, for the decision of long-run effects, we will consider the signs and significances of α_5 and α_6. This means that significantly positive α_5 and α_6 will support the validity of a full (if $\alpha_5 = \alpha_6 = 1$) or partial (if α_5 and $\alpha_6 \neq 1$) Fisher effect in the long-run when referring to 1. 1 denotes a *one-for-one* relation as prescribed by Fisher (1930). The same directions will be followed for testing a full or partial Fisher effect in the short-run between α_{2j} and α_{3j}. Positive signs of $\alpha_{2j,}$ α_{3j}, α_5 and α_6 indicate the same directional movements with the nominal interest rate (i_t). For instance, positive α_5 and α_6 will indicate that a rise in inflation increase the nominal interest rate and a fall reduces it, signifying the Fisher effect in the long-run. This is the same for the short-run Fisher effect between α_{2j} and α_{3j}. As far as we know this is the first study attempting to use the nonlinear ARDL model to test the Fisher effect for Canada. By following the potential advantageous outputs of using the nonlinear ARDL model, as explained in introduction, we will provide the empirical results of the study in the following section.

4. Empirical Results

Before running the model, we should make sure whether the series are stationary. To this aim, we apply the Ng-Perron (2001) unit root test that mitigates the size distortion problems of Phillips-Perron (PP) test. The test results of Ng-Perron test are reported in Table I. Furthermore, we also applied Kapetanios (2005) unit root test with multiple structural breaks since the sample covers the financial crisis period of 1991M1 – 2018M1. The test results of this method are presented in Annex 1.

The test results both in Table I and Annex 1 indicate that the series are stationary at different levels. The results of Kapetanios (2005) unit root test with multiple structural breaks in Annex 1 also verify that series are stationary at different levels. Hence, we apply bounds testing to reveal whether the series are cointegrated. The test results of bounds testing for the linear and nonlinear models are reported in Panel A and B in Table II. We also applied Maki (2012) cointegration test with multiple structural breaks to consider the same financial crisis. The test results are presented in Annex 2.

The critical values of the *F*-statistics have been tabulated by Pesaran et al. (2001: 300). If the calculated statistic lies below the lower bound, then the null hypothesis of no cointegration cannot be rejected. If it exceeds above the upper bound, it suggests cointegration. If it falls within lower and upper bounds, inference is inconclusive. Our calculated statistics are above the upper bounds at 1%, 5%, or 10% significances both in linear and nonlinear models. This means that the series are cointegrated in both models in the long-run. The results of Maki (2012) cointegration test with multiple structural breaks in Annex 2 also verify that series in both models are cointegrated. Hence, we can estimate the linear and nonlinear ARDL models. The estimates of the linear ARDL model in the long-run and short-run are reported in Panels A and B in Table III.

The test results in Panel A in Table III for the linear model support the evidence of partial Fisher effects only for 3-month treasury bill rates, 1-year bond rates, and 1-3 years bond rates in the long-run. This can be concluded because only their estimated coefficients are significantly positive and lower than 1. The linear model does not detect Fisher effects for other interest rates since their estimated coefficients are not significantly positive. Furthermore, the changes in inflation rate affect 3-month treasury bill rates the most. On the other hand, the test results in Panel B do not support evidence of the Fisher effect for any interest rates in the short-run since their estimated coefficients are not significantly positive. The short-run and long-run estimates of the nonlinear ARDL model and additional diagnostic statistics are reported in Panels C and D in Table IV.

The test results in Panel C for the nonlinear model support the evidence of long-run partial Fisher effects only for 3-month treasury bill rates, 1-year bond rates, 1-3 years bond rates and 3-5 years bond rates since the estimates of π_t^+ and π_t^- are significantly positive and lower than 1. This means that while increases in inflation rates (π_t^+) raise the nominal interest rates (i_t), decreases (π_t^-) reduce them.

However, if either π_t^+ or π_t^- is significantly positive this will also support the evidence of a new version of the long-run partial Fisher effect as described in Section 1. Thus, significantly positive π_t^+ for 5-10 years bond rates and π_t^- for 10+ years bond rates will support this new version of the partial Fisher effects in the long-run. Furthermore, increases (π_t^+) and decreases (π_t^-) in inflation rates affect 3-month treasury bill rates the most since the values of estimated coefficients of both variables are higher than the values of estimated coefficients of the other three interest rates. Additionally, the effects of decreases (π_t^-) in inflation rates on 3-month treasury bill rates and 1-year bond rates are more than the effects from increases (π_t^+). On the other hand, the effects of increases in inflation rates on 1-3 years bond rates and 3-5 years bond rates are more than the effects from decreases. The same test results in Panel C indicate that the effects of increases (π_t^+) and decreases (π_t^-) in inflation rates on 3-month treasury bill rates, 1-year bond rates, 1-3 years bond rates and 3-5 years bond rates are asymmetric. Because, the estimated coefficients of π_t^+ and π_t^- are in the same signs but in different sizes.

The test results in Panel D in Table IV support the evidence of partial Fisher effects in the short-run only for 5-10 years and 10+ years bond rates in different lags since the estimates of $\Delta\pi_t^+$ and $\Delta\pi_t^-$ are significantly positive. However, as described in Section 1, significantly positive $\Delta\pi_{t-1}^+$, $\Delta\pi_{t-5}^+$ and $\Delta\pi_{t-12}^+$ for 5-10 years bond rates and significantly positive $\Delta\pi_{t-3}^+$, $\Delta\pi_{t-4}^+$ and $\Delta\pi_{t-12}^+$ for 10+ years bond rates will support the evidence of a proposed version of partial Fisher effects in the short-run through π_t^+. Similarly, significantly positive π_t^- for 1-year bond rates, $\Delta\pi_{t-7}^-$ and $\Delta\pi_{t-9}^-$ for 5-10 years bond rates, and $\Delta\pi_{t-7}^-$, $\Delta\pi_{t-9}^-$ and $\Delta\pi_{t-11}^-$ for 10^+ years bond rates will support the evidence of the same version of partial Fisher effects in the short-run through π_t^-. Additionally, the test results of Panel D indicate that increases (π_t^+) and decreases (π_t^-) in inflation rates have asymmetric effects on all interest rates (except 10+ years bond rates only for $\Delta\pi_{t-2}^+$ and $\Delta\pi_{t-4}^-$) since the estimated coefficients of π_t^+ and π_t^- are the same in sign but different in size or different in sign.

5. Concluding Remarks

In this study, we investigate the evidence of the Fisher effect for Canada from a different methodological perspective. To this aim, we apply the nonlinear ARDL model. This model provides us a number of potential advantageous outputs to reexamine and reconsider the Fisher effect in detail. First, it allows us to decompose inflation series into two new series as increases and decreases in inflation rates derived from the original series. Thus, it enables us to examine the Fisher effect in terms of increases and decreases in inflation separately. Second, it enables us to reveal whether increases (π_t^+) and decreases (π_t^-) in inflation rates have symmetric or asymmetric effects on nominal interest rates. Third, this model may mathematically-technically provide us a way of describing and introducing a new version of the partial Fisher effect rather than using 1 as a threshold parameter proposed by Fisher as a *one-for-one* relationship.

The comparative findings of the linear and nonlinear models indicate that the nonlinear ARDL model detects lower size partial Fisher effects than the linear ARDL model detects for 3-month treasury bill rates, 1-year bond rates and 1-3 years bond rates in Canada in the long-run. Similarly, both models also indicate that 3-month Canadian treasury bill rates respond to the changes in inflation rates the most. Another common finding of both models is that the effects of changes in inflation on the nominal interest rates lessen when the maturity gets longer. Furthermore, the nonlinear model with its decomposed variables (π_t^+, π_t^-) reveal that π_t^+ and π_t^- have asymmetric (different) effects on the nominal interest rates both in the long-run and short-run. For instance, decreases in inflation rates affect the nominal interest rates more than increases in shorter maturity in the long-run. However, when the maturity gets longer, increases in inflation rates affect the nominal interest more than decreases in inflation rates. These different size effects of the changes in inflation rates on the shorter and longer - terms bonds may arise from many reasons which are not out of scope of this study. But among all potential reasons, one of them may be interpreted that the Canadian government has more power on the shorter-term bonds than longer term bonds in terms of reducing its cost of borrowing.

These separated (partial) impacts of increases and decreases in inflation on the nominal interest rates could be critically important for all economic actors in Canada before and after they take a position on their investment and policy decisions (for the Bank of Canada). Similarly, the proposed version of a new partial Fisher effect may also bring a different methodological and thereby an operational point of view to these players in terms of singular-partial effects of increases and decreases in inflation on Canadian 5-10 years and 10+ years bond rates in the long-run. Because, 5-10 years bond rates positively (in the same direction) respond to the increases in inflation but do not respond to the decreases in inflation. However, 10+ years bond rates slightly and positively respond to the decreases in inflation but do not respond to the increases in inflation. Additionally, this methodology also show need for more empirical studies using this methodology as well as other techniques for testing the Fisher effect for Canada and other countries in order to better understand the interaction between interest rates and inflation.

Appendix

The data of monthly nominal interest rates were obtained from the database of the Statistics Canada (CANSIM). The monthly inflation rates are measured by the percentage changes in CPI index. The data of CPI were obtained from IMF Data Planet.

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Table I: Ng-Perron Unit Root Test Results

Variable	**Ng-Perron test statistics**			
	MZ_a	***MZ_t***	***MSB***	***MP_T***
$i_{(1)}$	-105.33^{a}	-7.12^{a}	0.06^{a}	1.36^{a}
$i_{(2)}$	-20.80^{b}	-3.14^{b}	0.15^{b}	4.89^{b}
$i_{(3)}$	-26.23^{a}	-3.37^{a}	0.12^{a}	4.90^{b}
$i_{(4)}$	-98.21^{a}	-6.89^{a}	0.07^{a}	1.34^{a}
$i_{(5)}$	-22.27^{a}	-3.17^{b}	0.14^{a}	5.05^{b}
$i_{(6)}$	-21.29^{b}	-3.19^{b}	0.14^{b}	4.71^{b}
π	-6.61	-6.61	-6.61	-6.61
$\Delta\pi$	-17.30^{b}	-17.30^{b}	-17.30^{b}	-17.30^{b}
π^{+}	-10.91	-10.91	-10.91	-10.91
$\Delta\pi^{+}$	-16.05^{c}	-16.05^{c}	-16.05^{c}	-16.05^{c}
π^{-}	-5.24	-5.24	-5.24	-5.24
$\Delta\pi^{-}$	-35.63^{a}	-35.63^{a}	-35.63^{a}	-35.63^{a}
	Critical values			
1%	-23.80	-3.42	0.14	4.03
5%	-17.30	-2.91	0.16	5.48
10%	-14.20	-2.62	0.18	6.67

Note: a, b and c denote statistical significances at 1%, 5% and 10% levels respectively. The optimal lags were automatically selected by using the Modified Akaike Information Criterion. Δ denotes the first differences of the series. The numbers in parentheses, representing Canadian interest rates in different maturities, are as follows: (1): 3-month treasury bill rates, (2): 1-year bond rates, (3): 1-3 years bond rates, (4): 3-5 years bond rates, (5): 5-10 years bond rates and (6): 10+years bond rates. The null hypothesis of has a unit root in MZ_a and MZ_t, and stationarity in *MSB* and MP_T. MZ_a, MZ_t and MSB are based on an autoregressive estimate of the spectral density at frequency zero of error term and the residuals obtained from least squares detrending in these three tests. The MZ_a and MZ_t tests can be viewed as modified versions of the Phillips (1987) and Phillips-Perron (1988) Z_a and Z_t tests. *MPT* test is the modified version of the ADFGLS point optimal test.

Table II: Test Results of Bounds Testing

Panel A: Linear

			Critical Values					
	k	*F stat.*	I0 Bound			I1 Bound		
			10%	*5%*	*1%*	*10%*	*5%*	*1%*
(1)	1	7.39[a]	4.05	5.30	6.10	4.49	5.83	6.73
(2)	1	6.78[a]	4.05	5.30	6.10	4.49	5.83	6.73
(3)	1	8.62[a]	4.05	5.30	6.10	4.49	5.83	6.73
(4)	1	5.82[c]	4.05	5.30	6.10	4.49	5.83	6.73
(5)	1	8.26[a]	4.05	5.30	6.10	4.49	5.83	6.73
(6)	1	5.72[a]	4.05	5.30	6.10	4.49	5.83	6.73

Panel B: Nonlinear

			Critical Values					
	k	*F stat.*	I0 Bound			I1 Bound		
			10%	*5%*	*1%*	*10%*	*5%*	*1%*
(1)	2	6.28[a]	2.63	3.55	4.13	3.35	4.38	5.00
(2)	2	5.61[b]	3.38	3.88	4.99	4.02	4.61	5.85
(3)	2	6.22[a]	2.63	3.55	4.13	3.35	4.38	5.00
(4)	2	4.60[c]	3.38	3.88	4.99	4.02	4.61	5.85
(5)	2	46.85[a]	2.63	3.55	4.13	3.35	4.38	5.00
(6)	2	13.01[a]	2.63	3.55	4.13	3.35	4.38	5.00

Note: a, b and c denote statistical significances at 1%, 5% and 10% levels respectively. The numbers in parentheses, representing Canadian interest rates in different maturities, are as follows: (1): 3-month treasury bill rates, (2): 1-year bond rates, (3): 1-3 years bond rates, (4): 3-5 years bond rates, (5): 5-10 years bond rates and (6): 10^{+}years bond rates. k is number of regressors.

Table III: Estimation of the Interest Rate – Inflation Relationship (Linear)

	(1)		(2)		(3)		(4)		(5)		(6)	
Variable	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.
Panel A: Long Run												
π_t	0.85^{c}	0.05	0.73^{c}	0.08	0.22^{c}	0.08	-0.39	0.16	-0.51	0.13	-0.41	0.10
Panel B: Short Run												
Δi_{t-1}	-0.05	0.36	-0.009	0.86	-	-	0.08	0.13	0.06	0.20	-0.008	0.87
Δi_{t-2}	0.30^{a}	0.00	0.11^{b}	0.04	-	-	0.01	0.85	-0.05	0.27	-0.07	0.19
Δi_{t-3}	0.01	0.74	-0.004	0.93	-	-	0.05	0.36	0.02	0.62	0.09	0.10
Δi_{t-4}	-0.20^{a}	0.00	-0.13^{b}	0.01	-	-	0.02	0.65	0.01	0.73	0.03	0.55
Δi_{t-5}	-0.11^{c}	0.05	-0.08	0.15	-	-	-0.16^{a}	0.00	-0.20^{a}	0.00	-0.18^{a}	0.00
Δi_{t-6}	0.10^{c}	0.08	0.02	0.70	-	-	0.01	0.79	-	-	-0.003	095-
Δi_{t-7}	0.17^{a}	0.00	0.13^{b}	0.02	-	-	0.06	0.27	-	-	-0.0002	0.99
Δi_{t-8}	-0.06	0.27	0.008	0.88	-	-	0.05	0.32	-	-	0.07	0.15
Δi_{t-9}	0.13^{b}	0.02	0.15^{a}	0.00	-	-	0.11^{b}	0.03	-	-	0.05	0.28
Δi_{t-10}	0.03	0.55	0.07	0.18	-	-	-	-	-	-	-	-
$\Delta \pi_t$	-0.08^{c}	0.06	0.07	0.11	0.04	0.33	0.008	0.82	0.006	0.85	-0.002	0.92
$\Delta \pi_{t-1}$	-0.08^{c}	0.06	-0.07	0.10	-0.03	0.40	-0.01	0.78	0.02	0.45	0.01	0.51
$\Delta \pi_{t-2}$	-0.03	0.45	-0.007	0.87	-0.01	0.73	0.02	0.56	0.01	0.75	-	-
$\Delta \pi_{t-3}$	0.001	0.98	-0.01	0.81	-0.02	0.52	-0.007	0.84	-	-	-	-
$\Delta \pi_{t-4}$	-0.01	0.70	-0.07	0.10	-0.07^{c}	0.09	-	-	-	-	-	-
$\Delta \pi_{t-5}$	0.06	0.19	0.03	0.48	0.02	0.50	-	-	-	-	-	-
$\Delta \pi_{t-6}$	-0.08^{c}	0.07	-0.04	0.28	-0.03	0.37	-	-	-	-	-	-
$\Delta \pi_{t-7}$	0.06	0.16	0.04	0.30	0.08	0.04	-	-	-	-	-	-
$\Delta \pi_{t-8}$	-0.12^{a}	0.00	-0.14^{a}	0.00	-0.12a	0.00	-	-	-	-	-	-
$\Delta \pi_{t-9}$	0.004	0.92	0.02	0.51	0.04	0.27	-	-	-	-	-	-
$\Delta \pi_{t-10}$	-0.13^{a}	0.00	-0.14^{a}	0.00	-0.09^{b}	0.02	-	-	-	-	-	-
$\Delta \pi_{t-11}$	-	-	-	-	-0.02	0.57	-	-	-	-	-	-
Const.	0.002	0.99	-0.15	0.51	0.59^{a}	0.00	0.76^{a}	0.00	0.75^{a}	0.00	0.66^{a}	0.00
ECT_{t-1}	-0.01^{b}	0.02	-0.01^{b}	0.02	-0.008^{b}	0.01	-0.09^{a}	0.00	-0.08^{a}	0.00	-0.07^{a}	0.00
R^2	0.97	-	0.97	-	0.98	-	0.98	-	0.98	-	0.99	-
$Adj.R^2$	0.97	-	0.97	-	0.98	-	0.98	-	0.98	-	0.99	-
DW	2.01	-	1.97	-	1.80	-	1.97	-	1.99	-	1.95	-
χ^2_{SC}	0.28	0.86	3.90	0.14	2.40	0.30	0.72	0.69	0.07	0.96	7.40	0.11
χ^2_{FF}	1.52	0.18	2.39	0.01	1.86	0.06	0.0005	0.98	0.51	0.47	1.97	0.16
χ^2_{NOR}	2499.7	0.00	807.26	0.00	277.27	0.00	87.85	0.00	11.28	0.00	29.80	0.00
χ^2_{HET}	67.23	0.00	63.31	0.00	45.18	0.00	45.63	0.00	40.97	0.00	53.96	0.00
EG_{MAX}	-8.60	0.00	-17.44	0.00	-5.09	0.00	-17.57	0.00	-17.67	0.00	-17.38	0.00

Note: Note: a, b and c denote statistical significances at 1%, 5% and 10% levels respectively. χ^2_{SC} is Breusch-Godfrey LM test for autocorrelation, χ^2_{NOR} is the Jarque-Bera test for normality, χ^2_{FF} is Ramsey test for functional form misspecification, χ^2_{HET} for white heteroscedasticity, EG_{MAX} is largest value of the Engle-Granger residual-based ADF test. All these additional diagnostic test results signify that there is no autocorrelation, misspecification of the optimum models and heterogeneity. The series are normally distributed and cointegrated. The numbers in parentheses, representing Canadian interest rates in different maturities, are as follows: (1): 3-month treasury bill rates, (2): 1-year bond rates, (3): 1-3 years bond rates, (4): 3-5 years bond rates, (5): 5-10 years bond rates and (6): 10+years bond rates.

Table IV: Estimation of the Interest Rate – Inflation Relationship (Nonlinear)

	(1)		(2)		(3)		(4)		(5)		(6)	
Variable	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.	Coef.	Prb.
Panel C: Long Run												
π_t^+	0.48^a	0.00	0.24^a	0.00	0.13^a	0.00	0.36^a	0.00	0.30^a	0.00	0.07	0.16
π_t^-	0.60^a	0.00	0.36^a	0.00	0.009^a	0.00	0.003^c	0.09	0.001	0.38	0.001^c	0.09
Constant	9.08^a	0.00	8.38^a	0.00	0.52^a	0.00	-0.07	0.39	-0.12^b	0.02	-0.04	0.28
Panel D: Short Run												
Δi_{t-1}	1.23^a	0.00	0.43^b	0.03	-	-		-	-	-	-0.27^a	0.00
Δi_{t-2}	1.04^a	0.00	0.46^b	0.02	0.12^b	0.01		-	-0.27^a	0.00	-	-
Δi_{t-3}	0.38^b	0.01	0.58^a	0.00				-	-	-	0.18^a	0.00
Δi_{t-4}	1.01^a	0.00	0.52^a	0.00				-	-	-	-	-
Δi_{t-5}	0.79^a	0.00	0.54^a	0.00				0.00	-0.42^a	0.00	-	-
Δi_{t-6}	-	-	0.57^a	0.00				-	0.14^b	0.03	-	-
Δi_{t-7}	-	-	0.49^b	0.01	0.13^a	0.00		0.00	-0.28^a	0.00	-	-
Δi_{t-8}	-	-	0.44^b	0.02				-	-	-	-	-
Δi_{t-9}	-	-	0.61^a	0.00	0.19^a	0.00		0.00	0.16^b	0.01	-	-
Δi_{t-11}	-	-	-	-	-0.13^a	0.00		-	-	-	-	-
Δi_{t-12}	-	-	0.74^a	0.00				-	-	-	-0.32^a	0.00
$\Delta\pi_t^+$	-	-	-	-				-	-	-	-0.07^b	0.01
$\Delta\pi_{t-1}^+$	-0.76^a	0.00	-0.37^b	0.01				0.00	0.49^a	0.00	-	-
$\Delta\pi_{t-2}^+$	-0.55^b	0.01	-	-				0.01	-	-	-0.13^a	0.00
$\Delta\pi_{t-3}^+$	-1.23^a	0.00	-0.45^a	0.00				-	-	-	0.13^a	0.00
$\Delta\pi_{t-4}^+$	-0.48^b	0.02	-0.37^b	0.01				0.00	-	-	0.11^b	0.01
$\Delta\pi_{t-5}^+$	-0.88^a	0.00	-0.35^b	0.02				-	0.17^b	0.02	-	-
$\Delta\pi_{t-6}^+$	-	-	-0.40^a	0.00	-0.18^a	0.00		0.00	-0.21^a	0.00	-0.18^a	0.00
$\Delta\pi_{t-7}^+$	-	-	-0.29^b	0.04				-	-	-	-	-
$\Delta\pi_{t-8}^+$	-	-	-0.29^b	0.04				0.00	-0.42^a	0.00	-	-
$\Delta\pi_{t-9}^+$	-	-	-	-				0.00	-0.33^a	0.00	-	-
$\Delta\pi_{t-10}^+$	-	-	-0.39^a	0.00				-	-	-	-	-
$\Delta\pi_{t-11}^+$	-	-	-0.33^b	0.02				-	-	-	-	-
$\Delta\pi_{t-12}^+$	-	-	-	-				0.00	0.47^a	0.00	0.19^a	0.00
$\Delta\pi_t^-$	-	-	0.52^a	0.00				-	-	-	-	-
$\Delta\pi_{t-1}^-$	-0.25	0.34	-	-	-0.13^b	0.02		0.00	-0.58^a	0.00	-	-
$\Delta\pi_{t-2}^-$	0.36	0.11	-	-				0.00	-	-	-	-
$\Delta\pi_{t-3}^-$	-	-	-	-				-	-0.29^a	0.00	-0.15^a	0.00
$\Delta\pi_{t-4}^-$	-	-	-	-				-	-0.20^a	0.00	-0.13 ^{a}	0.00
$\Delta\pi_{t-5}^-$	-0.37^c	0.08	-	-				-	-	-	-	-
$\Delta\pi_{t-7}^-$	-	-	-	-				0.00	0.63^a	0.00	0.21^a	0.00
$\Delta\pi_{t-8}^-$	-	-	-	-	-0.20^a	0.00		0.00	-0.18^a	0.00	-0.14^a	0.00
$\Delta\pi_{t-9}^-$	-	-	-	-				0.00	0.42^a	0.00	0.12^a	0.00
$\Delta\pi_{t-10}^-$	-	-	-	-				0.00	-0.31^a	0.00	-	-
$\Delta\pi_{t-11}^-$	-	-	-	-				-	-	-	0.08^b	0.03
R^2	0.86	-	0.80	-	0.85	-	0.77	-	0.73	-	0.43	-
$Adj. R^2$	0.86	-	0.79	-	0.84	-	0.76	-	0.71	-	0.39	-
DW	1.96	-	2.10	-	1.90	-	2.06	-	2.10	-	1.94	-
χ^2_{SC}	0.00	1.00	241.61	0.00	0.25	0.45	0.00	1.00	0.00	1.00	0.00	1.00
χ^2_{FF}	18.93	0.00	0.54	0.45	0.56	0.45	58.48	0.00	43.26	0.00	0.02	0.82
χ^2_{NOR}	222.53	0.00	68.35	0.00	61.91	0.00	212.39	0.00	213.41	0.00	158.58	0.00
χ^2_{HET}	103.80	0.00	52.89	0.00	29.42	0.02	27.69	0.11	47.60	0.00	82.51	0.00
W_{LR}	70.47	0.00	59.28	0.00	66.08	0.00	1.99	0.15	2.41	0.12	1.45	0.22
W_{SR}	73.74	0.00	69.78	0.00	66.08	0.00	1.75	0.18	1.98	0.16	0.93	0.33
EG_{MAX}	-17.29	0.00	-3.63	0.02	-3.75	0.02	-5.29	0.00	-9.06	0.00	-4.72	0.00

Note: Note: a, b and c denote statistical significances at 1%, 5% and 10% levels respectively. χ^2_{SC} is Breusch-Godfrey LM test for autocorrelation, χ^2_{NOR} is the Jarque-Bera test for normality, χ^2_{FF} is Ramsey test for functional form misspecification, χ^2_{HET} for white heteroscedasticity, EG_{MAX} is largest value of the Engle-Granger residual-based ADF test. W_{LR} and W_{SR} are long and short-run Wald tests. All these additional diagnostic test results signify that there is no autocorrelation, misspecification of the optimum models and heterogeneity. The series are normally distributed and cointegrated. The numbers in parentheses, representing Canadian interest rates in different maturities, are as follows: (1): 3-month treasury bill rates, (2): 1-year bond rates, (3): 1-3 years bond rates, (4): 3-5 years bond rates, (5): 5-10 years bond rates and (6): 10+years bond rates.

Annex 1: Kapetanios (2005) Unit Root Test with Multiple Structural Breaks Results

Variable	**Test statistics**	**Structural Break Dates**
$\boldsymbol{i}_{(1)}$	-5.28	1995:M03; 2000:M11
$\Delta\boldsymbol{i}_{(1)}$	-6.24^{b}	1995:M02; 1998:M03
$\boldsymbol{i}_{(2)}$	-5.26	1994:M02; 1995:M01
$\Delta\boldsymbol{i}_{(2)}$	-10.57^{a}	1995:M01; 1997:M12
$\boldsymbol{i}_{(3)}$	-4.71	1994:M02; 1995:M01
$\Delta\boldsymbol{i}_{(3)}$	-17.09^{a}	1995:M01; 1999:M10
$\boldsymbol{i}_{(4)}$	-4.63	1994:M01; 1995:M01
$\Delta\boldsymbol{i}_{(4)}$	-10.57^{a}	1995:M01; 1997:M12
$\boldsymbol{i}_{(5)}$	-6.13^{b}	1994:M01; 1995:M01
$\boldsymbol{i}_{(6)}$	-6.52^{b}	1994:M02; 1995:M01
$\boldsymbol{\pi}$	-4.90	1994:M11; 1999:M02
$\Delta\boldsymbol{\pi}$	-9.24^{a}	1995:M05; 2003:M02
$\boldsymbol{\pi}^{+}$	-3.63	1995:M03; 2002:M06
$\Delta\boldsymbol{\pi}^{+}$	-16.04^{a}	2011:M03; 2014:M05
$\boldsymbol{\pi}^{-}$	-5.75	1994:M05; 2001:M05
$\Delta\boldsymbol{\pi}^{-}$	-8.20^{a}	1993:M11; 2001:M05
	Critical values	
1%	5%	10%
-6.58	-6.11	-5.84

Note: a, b and c denote statistical significances at 1%, 5% and 10% levels respectively. The optimal lags were automatically selected by using the Modified Akaike Information Criterion. Δ denotes the first differences of the series. The numbers in parentheses, representing Canadian interest rates in different maturities, are as follows: (1): 3-month treasury bill rates, (2): 1-year bond rates, (3): 1-3 years bond rates, (4): 3-5 years bond rates, (5): 5-10 years bond rates and (6): 10+years bond rates.

Annex 2: Maki (2012) Cointegration Test with Multiple Structural Breaks Results

			Panel A: Linear			
		Tao	*Critical Values*			
	RV	*stat.*	*1%*	*5%*	*10%*	*Structural Break Dates*
(1)	1	-5.08^{b}	-5.70	-4.60	-4.35	1992:M11; 1995:M11; 2001:M09; 2008:M03
(2)	1	-4.89^{b}	-5.70	-4.60	-4.35	1992:M11; 2007:M02; 2008:M09; 2018:M01
(3)	1	-5.06^{b}	-5.70	-4.60	-4.35	1995:M02; 1997:M06; 2007:M02; 2008:M10
(4)	1	-4.52^{c}	-5.70	-4.60	-4.35	1995:M02; 1998:M09; 2007:M02; 2008:M12
(5)	1	-5.08^{b}	-5.70	-4.60	-4.35	1992:M10; 1995:M11; 2001:M09; 2008:M03
(6)	1	-4.63^{c}	-5.70	-4.60	-4.35	2001:M10; 2003:M05; 2007:M03; 2008:M12
			Panel B: Nonlinear			
			Critical Values			
	RV	*Tao stat.*	*1%*	*5%*	*10%*	*Structural Break Dates*
(1)	2	-5.78^{a}	-5.54	-5.00	-4.73	1993:M06; 2005:M10
(2)	2	-5.03^{b}	-5.54	-5.00	-4.73	1992:M10; 1994:M06; 1998:M01; 2005:M10
(3)	2	-4.81^{c}	-5.54	-5.00	-4.73	1994:M01; 2003:M05; 2008:M10
(4)	2	-4.84^{c}	-5.54	-5.00	-4.73	1995:M02; 1998:M09; 2001:M08; 2005:M10; 2008:M11
(5)	2	-5.73^{a}	-5.54	-5.00	-4.73	1993:M12; 2001:M11; 2013:M06
(6)	2	-5.50^{b}	-5.54	-5.00	-4.73	1995:M02

Note: Critical values were taken Maki (2012: 3) Table 1. RV; Number of independent variables.